

# Arrival Manager

## Implementation Guidelines and Lessons Learned



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# Implementation GUIDELINES and Lessons Learned

Edition Number	:	0.1
Edition Date	:	17th Dec. 2010
Status	:	Proposed Issue
Intended for	:	General Public



# DOCUMENT CHARACTERISTICS

TITLE			
<b>AMAN Implementation GUIDELINES</b>			
<b>Publications Reference:</b>			
		<b>ISBN Number:</b>	
<b>Document Identifier</b>		<b>Edition Number:</b>	
		<b>Edition Date:</b>	
Abstract			
This document presents AMAN Implementation Guidelines. It provides an overview of available AMANs in Europe with recommended implementation guidance material, including material on required studies. It summarizes some of the identified issues and builds on the exchange of the lessons learned by AMAN pioneers. This document should be viewed in parallel with "AMAN Status Review 2010" ( <b>Reference 2</b> ).			
Keywords			
Airport	AMAN	ATCO	Arrival Management
Controller tools	Inventory	System Support	Sequencing / metering
Time to Gain	Time to Lose	TMA	Traffic flows
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STATUS, AUDIENCE AND ACCESSIBILITY				
Status	Intended for		Accessible via	
Working Draft	<input type="checkbox"/>	General Public	<input checked="" type="checkbox"/>	Intranet <input type="checkbox"/>
Draft	<input type="checkbox"/>	CND Stakeholders	<input type="checkbox"/>	Extranet <input type="checkbox"/>
Proposed Issue	<input checked="" type="checkbox"/>	Restricted Audience	<input type="checkbox"/>	Internet (www.eurocontrol.int) <input type="checkbox"/>
Released Issue	<input type="checkbox"/>			

# DOCUMENT APPROVAL

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# DOCUMENT CHANGE RECORD

The following table records the complete history of the successive editions of the present document.

EDITION NUMBER	EDITION DATE	REASON FOR CHANGE	PAGES AFFECTED
0_1		Original	

## Publications

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# EXECUTIVE SUMMARY

Operational requirements for Arrival Manager (AMAN) were developed in the late 1990s in the framework of EATCHIP. The ATM systems industry has been developing AMAN functionalities in line with the EATCHIP (later EATM) guidelines, and has delivered these (commercial) systems/products to a number of ANSPs.

In parallel, a number of major Air Navigation Service Providers (ANSPs) have been developing and prototyping AMAN tools according to their own specific needs.

Many of these systems are in day-to-day use across Europe. However, some major airports from the top 25 busiest airports in Europe still operate without a dedicated Arrival Management system.

This document summarises and describes guidelines/considerations for the implementation of AMAN products, and presents some high-level gathered experience from ANSPs using AMAN systems.

The information contained in the document has been gathered from several sources, both from ANSPs and Industry.

The “AMAN Status Review 2009” (**Reference 1**) contained sections and information on the AMAN Concept, AMAN System Elements and Issues at Technical/Operational level. These sections have been removed from the version of the AMAN Status Report 2010 (**Reference 2**), and are incorporated into this “AMAN Guidelines” document. The two documents, AMAN Status Review 2010 and AMAN Guidelines are complimentary and should be considered in parallel.

**“A controller would like an AMAN to be stable, correct and strict when traffic builds up -and a flexible, mind-reading and dynamic tool in other periods.”**

(Kristian Pjaaten, Avinor AMAN project leader)

Chapter 1 provides an introduction to the subject of AMAN, outlining the scope of the document. The definition, description of the concept and of elements of the AMAN tools can be found in Chapter 2. The core of the document (Chapter 3 and Chapter 4) outlines AMAN implementation considerations/expectations and provides information on required studies. It also suggests guidelines for the implementation process. Chapter 5 addresses the issues and the benefit expected from the sharing of experience between ANSPs Chapter 6 summarizes the link between AMAN implementation and SESAR. In the Annex, the different products on the AMAN market are described.

# CHAPTER 1 – Introduction

## 1.1 **General**

Arrival Management systems (AMANs) have been developed in Europe over the course of many years. Without a centralized or standardized approach, these systems, including their related procedures and methods of implementation, have developed somewhat independently. As such, these systems are now used in slightly different ways in different locations.

In some areas AMANs are used and regarded as essential sequencing aids, providing robust support for the ATCOs sequencing traffic to an airport. In other locations they are used primarily as “metering” tools, mainly used for regulating the flow of traffic into the TMAs surrounding busy airports. In yet other implementations they fulfil a traffic awareness role, or are used for coordination purposes. In some areas, they occupy only a background role for most of the time, working but not really “used”.

ESSIP 7.1 objective promotes the implementation of Basic AMAN, at least in the core area of Europe. Although only referring to a “Basic AMAN” (one that provides simple Time To Lose / Time To Gain - TTL/TTG - rather than more complex direct trajectory management solutions, such as “speed to be flown”) this ESSIP objective is seen as a baseline for establishing the use of AMANs, promoting their development and helping to position AMAN as a cornerstone in SESAR.

To capture the current situation in relation to AMAN implementation in Europe, a study was undertaken in 2009 to provide an **AMAN Status Review 2009 (Reference 1)**. This review has been updated to reflect the developing AMAN situation in 2010.

When researching for the AMAN Status Review, it was noticeable that very little commonly-available, or up-to-date, documentation for AMAN existed. In fact, the last major documentation covering AMAN was published in 1999 (**Reference 5**).

Also while doing this research it became apparent that there were many lessons to be learned – both operational and technical – from current and previous AMAN implementers. Although “well-known” in local circles, AMAN “issues” and “experiences” are not generally common knowledge across the ATM community, nor are they available in one place or in one document. This “lack of common knowledge” in fact, lead to a second study being undertaken, which is now piecing together at a high-level, information and “experiences” that could be useful, not only to future AMAN implementers, but also to current implementers. This information is summarized in these “AMAN Guidelines”.

The 2 documents, “**AMAN Status Review 2010**” (Reference 2) and “**AMAN Guidelines**” (this document) are complementary and should be considered in parallel.

“**The largest airports are important - The top 35 generate 50% of all flights.**”

“**Understanding the 2,000 airports in Europe is a challenge...a quarter of (those) airports accounts for 98% of IFR traffic.**”

Ref: EUROCONTROL “Trends in Air Traffic Volume 3”

## 1.2 **Targeted audience**

This document gathers information and experience from existing AMAN implementers and passes on some of their “lessons-learned” to future AMANs users. The idea behind the document and in the work involved in creating this document is to promote the sharing of experience; as such the targeted audience includes not only organisations who have yet to implement but also those who have already implemented AMANs.

The target audience for this document is as follows:

- ANSPs planning to implement an AMAN
- Pioneer ANSPs, willing to share their experience in AMAN development
- ANSPs already equipped but possibly not obtaining maximum benefit from their system
- ANSPs not directly using AMAN information, but in proximity to an AMAN influenced-airspace
- All stakeholders who may benefit from the AMAN process (Airports and Airlines)

## 1.3 **Scope**

The scope of the document is limited to the current AMAN systems, as available to the European ANSPs.

The document summarizes considerations and issues learned during the study of different implementations. The document is NOT intended to be a one-shot blueprint (or a fully-prescribed “EUROCONTROL method”) for implementing AMAN. The information in it should be considered and adapted to suit differing local requirements.

## 1.4 *Abbreviations*

AAMS	Airport Airside Management System
ACAS	Airborne/Aircraft Collision Avoidance System
ACC	Area Control Centre or Area Control
ACI	Airports Council International
AIP	Aeronautical Information Publication
AMA	Arrival Management message
AMAN	Arrival Manager System
ANSP	Air Navigation Service Provider
APP	Approach Control
ASF	Arrival Sequence Function
ASL	Arrival Sequencing List
ASPA S&M	Airborne Spacing Applications Enhanced Sequencing and Merging operations
ATC	Air Traffic Control
ATCO	Air Traffic Controller
CCTV	Closed Circuit Television
CDA	Continuous Descent Arrival (ICAO)
CDA	Continuous Descent Approach
CDM	Collaborative Decision-Making
CFIT	Controlled Flight into Terrain
CFMU	Central Flow Management Unit
COP	Coordination Point
COTS	Commercial Off-The-Shelf
CTA	Calculated Time of Arrival (CFMU)
CTA	Control Time of Arrival
CTO	Calculated Time Over
CTO	Computed Time Over (CFMU - CASA)
CWP	Controller Working Position
DCB	Demand Capacity Balancing
DFS	Deutsche Flugsicherung GmbH
DLI	Determined Landing Interval
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V.
DMAN	Departure Manager System
DMET	Departure Metering
EAT	Expected Approach Time/Estimated Approach Time
EATCHIP	European Air Traffic Control Harmonisation and Integration Programme

ENAV	Ente nazionale di assistenza al volo
ENR	En Route, En-route
ESARR	EUROCONTROL Safety Regulatory Requirement
ESSIP	European Single Sky Implementation
ETO	Estimated Time Over
FAB	Functional Airspace Blocks
FDPS	Flight Data Processing System
FIR	Flight Information Region
FMS	Flight Management System
FYROM	Former Yugoslav Republic of Macedonia
GPWS	Ground Proximity Warning System
GSN	Goal-structuring Notation
HF	Human Factors
HMI	Human-Machine Interface
IAA	Irish Aviation Authority
IAF	Initial Approach Fix
IBP	Inbound Planner
ICAO	International Civil Aviation Organization
IRM	Integrated Runway Manager
LSSIP	Local Single Sky Implementation
LVNL	Luchtverkeersleiding Nederland
MAC	Mid-Air Collision
MONA	Monitoring Aids
MSAW	Minimum Safe Altitude Warning
MTCD	Medium-Term Conflict Detection
MTOT	Managed take-off Time
NATS	National Air Traffic Services
OLDI	On-Line Data Interchange
OPS	Operations
OSED	Operational Services and environment description
P-RNAV	Precision Area Navigation
RDPS	Radar Data Processing System
RTA	Required time of Arrival
SAM	Safety Assessment Methodology
SAME	Safety Assessment Made Easier
SARA	Speed and Route Advisories
SES	Single European Sky
SESAR	Single European Sky ATM Research
SFPL	System Flight Plans

SGMAN	Stand/Gate Manager
SJU	SESAR Joint Undertaking
SL	Service Level
SMAN	Surface Movements Manager
STA	Scheduled Time of Arrival
STAR	Standard Terminal Arrival Route
STCA	Short-Term Conflict Alert
SYSCO	System Coordination
TLS	Target Level of Safety
TMA	Terminal Control Area
TOD	Top of Descent
TP	Trajectory Prediction/Predictor
TTG	Time to gain
TTL	Time to lose
VFR	Visual Flight Rules
WP	Work Package
WTC	Wake turbulence category

# CHAPTER 2 –Definition and concepts

## 2.1 *Definition*

In aviation terms, “**Arrival Management**” is a general term given to the process of safely and effectively arranging arrivals into a smooth efficient flow for landing at a destination airport.

Different elements of the ATM system can impact on arrival management and vice versa, arrival management can also impact on, and place requirements on, other elements of the system. Airspace design and route structure, software available or being used are all important elements to be considered in the overall context of arrival management.

To assist in the arrival management process, several aids and support are already available and being used. These can range from simple pieces of paper (such as flight-schedule printouts, or flight-progress strips arranged in sequence on a flight-progress board), to electronic aids, where simple arrival information (such as ETA) is presented to those ATCOs handling the flight.

At the top of the range sits dedicated software functionality, which not only assists in sequencing and optimising the flow of arriving flights, but also provides information (or advisories) to the ATCOs on what is needed to create and maintain the arrival sequence.

Although no agreed definition is in place, when people consider or talk about **dedicated Arrival Management software**, or **AMANs**, they are usually considering this type of software specifically designed to provide assistance in metering and sequencing arrival streams of traffic and which gives, via electronic display, all the time management, and other information needed to implement efficient arrival management.

## 2.2 *General concept of AMAN*

### 2.2.1 *High-level aims and objectives*

The general objective of an Arrival Manager (AMAN) is to provide electronic assistance in the management of the flow of arriving traffic in a particular airspace, to particular points, such as runway thresholds or metering points.

Its main aims are to assist the controller to optimise the runway capacity (sequence) and/or to regulate/manage (meter) the flow of aircraft entering the airspace, such as a TMA. It also aims to provide predictability for its users (both ground and air) and at the same time minimise the impact on the environment, by reduced holding and low-level vectoring.

To meet these objectives, the AMAN system provides a sequence at the runway, and also provides an expected or scheduled time for each flight at the runway or at/over different fixes.

The AMAN is biased towards linear delay absorption instead of orbital holdings, aiming to assist in eliminating low-level orbital holding, or at least reducing holding on arrival to a minimum.

The planning and/or sequencing function of the AMAN also aims to reduce controller workload, particularly in case of perturbations (such as runway closure).

The AMAN itself is usually managed by a dedicated controller (such as, a “Supervisor” or “Manager” in Approach) and the computed information can be distributed in Approach sectors and also upstream to ACC sectors and other centres.

“Safety”, “The Environment”, “Capacity” and “Efficiency” are all target improvement areas of the ATM system, but these can often be seen to be acting in opposite directions. For instance, capacity at an airport may need to be increased, but it may also need to be achieved in a tightly controlled, environmentally-friendly way. AMAN tools strive to assist in combining and balancing those factors and they generally succeed, remaining well-accepted by controllers as useful support tools.



Figure 1: Competing ATM improvement target

## 2.2.2 General AMAN principles

The following section contains a brief and high-level resume of general AMAN operations, methods and principles. Although several AMANs are now also used with “coordination” functionality, the following section briefly describes just the sequencing/metering elements.

### Input to the AMAN system:

Generally speaking, as its main input sources, an Arrival Manager uses the flight plan data retrieved from a Flight Data Processing System (FDPS) and the radar data from a Radar Data Processing System (RDPS), which is then correlated to flight plan data.

The system utilises an aircraft performance model and it is also fed with known airspace/flight constraints, such as speed restrictions (e.g. 250kts below FL100) to be used in the calculation of predicted times and aircraft trajectories. Wake Turbulence Category information is also taken into consideration.

Weather information (wind) is also usually made available to the AMAN, to assist in more accurate flight prediction.

Manual inputs to the AMAN include insertion of the landing rate or separation on final and/or the cadence of landing for a runway, or “slots” to block a runway for a specified length of time.

An AMAN system may also take into consideration prescribed optimisation criteria.

Processing phase in the AMAN system:

In the initial phase, a trajectory prediction process delivers an estimated time (unconstrained) for a flight, at a particular point (runway threshold, TMA entries, IAF or feeder-fixes). This process uses either an AMAN-internal or an “external” trajectory predictor, such as the trajectory predictor in the FDPS.

The sequencer element of the AMAN then builds a global sequence, which generally integrates the flow of traffic on a “first come, first serve” principle, although other principles may also be applied, such as equity, distribution of delay, and wake category grouping. This then results in a scheduled sequence and with a scheduled (constrained) time for each aircraft.

These times – “constrained” (taking into account all arriving traffic) and unconstrained (aircraft considered alone in the sky) - are then compared and “delay information”, if applicable, is provided as an output of the system (see Figure 2: “L” Loose message in the timeline label).



Figure 2: "L" Loose message in the timeline label

Generally, AMANs have several defined horizons, during which flights are recognised/captured, planned, sequenced, re-sequenced if necessary and then ultimately frozen in the arrival process. A position in the sequence is frozen only when the flight has entered a stable horizon. The location or distance from touchdown for these horizons is a matter for local implementation. Some systems operate dynamically (with constant updates) until quite late in the flight.

The basic process is summarized in the following figures (Figure 3: Current AMAN (vertical view), Figure 4: Current AMAN (lateral view)) and short “generic” scenarios:

1. Around 150-200nm from touchdown, the aircraft is captured. This distance is often called the AMAN horizon
2. On the ground, the AMAN system computes the aircraft's preferred Arrival Time
3. The flight is then sequenced in the flow of traffic, in function of its computed preferred Arrival Time and sequencing criteria
4. The AMAN system displays notifications and advisories to the ATCO, who uses them to sequence the aircraft (via R/T)
5. The aircraft follows the instructions given by the ATCO

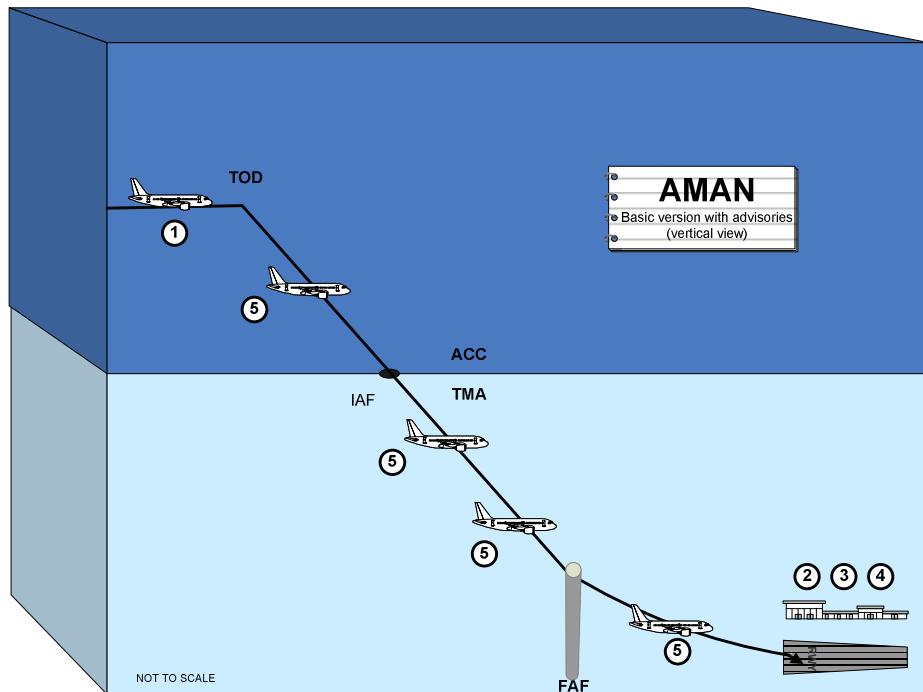


Figure 3: Current AMAN (vertical view)

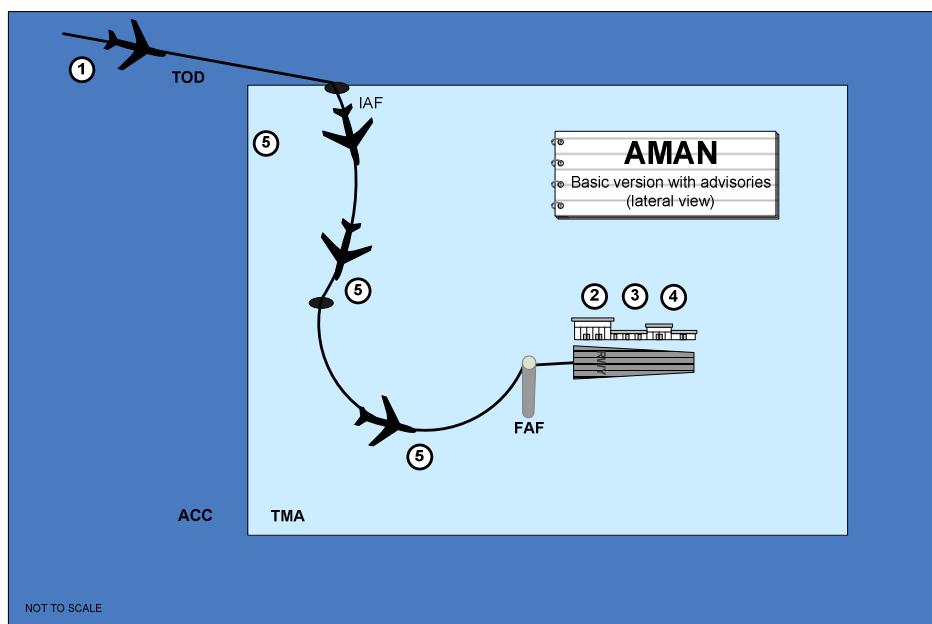


Figure 4: Current AMAN (lateral view)

### Output of the AMAN system:

An optimised sequence, a time-line, time-information and delay management advisories are all usually provided on a screen for the AMAN supervisor. These advisories can include: Time to Lose (TTL) or Time to Gain (TTG), speed advisories or turn advisories.

The AMAN display (as used by the AMAN “supervisor”), or the output of the AMAN in a simpler version (perhaps just the action required, such as TTL/G), may also be distributed to other sectors/ACCs or airports for sequence awareness, delay actions and co-ordination purposes.

### Managing the AMAN system:

Generally an AMAN supervisor manages the AMAN. He/she sets and adjusts landing rates, handles runway closures/switches and also other perturbations (go-around, aircraft proceeding to diversion airport during the approach...). The AMAN manager is usually responsible for changes to the sequence, swapping 2 or more aircraft as needed. He/she is also generally responsible for manually reserving slots for pop-up traffic, traffic originating within the AMAN horizon.

### Operations of the AMAN system:

Although the AMAN supervisor is usually responsible for interacting with/monitoring the progress of the flights in the AMAN, it is the sector ATCO who remains in charge and who is responsible for the tactical application of any delay, and for the overall control/safety of the flights concerned.

### Acceptance of the AMAN system:

The use of the AMAN varies somewhat from ACC/APP to ACC/APP, and its acceptance and use by controllers also varies from ATCU (Air Traffic Control Unit) to ATCU. In some cases the AMAN is left operating relatively passively in the background, whilst in other areas the AMAN has become such an integrated part of the daily routine that its unavailability can lead to reduced acceptance rates.

## **2.2.3 Types of AMANS**

It is a complex task to define/classify all of the different types/levels of automation used in arrival management. Individual interpretations of what constitutes “arrival management functionality” are widespread.

From the study performed in the “AMAN Status Review – 2009” (**Reference 1**), it seems that “Arrival Management” support can be divided into 3 main categories:

- A simple “non-dedicated” arrival management category (basic FDPS functionalities)
- Today’s current “dedicated AMAN”
- Tomorrow’s (developing) “dedicated AMAN”

The following are brief descriptions of the first two of these categories. The next generation of AMANs, or how AMANs might develop, is discussed in a later annex.

### FDPS with (limited) arrival management functionalities

Arrival Management functionality in this case is not a stand-alone product. It is embedded in

the Flight Data Processing System and uses FDPS components to deliver arrival/sequencing information for the inbound traffic flow.

Generally, the sequence supplied is used as background information and not to optimize the flow.

This type of “non-dedicated” arrival management functionality is currently generally used in countries and in airports with relatively low-to-medium traffic levels.

The extent to which those areas with FDPS basic arrival management capabilities could be considered alongside what are known as Arrival Managers or AMANs is an open question, and one which needs to be addressed in the context of the positioning of AMAN (or arrival management) in SESAR’s Step 1 and future developments.

### Today’s AMANs

The minimum common functions of today’s dedicated basic AMANs can probably be summarised as those related to the building of an **optimised sequence** of aircraft, and the **metering of traffic** to that sequence. They also include functions related to the monitoring of the sequence, and to the provision of any necessary updates.

In these dedicated AMAN systems, aircraft are generally **sequenced** using set criteria. This “sequencing” criteria may vary from place to place, but could include, for example, equity, wake turbulence category and runway capacity or requirements.

In terms of **metering**, these systems usually begin with a planning phase, where aircraft arrival times are not fixed and the aircraft can “float” to some extent within the sequence. (i.e. the sequence is not yet “stable/fixed”). In a later stage the sequence passes into a more stable/fixed phase where less system changes are permitted or occur. Ultimately the sequence is developed into a completely stable sequence where no system changes occur. The precise points or distances at which these “phases” occur is a matter for local implementation, with some users favouring stability further out, and others favouring a more dynamic handling of the flights by the AMAN until a much later stage in the arrival process.

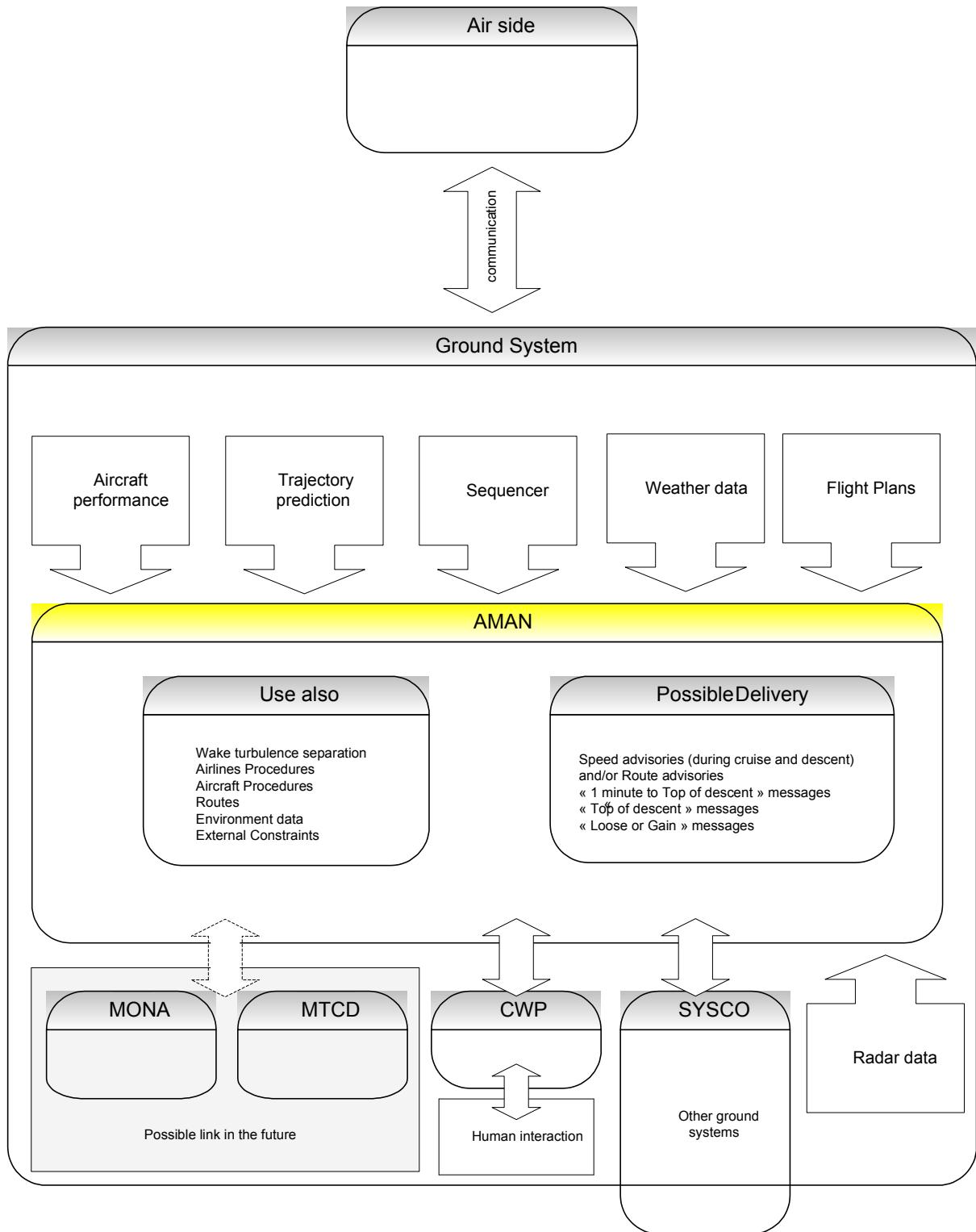
The metered sequence is linked to a timeline which gives as an output information of planned time, and “time to lose” or “time to gain” for each aircraft to meet its computed time at the reference point. In this case, the controller is in charge of finding the appropriate instruction for the aircraft, corresponding to the “lose” or “gain” advisories. This can include vectoring, path stretching, speed changes or holding.

In some instances, when an aircraft has to lose or gain time, some systems can now present specific advisories to the controllers that, after consideration by the ATCO, can then be transmitted to the aircraft. These can be a recommended speed, or a turn instruction at an appropriate place (This will be the case for the AMAN in Oslo when the Point Merge System will be implemented in 2011 in Oslo airspace).

Today’s AMANs can accommodate routine perturbations such as a runway closure, and are generally linked/feeding to 1 or 2 runways, although some systems are being developed to handle 3 or 4 runways. They may also possibly be linked to, or can consider, a Basic Departure Manager (DMAN), although, since DMAN is not as “mature” as AMAN that is not normally the case.

## 2.2.4 System elements

The following figure, Figure 5: Possible elements of a system, is a high-level representation of elements/modules that are often present in AMAN systems, or that *might* be “considered” for interaction with the AMAN in the future:



**Figure 5: Possible elements of a system incorporating AMAN**

As can be seen, various modules in the ground system can be involved in Arrival Management and some of their performances/characteristics/variations possibilities/differences are mentioned below:

**Aircraft performance model module:**

- Air Traffic Management (ATM) systems, including the AMAN, involve planning of traffic flows that rely on accurate estimation of aircraft performances. The aircraft performance module is a database of information on how different aircraft perform, using either a kinetic or kinematic approach. The available data bases can vary, from an extensive range of aircraft types to just a few aircraft models. Some modules use a “comparative” method, where aircraft performance for specific types is “translated” to the performance data of another, similar type of aircraft

**Trajectory Prediction module:**

- The Trajectory Prediction Module predicts the future progress of individual aircraft on the basis of the current aircraft condition and position, estimates of intent, expected environmental conditions and procedures, and computed models of aircraft performance. The AMAN may possibly use the Trajectory Predictor engine (TP) from the FDPS or the AMAN system may use its own TP process (better tuned for predictions of flight within the TMA)

**Sequencer module:**

- The sequencer module of an AMAN uses locally-prescribed sequencing criteria, and can be designed to build a sequence based on relative times (one aircraft being sequenced a set time behind the previous) or can mix relative times with fixed times (where a specific time is fixed for a flight in the sequence)

**Weather data model module:**

- Correct wind information is an important element of trajectory prediction, both for the aircraft systems (FMS) and for the ground systems calculating the future trajectory of the flight. Wind information can be common for all the airspace in function of altitude layers or possibly linked to a zone/bloc of airspace in function of the altitude (higher granularity). The data can also be loaded at specific periodic intervals (such as, 4 times a day) or more dynamically, in function of currently observed or reported wind information

**Flight plan data source and radar data source:**

- This data is at the source of the computation process. If this data is not complete or correct, accurate prediction is impossible. If flight data is supplied late (asymmetric airspace with a “short-side”), stable planning for the AMAN may be impacted. Radar data may also be used to track the aircraft according to their “plan” in the AMAN, with AMAN times updated from radar information

**SYSCO connection module:**

- In terms of AMAN, a way of seamlessly passing required AMAN information to the areas that need that information must exist. SYSCO is a typical way of providing this controller-to-controller connection, using OLDI-standard messages (including AMA messages) although other methods are also employed

**CWP HMI:**

- In nearly every ACC or APP local or customised HMIs are being used. When AMAN is added to the CWP, additional HMI possibilities related to AMAN can be considered.

Generally, for the AMAN supervisor, these at least include a timeline, time-management information, the aircraft callsign and wake turbulence category

- The output of the system can be colour-coded indications, or figures reflecting the time to lose or time to gain, or reflecting the advisories
- Those indications can be available on the timeline only, or on the timeline and the aircraft label on the screen
- For the controllers actually implementing the AMAN advisories or instructions, the AMAN indications can be propagated upstream using the same HMI (info only), on a simplified HMI, under text format or even more basically via CCTV or phone calls. It can also be incorporated directly into the radar label

The selection of the method of display is dependent on local choices, local factors and the technology available.

Colour-coding is an example of representation, such as in Figure 6: Colour-coded information on timeline.

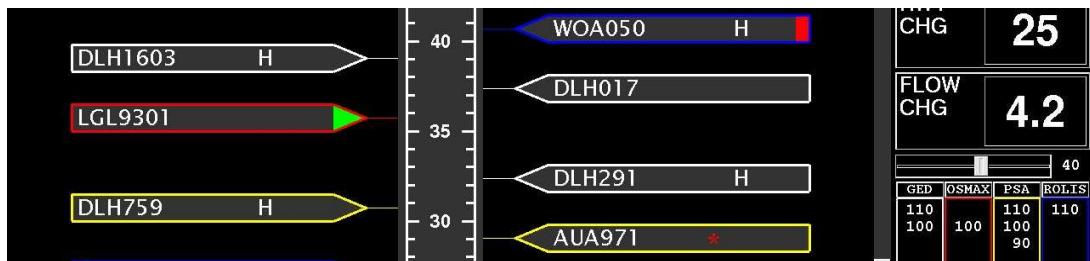


Figure 6: Colour-coded information on timeline

Another example is the information being displayed in the aircraft label, such as in Figure 7: Information in the aircraft label.

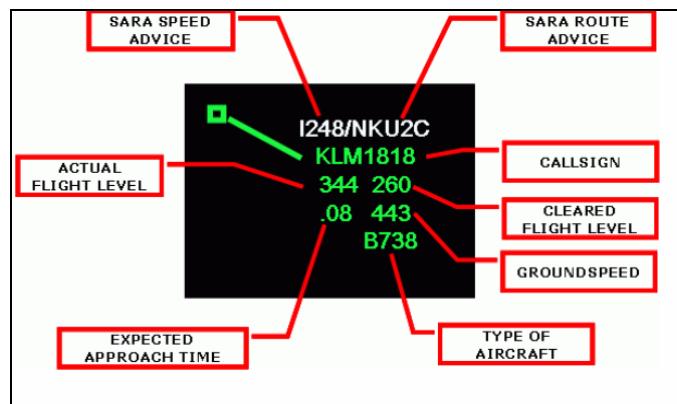


Figure 7: Information in the aircraft label

#### MONA and MTCD:

- Today's AMANs are pretty much stand-alone modules. In the future it is likely that a more "integrated" view of arrival management, and indeed of ATM as a whole, might be considered. In that instance, controllers using system support for arrival management ideally would likely receive integrated system support tools.
- Without anticipating future tool developments, examples of current tools or systems which might be considered for integration with AMAN in the future are MONA and MTCD. MONA is a monitoring aid that monitors traffic against clearances or flight-plans, while MTCD stands for Medium Term Conflict Detection, a module designed to assist in early detection of conflicts

Air/Ground Link module:

- The AMAN instructions and advisories are today “actioned” by the controller, who translates the required instructions into the necessary clearances, and transmits them via voice to the aircraft. With an increased use of Datalink in ATC, ideally, some AMAN information or instructions could (or even should) be transmitted via Datalink to the aircraft.

## 2.2.5 AMAN information exchange for ATC

Whether for basic systems or for more advanced ones, the information and advisories generated by the system can be forwarded/exchanged by different means between the AMAN, the AMAN supervisor and the users of the information in sectors upstream and downstream.

Usually this is done

- Via a display of the AMAN (supervisor) screen (timeline) at other controller positions. This can either be incorporated into the ATCOs situational display, or might also be done via a separate AMAN screen or display
- Via a display of an advisory in the aircraft label of a particular flight or
- Via a text-based message, summarizing the advisories for a sector

One method of transferring arrival management information electronically, system-to-system, could be via “AMA” messages to adjacent sectors (dedicated OLDI message - **Reference 9**) OLDI AMA messages, for “Arrival Management” coordination/transfer, contain the following items of data:

- Message Type
- Message Number
- Aircraft Identification
- Departure Aerodrome
- Destination Aerodrome

Based on bilateral agreement, they may also contain one or more of the following items of data:

- Metering Fix and Time over Metering Fix
- Total Time to Lose or Gain
- Time at COP (Coordination Point)
- Assigned speed
- Route

Note: The item Route contains the “requested routing” of the flight.

Alternatively, transfer of Arrival Management information could be done via similar message protocols used by the system concerned.

Additionally, if limited or no electronic coordination facilities exist, AMAN information and required actions could be transferred

- Via VOICE when the controllers are located in the same room
- Via PHONE when the controllers are not located in the same room

Examples of CWP-design are available on the previous drawings: Figure 6: Colour-coded information on timeline and Figure 7: Information in the aircraft label.

## **2.3 AMAN interoperability with other ATM elements/techniques/processes.**

Arrival management system support can interact, with several other operational techniques and processes involved both in arrival management and in the airport processes. For example –

### **2.3.1 Point Merge System (PMS)**

Point Merge is a new way to merge arrival flows that:

- is based on a specific precision area navigation (P-RNAV) route structure
- enables continuous descent approaches (CDAs) even under high traffic load
- is being considered for implementation at several locations across Europe
- is considered as a building block for 4-D trajectory management in SESAR

Point Merge is a developing Arrival Management Technique, which, in itself, does not rely on dedicated or automated ground system support. Point Merge uses P-RNAV technology currently on board of the aircraft, and a systemised approach to ATC operations and to the airspace design.

Point Merge simulations, however, conducted in preparation for its implementation in Oslo, Dublin and Rome, have shown that integration with an AMAN system support could also lead to further benefits from Point Merge itself.

Interoperability between Point Merge and AMAN has been the subject of a series of simulations that have taken place in Rome in 2008, and 2009. Basically the AMAN system was used, when needed, to implement time constraints prior to the sequence leg entry point or at an appropriate metering point while flights were still in En Route or in Extended-TMA, thereby metering traffic into the Point Merge area of operation and minimising the use of the sequencing leg.

More info: [http://www.eurocontrol.int/eec/public/standard\\_page/proj\\_Point\\_Merge.html](http://www.eurocontrol.int/eec/public/standard_page/proj_Point_Merge.html)

**Reference 12:** EUROCONTROL - Point Merge Integration of Arrival Flows Enabling Extensive RNAV Application and CDA – OSED Version: 1.0. Date: 21st April 2008.

### **2.3.2 Airport Collaborative Decision Making (CDM) process**

Airport CDM is a concept which aims at improving operational efficiency at airports by reducing delays, improving the predictability of events during the progress of a flight and optimising the utilisation of resources.

It involves partners (airport operators, aircraft operators/ground handlers and ATC) working together more efficiently and transparently, and sharing data in an open way. Improved decisions based on more accurate and timely information are possible, resulting in all airport partners having the same operational picture, with the same meaning to all involved.

AMAN information can be an integral part for the actors/partners involved in the CDM process.

Although benefits could be expected from this interaction between AMAN and CDM, questions may also arise because of it. The questions to be considered, in this case, might be: how much is ATC linked/tied to AMAN advisories, and how “fixed” will the AMAN process be, or need to be, to successfully integrate into, and with, CDM?

For example, what would be the impact/consequences of ATC implementing a late change to the sequence (and so the landing time and time at the gate) when all the actors may rely on the published planning?

This question is already pending at some airports having AMAN information available.

More info: <http://www.euro-cdm.org/>

## 2.4 ***What a current AMAN is or is NOT***

The following table (Table 1: What AMAN is or is NOT) and the text below outline briefly some of the common perceptions and mis-perceptions about AMAN.

	<b>AMANs are</b>	<b>AMANs are not</b>
1	Planning tools	Full trajectory monitoring tools
2	Metering traffic to metering points	Conflict detection and resolution tools
3	Support for controller decisions	A replacement for controller decisions
4	A traffic flow awareness distribution	The ultimate solution in ATM

**Table 1: What AMAN is or is NOT**

1. AMAN IS indeed a planning and sequencing tool. The core functionality of AMAN is designed to assist controllers in planning, and in operating, busy flows of arrival traffic at an airport.  
Although the AMAN can “monitor” and react to radar information and time updates of the aircraft as it progresses along its longitudinal path, it IS NOT a full trajectory monitoring tool, monitoring every aspect of a flight’s lateral, or vertical movement.
2. AMAN IS designed to assist in metering traffic into the approach or TMA airspace. When AMAN information and advisories are actioned in the ACC or feeder sectors, the result is usually a better regulated and metered flow in the APP/TMA.

Although the tool can assist in metering traffic, thereby smoothing bunches, AMAN IS NOT designed as a conflict detection tool, nor as a conflict resolution tool. AMAN “advisories” or the clearances required to implement the AMAN sequence are not automatically conflict free. In fact, an AMAN-sequence of a faster aircraft ahead of one that may already be physically in front of it, needs the controller to ensure that any passing is done “conflict-free”.

3. AMAN IS a controller support tool. As the wording states its aim is to provide “support” for the controller in executing their arrival management tasks. The controller is still an essential element of arrival management.

How a controller performs his/her job is more complicated than most people outside ATC realise. Many judgement factors are often instantly employed as an ATCO goes about their daily work, including sequencing aircraft. The AMAN software IS NOT capable of emulating all the factors that a controller considers, and as such will never replace the controller in their normal “control” functions or responsibilities.

4. AMAN IS a tool that facilitates the traffic situation awareness amongst the controllers. It can show controllers the overall arrival traffic situation at a glance and it has been shown to contribute to better understanding of the traffic situation between controllers of adjacent sectors. Additional functionality attached to the AMAN in many areas today also allows it to facilitate coordination between sectors effortlessly and easily.

Although an AMAN can help in supporting the controllers in arrival management, and it can provide additional situational awareness and functionality with it, an AMAN IS NOT the ultimate solution for all the problems in ATC or aviation either now or even in the future. It needs to be seen, and developed, as part of a suite of tools and functionality that can go some considerable way to improving ATM, but it is not the “ultimate” ATM tool.

# CHAPTER 3 – Required Studies

The decision to implement an AMAN can arise from different reasons: to reduce workload, to increase the capacity (operational needs/cases), to better manage arrivals in an environmentally constrained airspace (environmental needs/cases). Whatever the need or case driving the decision to implement AMAN, additional required study cases such as those for Safety and Human Factors, will need to be conducted prior to the implementation.

It is the responsibility of the ANSP concerned to perform any or all required studies prior to the implementation of any new software, such as an AMAN. This is to ensure that any local particularities for the planned implementation are well incorporated.

Commercial AMAN suppliers generally do not include many (if any) of the studies (Human Factors, Safety, Business Cases...) required by the ANSP, in the package that they deliver with the AMAN product. Some suppliers, however, are willing to provide information, or to assist in performing the different studies for their client; however this may be at extra cost.

The information presented in the following chapter is intended to give an overview of some of the studies that may be required by an ANSP during the decision and implementation process.

The information contains high-level principles, descriptions and requirements. It is not intended to replace any of the particular cases to be undertaken, but merely to add value to these cases by presenting, in one document, some of the considerations.

Specific important issues related to some of the cases (particularly Human Factors and Safety Cases) are documented in a later section, under Lessons Learned (CHAPTER 5 –).

**Remark:** The content of this chapter is NOT meant to be a one-shot blueprint (or a fully-prescribed “EUROCONTROL method”) for implementing AMAN. The information in it should be considered and adapted to suit differing local requirements.

## 3.1 **Human factors case**

It is important to identify the human performance benefits and potential issues, in order to facilitate acceptance and a smooth transition and also to realize the full benefits of an AMAN implementation. In order to do so, it is recommended to carry out a Human Factors (HF) Case or assessment when planning to implement AMAN.

The information in this section comes from “The HF Case”, a EUROCONTROL document (**Reference 6**).

### 3.1.1 **The Human Factors Case methodology**

The HF Case is a five-stage process to systematically identify and mitigate HF Issues as early as possible in the project life-cycle. The HF Case stages are (see Figure 8: Human

factors case):

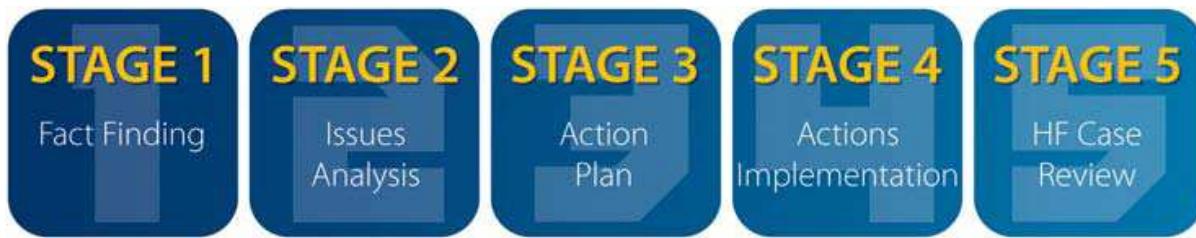


Figure 8: Human factors case

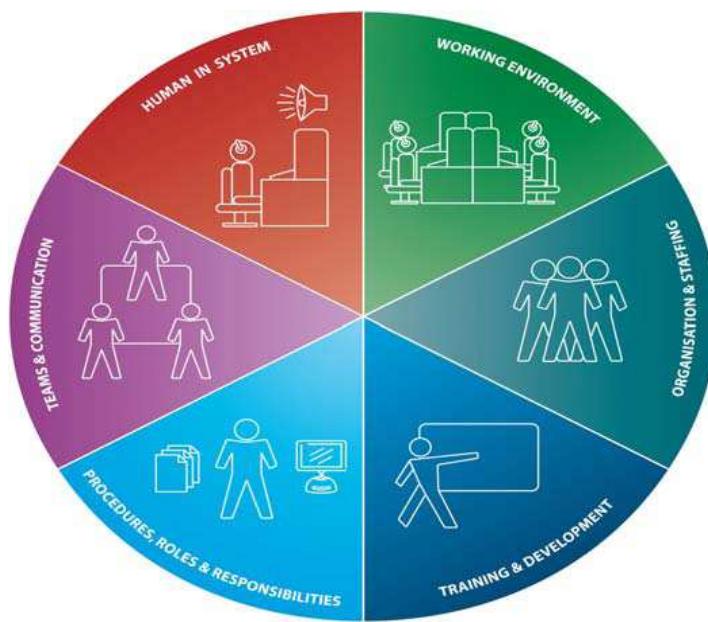
- **Stage 1 - Fact Finding:** The objective of this stage is to scope the project from an HF perspective to identify: (a) what is the nature of the change, (b) which actors will be affected and (c) how will these actors be affected.
- **Stage 2 - Issues Analysis:** This stage identifies and prioritises the project-specific HF Issues and their potential impacts on the human and the ATM system.
- **Stage 3 - Action Plan:** In this stage, an Action Plan is developed which describes actions and mitigation strategies to address the HF Issues identified for the project.
- **Stage 4 - Actions Implementation:** This stage implements the Action Plan. The output is the HF Case Report which provides findings and conclusions from the actions taken to address the HF Issues from Stage 3.
- **Stage 5 - HF Case Review:** This stage provides an independent review of the HF Case. It suggests recommendations for improvements to the HF Case methodology.

One of the crucial stages in the HF case is the Human Factors (HF) Issues Analysis. This Issues Analysis is usually done in brainstorming sessions between the Project Manager, system designers, operational staff, training specialists and an HF specialist.

The aim of this Issues Analysis is to identify as many potential problems that could compromise the success of the proposed system change (i.e. the implementation of AMAN).

For all of the identified issues, the impacts on the human (i.e. the controller) and on the ATM system (in terms of safety, capacity, efficiency, etc.) are identified.

To facilitate the identification of HF issues, the HF Case classifies HF issues into six main categories called the “HF Pie”.



**Figure 9: Human factors pie**

The categories in the pie are:

- Human in System (i.e. human-machine interaction and allocation of tasks between human and machine.)
- Teams and Communication (i.e. task distribution between actors and interaction between them)
- Procedures, Roles and Responsibilities (e.g. roles and responsibilities of actors and their working methods)
- Training (e.g. competence requirements, training design and planning)
- Organisation and Staffing (e.g. resource and transition management staff planning)
- Working Environment (i.e. work place layout and physical environment: light, noise, temperature)

Note that not all categories may be equally relevant for a project. For instance, with an “integrated” solution (where the AMAN information is incorporated directly onto the CWP of the ATCO) the impact of an AMAN implementation on the physical working environment may be negligible. On the other hand, if the display used is not incorporated into the CWP, or is not properly incorporated into the ATCOs’ physical working space then it may be relevant.

More guidance on how to carry out a Human Factors Case can be found in “The HF Case” (**Reference 6**).

### 3.1.2 Human Factors Issues and Impacts related to AMAN

It is recommended to carry out a HF case for each local implementation of AMAN.

To understand the impact of the AMAN implementation on the various actors, the following questions, amongst others, would probably need to be addressed:

- In which way will the operator’s task and task demands change by the introduction of an AMAN?
- What is the likely impact of the task changes on human performance (i.e. human error)?

- Will the operators accept and trust the new/changed system or tool?
- Will they be motivated to use it?
- Will there be excessive training and/or re-training costs?
- Will a different type of profile be needed to select candidates?
- Will the system fit in with conventional job roles and, if not, have new roles been considered?
- Will the operators have the right skills, and has adequate training been planned?
- Will the operators still be able to take over if/when the system fails?
- Will there be sufficient operators available to use/man the equipment?

It is important to understand that this list is not exhaustive, and that other Human Factor questions could also arise during the planning and implementation phases.

Local Human Factors experts should be employed in the implementation project from an early stage, to help direct/assist the project on HF issues and also to help mitigate problems that may arise at a later stage.

### 3.1.2.1 *HF Issues*

On the basis of feedback from pioneer users, a number of generic HF issues related to AMAN implementation have been identified. These issues are ordered according to the “HF Pie” categories and are listed in Table 2: Human factors issues.

For all the issues reported or identified, some high-level and initial suggestions are also made on how an ANSP might address them.

Top	Issues	AMAN specific guidelines remarks
1	Human in System	Optimal usability  AMAN performance should be assessed and tuned to meet the real traffic characteristics of the users' environment.  Also the degradation in performance of AMAN due to various conditions (e.g. during extreme weather conditions - very high winds, hardware processing performance) should be evaluated
2		Trajectory prediction (function) accuracy  The TP accuracy should be optimised to maximize the performance of the AMAN.  Ideally, an AMAN would have a dedicated TP, closely matching aircraft performances when they are flying in the TMA (especially their performance for non-clean configuration).  Procedures, such as a mandatory speed reduction to 250kts at FL100, should be correctly inserted in the system, as well as particular local procedures, to reflect the flown aircraft trajectories as close as possible.

	Transition Management	<p>Implementation of an AMAN system can be phased, from being used in the background, to being informative, to use for planning and finally for use as an active sequencing and metering tool.</p> <p>Alternatively, an AMAN can be introduced into operations in a “big bang” method along with other tools and procedural changes being implemented.</p> <p>Either way, a strategy for building trust and confidence and being able to fine-tune the system’s parameters is necessary.</p>
3	Data input and effect on reliability	<p>Updating the system and its impact on the reliability of AMAN should be facilitated by the HMI design and emphasised in procedures and training.</p> <p>Ideally, the input required to be done by controllers should be minimal. Only dedicated controller(s) should be allowed to manipulate the sequence built by the AMAN. Dedicated controllers should be responsible for the daily tuning parameters, such as establishing metering rates at certain fixes or runway closure.</p>
4	HMI and impact on messaging and coordination	<p>Good HMI principles and design for display and messages should be defined and implemented.</p> <p>In the first instance, usability of the HMI is achieved through the design process (e.g. Controllers should be involved in order to elicit local user requirements and to carry out usability tests).</p> <p>Secondly, ideally, the number of AMAN messages displayed to the controllers (e.g. messages for TTG/TTL) should be minimized, within the limits of operational acceptability. The way that these advisory messages are displayed to controllers should be carefully studied, and implemented according to local HMI requirements.</p> <p>Thirdly, generally, AMANs are reported as good facilitators for coordination between sectors, as the general traffic situation awareness is better shared between the actors with an AMAN, so the way that messaging is best displayed/used for coordination should also be investigated.</p>
5	AMAN advisories	<p>The nature and display of AMAN advisories should be carefully chosen with respect to the time for an optimal action implementation.</p> <p>Generally an AMAN supplies “Time to lose/gain” information. Some AMANs will also supply speed and/or route advisories. These need to be displayed with sufficient time to allow the controller to act on them.</p> <p>Sometimes, controllers may want the possibility to disregard the advisories and revert to conventional way of working, when judged necessary. This capability should also be considered.</p>

6	Teams and communication	Impact on communication and coordination between controllers	<p>An assessment on the impact of AMAN on the communication and coordination between the PC and TC, and between controllers in different sectors, should be undertaken and any adverse effects mitigated.</p> <p>Generally, AMANs are reported as a good facilitator for coordination between sectors, as the general traffic situation awareness is better shared between the actors with an AMAN.</p> <p>However, additional coordination may also be required due to the impact of using AMANs in the upstream sectors.</p>
8	Procedures, roles and responsibilities	Working method	<p>Working methods/procedures/roles and responsibilities should be developed (and where necessary adapted) to local environments to enable the controller to work effectively and efficiently with AMAN.</p> <p>The implementation of the AMAN might be phased, from running in the background, to informative use, to use as a planning tool and finally to use as a full sequencing and metering tool.</p> <p>At each phase, care should be taken that the proposed working methods reflect any changing uses of AMAN.</p>
9		Impact on demand task and vigilance	<p>The prescribed way of using AMAN should be validated to understand the impacts on task demand and vigilance and any adverse impacts should be mitigated.</p> <p>Pioneer ANSPs have reported a very positive impact of AMAN on task demand when AMAN is completely/fully used as a sequencing and metering tool. However this impact should be monitored in individual implementation</p>
10		TP assumptions about aircraft behaviour and specification procedures in	<p>Predictions used in ATM systems are relying on “perfect” aircraft behaviour as modelled by the TP. If the modelling does not match the real aircraft behaviour, the sequence built by the AMAN can be compromised and subsequently the level of trust in the system can be lowered.</p> <p>The aircraft performance data base, the trajectory prediction process and the coding of arrival procedures are of the highest importance when considering an AMAN implementation.</p>

11		<p>Familiarization in real environment</p>	<p>Training in the use of AMAN should be adapted to local needs and conditions. Simulations, shadow mode and using the tool in the real environment should all be considered to ensure controllers' familiarization.</p> <p>Several implementers report that the time spent in simulations is well repaid after the system goes live. After a theoretical course, the controller should have the opportunity to work with AMAN in an operational setting (in real-time simulations). Those sessions should be monitored to confirm that the optimum use of the system is well understood.</p> <p>Controllers should also be trained on the limitations of the system (conditions in which the proposed sequence may not be optimal, unforeseen situations).</p> <p>The impact of changing the sequence (and the possible chain reaction in other sectors) should be clearly demonstrated.</p>
12		<p>Knowledge on displayed information</p>	<p>Training on AMAN should emphasise how the system works and the data that underlies it, the reason why certain information is displayed and its impact on the AMAN behaviour.</p> <p>During training the controller needs to understand the importance of updating the system when required and the impact that updating the system has on the displayed information and on the behaviour of the AMAN itself.</p>
13		<p>Work strategy management</p>	<p>Controllers should be trained to develop appropriate work and time management strategies when using AMAN so that they can deal appropriately with the requirement to "comply" with the system requests/advisories.</p> <p>AMAN should be seamlessly incorporated into the ATCO's work management.</p>
14	<p>Training</p>	<p>Skill change</p>	<p>The impact on an ATCO's skills set of using AMAN should be monitored, especially in relation to the different applications of AMAN.</p> <p>Using a basic AMAN, the standard tasks of the controller generally do not change too much. The controller remains fully responsible for traffic separation in their own area.</p> <p>Where AMAN systems provide turn/speed advisories the impact of using these should be assessed.</p> <p>Regarding the dedicated AMAN supervisor position: the new role with new responsibilities requires a new set of skills and the way that these are to be acquired should be carefully considered.</p>

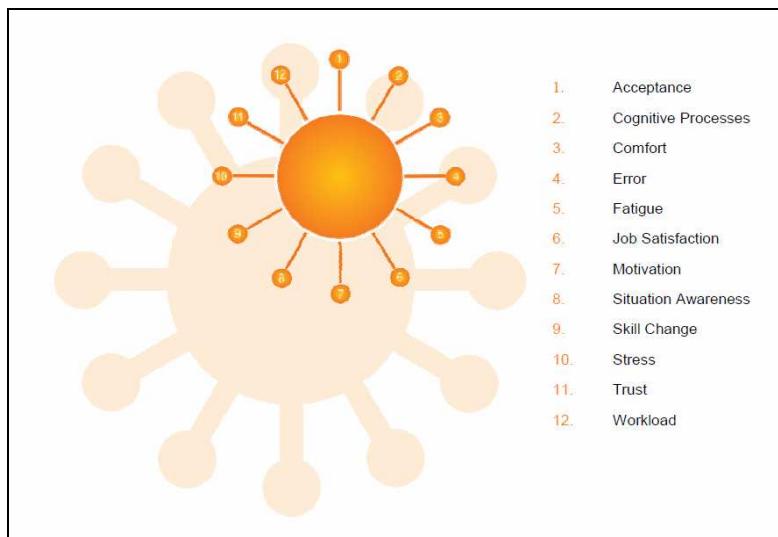
16		AMAN failure	<p>Training on AMAN should also include training for an AMAN failure, including the application of any contingency plans for traffic reduction.</p> <p>The controller should be immediately made aware of any AMAN failure (this is an HMI issue) and what to do.</p> <p>Procedures might be considered to reduce the traffic level, as the controllers may not be able to handle the same amount of traffic without the support of AMAN.</p>
17	Organisation and staffing, post-implementation monitoring	Staffing of controller positions	<p>The impact of using the AMAN with different staffing levels and positions should be monitored.</p> <p>Some implementations have considered combining the AMAN supervisory position with a regular ATCO working position. Others employ a dedicated AMAN supervisor ("TMA/APP supervisor"). The impact of using these different configurations should be considered.</p>
		Post-implementation monitoring	<p>The AMAN working method taught during training should be monitored post implementation and any adverse effects minimised.</p> <p>Additionally the experience from real-life operations and daily use of the system should be fed back into new and refresher training.</p>
18	Working environment	Work place layout	<p>The physical working environment is not fundamentally changed when the AMAN information is displayed on an extra window within the controllers working display.</p> <p>However, when the AMAN information is displayed on a separate display, or when it corresponds with the opening of a new dedicated "AMAN supervisor" position, this may require more fundamental changes to the layout at a sector-position level, within the OPS room.</p>

**Table 2: Human factors issues**

The identified HF issues are listed in CHAPTER 5 –“Lessons Learned”

### 3.1.2.2 *HF impacts*

Within the HF Case methodology, HF issues are classified according to their impact on Human Performance. The HF Impacts Wheel illustrates this.



**Figure 10: Human factors impact wheel**

Generally, mitigations and/or recommendations are supplied per issue, not per impact.

The impact analysis serves to understand what the consequences of an issue are (and so reflects how important it is to implement the mitigation).

Nevertheless, the HF impact of AMAN is included below (Table 3: HF impacts of AMAN) to provide a view on the main findings of feedback discussions with ANSPs who have implemented AMAN.

HF impact	Main findings guidelines/remarks
Acceptance	<p>Several issues relating to ATCO acceptance of the system have been mentioned as being important by previous AMAN implementers. These include:</p> <ul style="list-style-type: none"> <li>• Transition Management (how to plan and organise the transition, how to manage the team, and how to manage the transition from non-AMAN to AMAN operations) needs to be well handled, especially as challenges may arise during the transition and cause delays in implementation</li> <li>• The expectations of the controllers need to be properly matched to the capabilities of the tool as unrealistic expectations can lead to poor acceptance, even if the tool itself is performing correctly</li> <li>• Usability of the tools: The AMAN needs to be “usable” in order to avoid it not being used at all or not used as intended</li> </ul>
Cognitive Process	<p>Cognitive processes refer to the mental operations that are needed to carry out a task, in this case an ATC task.</p> <p>Generally, AMAN can be expected to decrease the amount and complexity of cognitive processes involved in building an arrival sequence.</p> <p>Nevertheless, there may also be situations in which the controller is faced with new mental demands, for instance, when considering changes to the AMAN sequence or advice.</p>

Comfort	No particular information regarding comfort changes has been received.
Error	<p>There is a potential for misinterpreting AMAN information especially if controllers are not trained properly.</p> <p>There is also potential for over-reliance on some AMAN advisories such as speed/turns especially if a reactive approach (waiting for AMAN advisories before acting) is adopted by the controllers.</p>
Fatigue	This HF issue is not considered to have a direct impact unless there are significant changes in workload and working conditions (rosters).
Job satisfaction	<p>This HF issue is not considered to have a direct impact unless there is a significant change to the job and role (e.g. AMAN supervisor position).</p> <p>However, any impact should be monitored over time and adverse effects addressed.</p>
Motivation	<p>Transition challenges and delays in implementation – e.g. training not done in a timely fashion and lack in transparency about the change can impact motivation in the short term.</p> <p>A strategy for building trust and confidence and maintaining motivation (keeping ATCOs in the loop from the beginning and all through the process) is necessary.</p>
Situation Awareness	<p>Generally, better situation awareness is reported, if the AMAN information is shared between the actors.</p> <p>This improved situation awareness helps the controller to better understand the flow of traffic and possible restrictions s/he is faced with.</p>
Skill change	<p>This HF issue is not considered to have an immediate impact unless there is a significant change to the job and role (e.g. AMAN supervisor). However, an assessment should be made of the potential impact on the ATCO training issues related to skill change.</p> <p>Potential de-skilling might be an issue, depending on the precise implementation of AMAN advisories (speed and/or turn advisories, depending on their range and extent of use) or a lack of practise in building the arrival sequence without system support.</p>
Stress	There may be some initial stress in adjusting to the new system, especially in the early days of transition which should be monitored.
Trust	<p>Issues related to over-trusting or to distrusting the AMAN tools should be assessed and monitored and any necessary action taken to mitigate any adverse effects.</p> <p>The perceived accuracy and behaviour of AMAN will influence whether (and to what extent) the controller trusts the system and follows the proposed working method.</p> <p>If the automation is perceived as imperfect or unsuitable, the controller may continue to work conventionally (due to mistrust). In addition, the controllers need to have an understanding of the basic algorithms behind AMAN planning to interpret the</p>

	information provided in a competent way (to avoid over-trust).
Workload	<p>In general workload when using AMAN is not reported as being significantly increased but the distribution of workload between the sectors is very often reported as being shifted upstream.</p> <p>The workload for the Approach controllers will usually decrease with AMAN as the metering takes affect (this is one reason for introducing this automation). The workload in ACC will probably increase due to actions required for an earlier sequencing/metering of the traffic (and the extra instructions/constraints to exchange with the aircraft, also due generally to extra time spent by aircraft in ACC sectors).</p>

Table 3: HF impacts of AMAN

## 3.2 Safety case

### 3.2.1 Introduction

It will be for each implementer to undertake a detailed safety study, with AMAN definition and design, taking account of their specific operational context and needs, and to plan for implementation, transition and operation. It will be for each service provider and their national regulators to determine, within the context of overall requirements, how to optimise the balance between the potential safety, operational and efficiency benefits of AMAN.

From this, implementers will need to carry out a safety assessment (in accordance with ESARR 4 or equivalent safety regulation), and where applicable develop a full Safety Case, demonstrating operational safety, and providing a basis for licensing and auditing by national safety regulators.

EUROCONTROL is developing material, in addition to its traditional Safety Assessment Methodology (SAM), in the form of a 2-part document called Safety Assessment Made Easier (or SAME), as follows:

- Part 1 (**Reference 10**), formally released in January 2010 following approval by the Safety Team, establishes the need for a broader approach than that detailed in SAM – i.e. assurance must be provided that a system will work safely in the absence of failure (the *success* approach), before considering the implications of failure itself (the traditional *failure* approach).
- Part 2 (**Reference 11**) details how to carry out and document the broader approach – it necessarily focuses mainly on the new, *success* approach and refers out to SAM for the *failure* aspects. It was delivered to EUROCONTROL in 2010.

As the above material is highly relevant to the introduction of a tool such as Basic AMAN, the guidance which follows below is based on that approach.

### 3.2.2 Modelling and Analysing the System

The approach described in SAME is based on good systems-engineering practice. As such it uses a hierarchy of models of the ATM system, as follows:

- a service-level description, commonly using a “barrier” model interpretation of the ICAO Global ATM Concept
- a functional model, describing the functions performed by the system, but without any reference to the actors (human or machine-based) that might perform those

functions

- a logical model, describing what each actor in the system does but without reference to physical items such as hardware, software, procedures, CWP, training etc
- a physical model, fully describing what is to be implemented in terms of hardware, software, procedures, CWP, training etc

This is illustrated in Figure 11: Hierarchy of Models and Safety Requirements: which shows a typical hierarchy of systems-engineering models used in the safety assessment process and the related safety information, for the Definition and Design & Validation phases of the lifecycle.

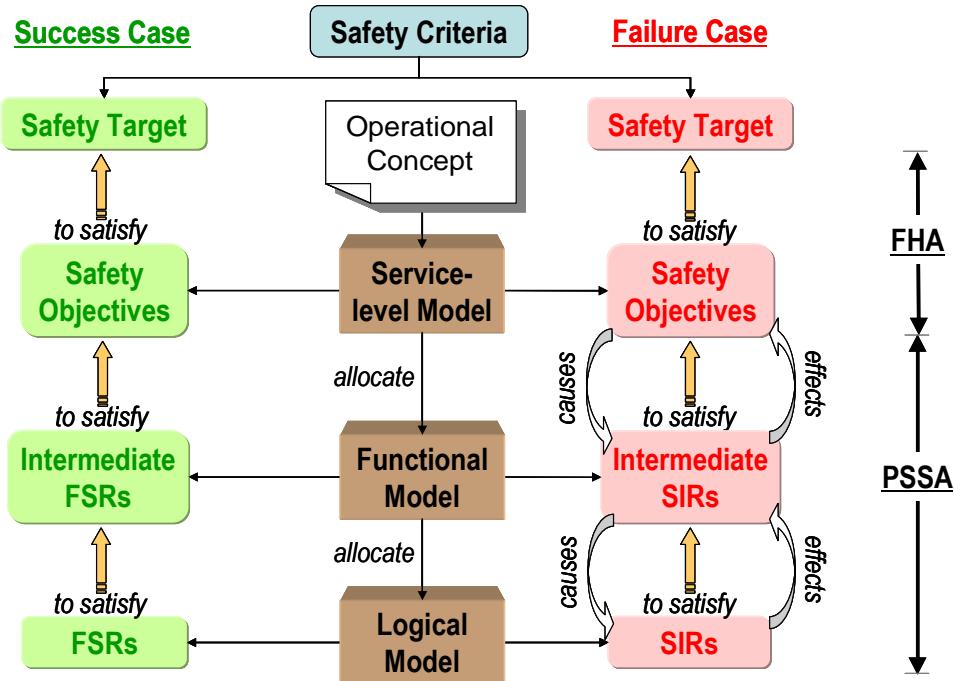


Figure 11: Hierarchy of Models and Safety Requirements

The progressive development of Service-level, Functional and Logical models from the related Operational Concept is (or should be) a normal part of the systems-engineering process on a project that introduces change (i.e. addition, modification or replacement) to an ATM system; in other words, the models are not specific to the safety process but should support any rationale for such a change – safety, capacity, efficiency, environment, security, economy etc.

What is necessary for a safety assessment is to analyse those (common) models to ensure that they are complete, correct and sufficient from a safety perspective – i.e. that, ultimately, they satisfy the Safety Criteria (including the project-specific Safety Targets).

### 3.2.3 Safety Criteria

Safety Criteria, selected for the Project, include:

- the regulatory and organisational requirements
- any standards to be applied
- the specific Safety Targets to be met

Safety Targets fall into three broad categories as follows:

- compliance with an absolute target – e.g. the ESARR 4 design target or ICAO Target

Level of Safety (TLS) – or portion thereof. Such targets are usually quantitative.

- relative to an existing (or previous) level of safety. Such targets may be quantitative or qualitative.
- where the risk is required to be reduced as far as reasonably practicable. Such targets are usually qualitative.

In general, absolute targets are preferred since satisfaction of them does not depend on proof of past safety achievement and such proof may be difficult if a suitable baseline does not exist or sufficient historical data is not available.

However, in some cases, there may be a problem in establishing a suitable absolute target because either:

- a regulatory target has not been set for the operational environment concerned, or
- for Project Safety Cases, it may not be feasible to determine what portion of the overall target it would be reasonable to allocate to the scope of the system concerned.

As an alternative to the absolute approach, a relative Safety Argument (i.e. based on a relative target) could be used for a Project Safety Case if:

- a well-defined baseline, prior to the introduction of (or change to) a “system”, could be established, and
- it can be shown, or at least reasonably be assumed, that the baseline situation was safe.

A reductive approach is called for by ESARR 3 (paragraph 5.1.4), which requires ANSPs to reduce risk as far as reasonably practicable. It is an important target for in-service safety monitoring – especially regarding incident investigation and corrective action.

It is usual to specify more than one type of target, and sometimes all three. In ATM, reducing risk as far as reasonably practicable is rarely adequate on its own<sup>1</sup> but it is often useful in support of one (or both) of the other two targets.

### 3.2.4 Using a Barrier Model

#### 3.2.4.1 General Description

The delivery of the ATM services can be described in the form of the Barrier Model of the ATM system shown in Figure 12: Barrier Model for Approach Airspace.

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<sup>1</sup> Both ATM 2000<sup>+</sup> and ESARR 4 require, as a minimum, that risk must not increase – reducing risk as far as reasonably practicable on its own does not ensure that this minimum requirement is met.

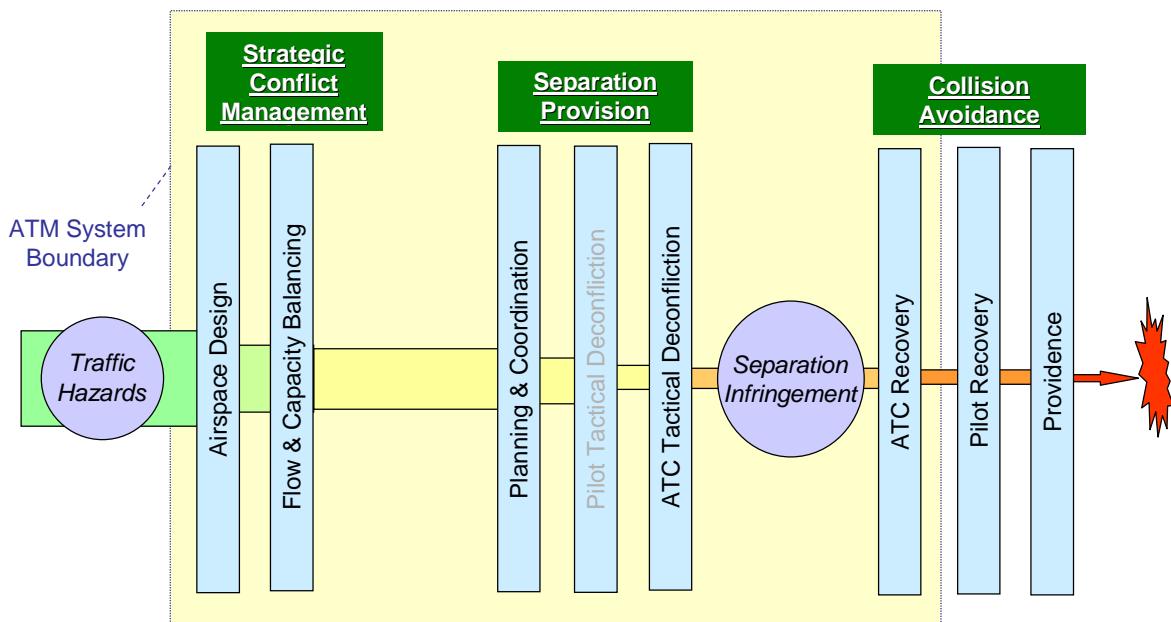


Figure 12: Barrier Model for Approach Airspace

Overall, the model is consistent with the ICAO Doc 9854 (**Reference 8**) description of Conflict Management:

- whose purpose is to limit, to an acceptable level, the risk of collision between aircraft and hazards (sic), and
- which is applied in three layers: Strategic Conflict Management; Separation Provision; and Collision Avoidance.

The inputs to the model are the (pre-existing) hazards that are inherent in the existence of air traffic, in the various phases of flight – the level and complexity of the traffic, *inter alia*, will determine the subsequent behaviour of the barriers within each layer of Conflict Management.

Four pre-existing safety risks are associated with the pre-existing hazards for Approach Airspace:

- mid-air collision (MAC)
- controlled flight into terrain (CFIT)
- wake-vortex encounter
- restricted-airspace infringement

The fact that traffic is both converging and descending towards the ground means that these pre-existing risks are inherently higher in Approach airspace than in, say, En Route airspace.

The barriers are grouped under the three, ICAO-defined layers of ATM. Each barrier is defined so as to be largely self-contained, and contributes positively to aviation safety by removing a percentage of the conflicts which exist in the operational environment, as follows<sup>2</sup>.

Within the Strategic Conflict Management layer:

- *Airspace Design* provides structuring of the airspace so as to keep aircraft apart spatially, in the lateral and / or vertical dimensions

<sup>2</sup> It should be noted that the Barrier Model is a simplified illustration, not a precise model, but can be useful in gaining a high-level understanding of major operational changes.

- *Flow & Capacity Management* mainly prevents overload of the Separation Provision barriers although, by simply smoothing out the flow of traffic, it does in effect reduce the peak number of potential conflicts in the areas affected

Within the Separation Provision layer:

- *Planning & Coordination* involves planning the routing, sequencing and timing of individual flights so that the aircraft, if they followed their planned trajectories, would converge to a single, appropriately spaced landing sequence without infringing any of the prescribed minimum separation. It includes the whole of the proactive role of ATC in avoiding conflicts<sup>3</sup> – cfr ATC Tactical Deconfliction – including coordination with adjacent sectors
- *ATC Tactical Deconfliction* reflects the more reactive ATC role in monitoring the execution of the plan (see Planning & Coordination) by detecting conflicts if and when they do occur and resolving the situation by changing the heading, altitude or speed of the aircraft
- *Pilot Tactical Deconfliction* involves the Flight Crew detecting conflicts when they do occur and resolving the situation by changing the heading, altitude or speed of the aircraft appropriately. Pre-SESAR, this barrier (shown “greyed out”) applies only to VFR aircraft in managed airspace and to all traffic in unmanaged airspace, and is not considered further in the safety assessment

The Collision Avoidance layer is intended to recover the situation only for those potential accidents that Strategic Conflict Management and Separation Provision have failed to remove from the system. In general, these may be considered as:

- *ATC Recovery* – this represents “late” intervention by ATC, triggered, for example, by STCA and/or MSAW
- *Pilot Recovery* – intervention by the Flight Crew triggered, for example, by an ACAS RA and/or GPWS
- *Providence* – i.e. the chance that aircraft involved in a given encounter, albeit in close proximity, would not actually collide

One very important thing that the above barriers have in common is that, because of inherent finite limits in their functionality and performance, none of them (neither singly nor in combination) is 100% effective even when working to full specification. The degree and extent to which the barriers are able to reduce risk (by removing conflicts or avoiding collisions, as appropriate) depends primarily on the operational concept and on the functionality and performance of the various elements of the ATM system that underlie each barrier.

Of course, should any of the barriers fail then the risk will increase during the period of failure because the barrier is simply ineffective and/or a new source of risk is induced by the failure.

### 3.2.4.2 Using the Barrier Model for Basic AMAN

What should be evident from the above and from an understanding of Basic AMAN is that the tool (having no conflict-detection or -resolution capabilities) fits entirely within the description of the *Planning & Coordination* Barrier.

Although it does not change what this Barrier does, in any way, it can have a negative effect on safety simply by impacting the operation of the Barrier and therefore allowing more traffic

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<sup>3</sup> It is important to note that in Terminal Area operations in particular, the P&C barrier is not restricted to what might be thought of the specific role of the Planner Controller (if it exists) – on the contrary, it also encompasses most of what the Tactical Controller does in terms of developing a plan, executing the plan and monitoring the progress of each flight against the plan.

to flow through the system<sup>4</sup>.

This is a change in the Operational Environment, but not a change to the ATM system at this level of abstraction, and needs to be taken into account in the safety assessment.

### 3.2.5 Using a Functional Model

A Functional Model would not be particularly useful for the safety assessment of Basic AMAN. This is because the *Planning & Coordination* Barrier is typically represented by a single function which we could call *Sequencing & Spacing*. Thus analysing this function would tell us little more than already seen at the Barrier Model level - i.e. the function remains unchanged because it is defined independently of the actors involved.

### 3.2.6 Using a Logical Model

As this is the level at which the allocation of the above abstract functions to human and machine-based actors is made, then clearly analysis of the Logical Model is highly relevant to a Controller tool such as Basic AMAN.

A typical Logical Model for Approach airspace is shown in Figure 13: Simple Logical Model for Approach Airspace: Simple Logical Model for Approach Airspace. This model captures all aspects of the Barrier (and Functional) model not just those applicable to the *Planning & Coordination* Barrier and *Sequencing & Spacing* function.

The Basic AMAN is shown, in this example, to be under the control of a Planner – that does not preclude the possibility of having a separate AMAN Manager role. The aircraft elements are also shown in some detail, as would be necessary, for example, for some form of RNAV application. For a simple AMAN safety assessment it would not be necessary to elaborate those elements.

It should be evident from the earlier discussion above that most of the safety assessment for a Basic AMAN would be focused on the Logical Model (for deriving Safety Requirements) and on the subsequent Physical Model and its Implementation (for showing that those Safety Requirements have been satisfied). In this respect, the key issues to be addressed include:

- showing that the system has sufficient functionality – i.e. software functions and human tasks
- showing that this functionality and the data used in the system is coherent and consistent
- showing that the system behaves as intended for the full range of normal conditions – i.e. those conditions expected to be encountered on day-to-day basis
- showing that the system will continue to function adequately under the full range of abnormal conditions – i.e. those that the system may encounter exceptionally and infrequently
- assessing the consequences and likelihood of failures within the system and showing that the overall (net) risk of AMAN-based operations is within the Safety Targets

SAME Part 2 gives detailed guidance on how to address all of the above issues.

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<sup>4</sup> Work under the SESAR Programme has shown that mid-air collision risk increases with the square of any increase in traffic levels.

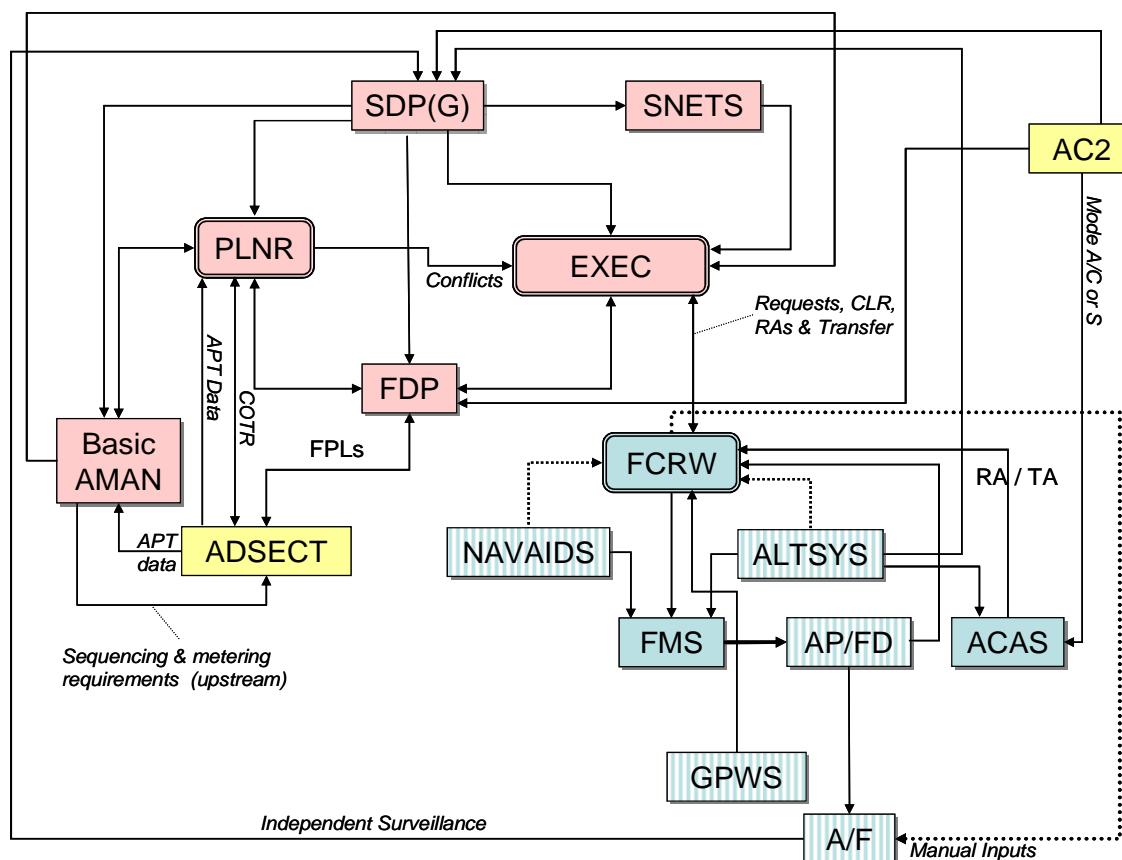


Figure 13: Simple Logical Model for Approach Airspace

### 3.2.7 Safety Plans, Safety Arguments and Safety Cases

#### 3.2.7.1 Introduction

A Safety Case is similar to a legal case, which is presented (by both sides) as a series of arguments, deriving from an overall claim of guilt (or innocence), followed by the presentation of evidence to show that each argument is true.

The same idea applies to a Safety Case, except that the overall Claim is invariably that something (e.g. a service or system) is acceptably safe. The Safety Case then breaks the Claim down into a set of Safety Arguments; each supported by rationales and Evidence, such that the Claim may be considered to be valid if (and only if) the Evidence shows each Argument to be true.

Since the Safety Argument represents what has to be shown to be true and the Evidence is the information which shows that it is true, SAME is based on what is known as an argument-driven approach in which all the safety activities, which produce the evidence are themselves determined entirely by the need to satisfy the argument.

This is illustrated in Figure 14: Safety Argument and the Lifecycle, and shows the following simple relationships:

- there is one principal Safety Argument for each phase of the lifecycle
- the decomposition of each Safety Argument (including, at the lowest-level of decomposition, the so-called *Safety Assurance Objectives*) determines the *Safety Assurance Activities* that go on in each lifecycle phase
- the Safety Argument, Safety Assurance Objectives and Safety Assurance Activities should, therefore, form the core of the Safety Plan

- the Evidence for the Safety Case is simply the output of the Safety Assurance Activities
- the same Safety Argument, together with its supporting Evidence, forms the core of the Safety Case; there is, therefore, a straightforward auditable trail for the entire safety assurance process, from planning, through execution, to documentation of the results

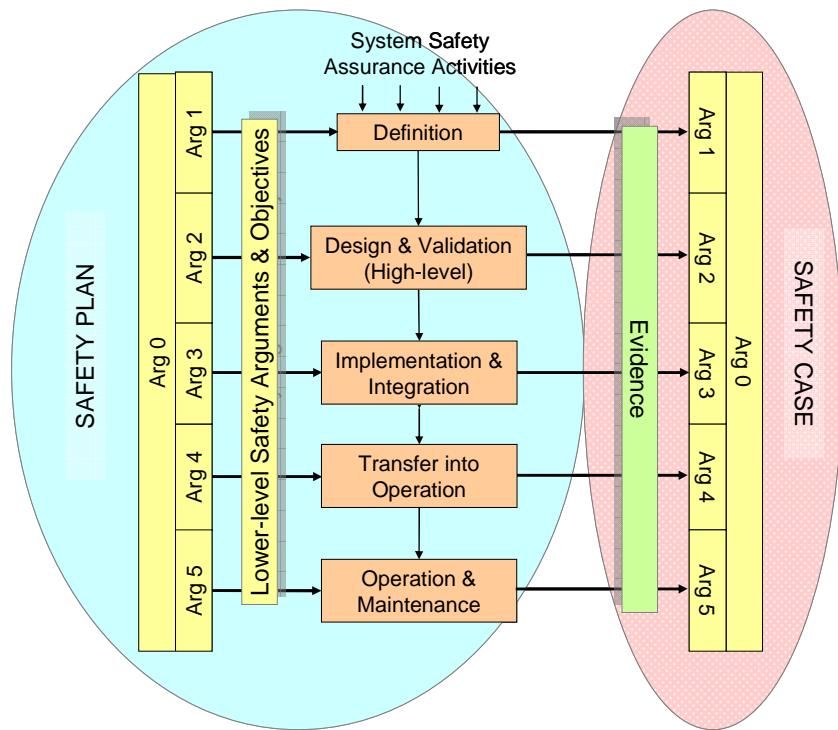


Figure 14: Safety Argument and the Lifecycle

### 3.2.7.2 A High-level Safety Argument for an ATM System Change

If we wanted to demonstrate (in, say, a Safety Case, just prior to entry into operational service) that a proposed change Subject X would be acceptably safe (as defined by the agreed Safety Targets), in a defined operational environment, then we could do so by showing that:

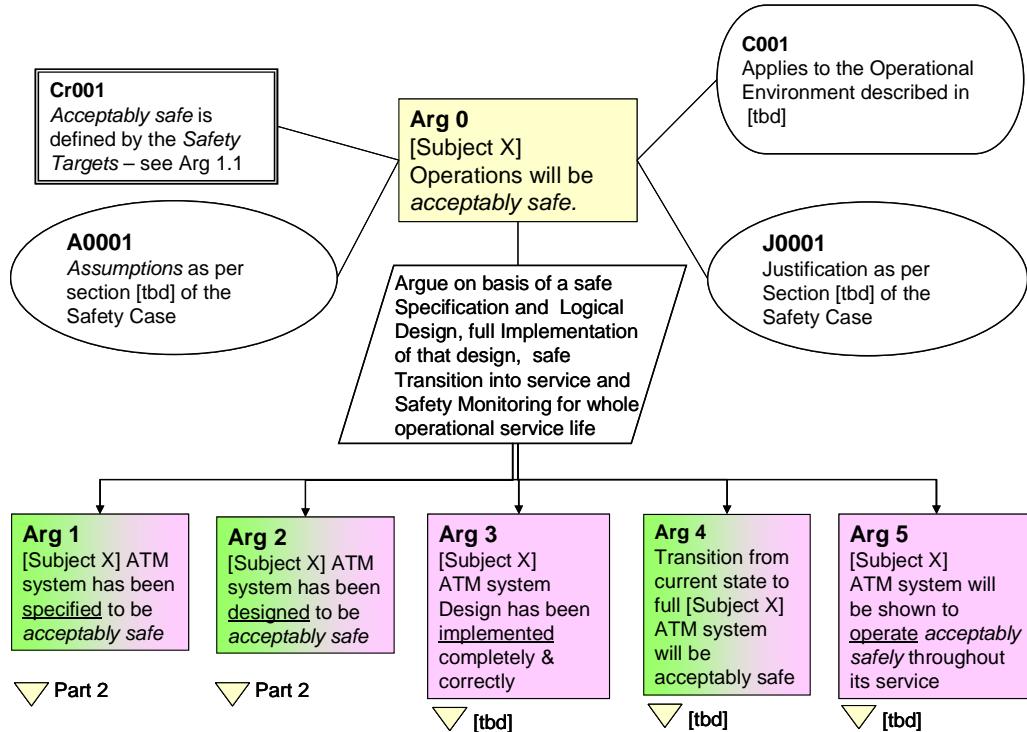
1. *Subject X ATM System has been specified to be acceptably safe* – this refers to the service-level model of the system
2. *Subject X ATM System has been designed to be acceptably safe* – this refers to the Functional and Logical models of the system
3. *Subject X ATM system design has been implemented completely and correctly*
4. *The transition from current state to full Subject X ATM system will be acceptably safe*
5. *Subject X ATM system will be shown to operate acceptably safely throughout its service*

We would probably also want to justify why the change was being made (e.g. increasing capacity to meet airspace user demands) and also declare any fundamental assumptions that were being made (e.g. that the ATM system before the change was at least tolerably safe).

Figure 15: Generic ATM safety Argument presents exactly the same information in pictorial

form, using what is called Goal-structuring Notation (GSN).

The logic underlying Figure 15: Generic ATM safety Argument is that the top-level Argument (Arg 0) can be claimed to be true if (and only if) Arg 1 to Arg 5 are shown to be true.



**Figure 15: Generic ATM safety Argument**

SAME Part 2 provides considerable guidance on how to decompose the generic Argument to the necessary detailed level.

### 3.2.7.3 Adapting the Generic Safety Argument

One of the many strengths of the argument-driven approach is that it allows for the generic Safety Argument to be adapted to suit a particular project.

A good example of this is the point about Basic AMAN made, in section 3.2.4.2 - Using the Barrier Model for Basic AMAN, that Basic AMAN does not alter the service-level description (i.e. the specification). This provides the opportunity for the Safety Case to present the rationale for not needing to address Argument 1. Furthermore, for the similar reasons stated in 3.2.5 - Using a Functional Model, it is also legitimate to present a rationale for not addressing those detailed parts of Argument 2 that relate to the Functional Model.

Detailed guidance on this, and on developing and executing a Safety Plan, is provided in SAME Part 2.

The identified Safety issues are listed in CHAPTER 5 – “Lessons Learned”.

### 3.3 **Business case**

There is no example available of a “traditional (Pre-implementation)” Business Case for AMAN supplied by industry.

When implementing AMAN, the ANSPs invest mainly for the benefits of the airlines but they also invest for their own benefits. So it is difficult to measure who exactly makes the precise savings, or who receives most of the benefits from the system when it is employed.

- The benefits can be qualitative via a mean of global plans, allowing more stable plans for airlines
- The benefits can be quantitative, for example, via shorter airborne delay absorptions for example

Post-case analysis seems to be the best method to have an idea of the benefits of a new Arrival Management System, albeit available only after the system has been purchased and implemented. Nevertheless, most of the time, other changes are also often introduced together with the AMAN software. In this case, it is even more difficult to split the benefits resulting from the AMAN tool only from the benefits of new airspace design or new coordination procedures for example, introduced together with the AMAN tool.

Post-case analysis can be done by documenting the general benefit that the ANSPs estimate they receive. Studies on fuel used in specified configuration of arrivals to an airport can also supply quantitative data, when compared against the original baselines.

Post-case study is for the moment the best option for Business Case.

There are currently no standard KPI for AMAN (KPIs are relevant for AMAN but difficult to assess and quantify).

#### 3.3.1 **Environment**

An Environmental study would likely be part of the overall purchase/implementation case for an AMAN.

Environmental benefits, which can be expected by the general community from the implementation of an AMAN, are:

- Pollution: There should be a reduction of emissions, which results from the “general” flight efficiency gains. The expected reduction in average fuel consumption/flight will reduce CO2 emissions.
- Noise: There may be no direct effect from an AMAN implementation on noise, but an AMAN system may help in balancing the traffic on different runways and may also help in facilitating CDAs for aircraft even in higher density of traffic, thereby reducing the noise at lower levels.

#### 3.3.2 **Operations**

Likewise, operational aspects/requirements will usually be developed during the overall purchase/implementation case for an AMAN.

These will normally cover the initial and the new operational situation and procedures: whether e-strips are used or not, whether electronic coordination is employed or not.... They will also help define the requirements/expectations regarding HMI issues.

When operational aspects are considered new working methods may be proposed to the

ATCOs, with new roles, responsibilities and procedures. These may be valid not only for the operations inside their own sector/s but can also impact the way of working with other/higher sectors, even outside their own “home” FIR.



Figure 16: ATCO at work

### 3.3.3 Examples of post-implementation declared benefits

- **INFO MAESTRO**

Paris CDG (France): Although not a declared “benefit” in itself, in Paris the nominal TMA capacity may be reduced by 30 percent if MAESTRO is not available (occurred once in 2001).

Copenhagen (Denmark): Runway capacity for EKCH has been increased by 15 percent, attributed to AMAN implementation.

Stockholm Arlanda (Sweden): Increased capacity and efficiency for airlines has been reported due to less time spent in holding and also due to shorter routes being facilitated by the AMAN and the metering of traffic.

- **INFO 4D PLANNER**

“In Germany, the 4D Planner is in use at Munich and Frankfurt airport. Early results show a reduction in the average approach time of approximately 60 seconds.”

Originally, the request for AMAN was originating from ATC. Due to CDM being put in place, the request comes now also from Airports departments”.

# CHAPTER 4 –Implementation considerations/expectations

## 4.1 *Introduction*

In drawing up their Global Air Traffic Management Operational Concept, Doc 9854, ICAO has identified several “expectations” related to a global ATM system implementation.

These expectations come from various efforts to document users’ requirements, and while they relate to the overall ATM system and concept, they might also be applied to individual elements of that system.

In relation to the implementation of a software system element such as an AMAN, though, it must also be remembered that ATM is a system composed of many “linked” elements and as such AMAN cannot and should not be considered purely in isolation. The AMAN also needs to be considered in conjunction with the airspace and environment in which it will be used, and the procedures for its use also need to be considered at the same time.

While safety is recognised as being of the highest priority in ATM, the expectations below are shown in alphabetical order, as they would appear in English:

- Access and equity
- Capacity
- Cost-effectiveness
- Efficiency
- Environment
- Flexibility
- Global interoperability
- Participation by the ATM community
- Predictability
- Safety
- Security

**“Measuring programming progress by lines of code is like measuring aircraft building progress by weight.”**

(Bill Gates, American Entrepreneur and Founder of Microsoft)

From those 11 users' expectations, perhaps the ones most relevant to AMAN – Safety, Capacity, Efficiency, Environment and Interoperability are briefly reviewed below.

#### 4.1.1 Safety

As stated previously, safety is considered to be of the highest priority in aviation.

When implementing, or considering the implementation of an AMAN, appropriate risk and safety management processes should be applied prior to, during and after the implementation.

Some AMAN suppliers have a "Safety Management Process" in place; within which they can supply a generic safety case to the ANSPs. Local considerations obviously have to be considered and included, and the final safety documentation must be approved by the appropriate regulatory authorities. This applies whether the AMAN is delivered as a stand alone package or as part of a bigger system upgrade.

The implementation of an AMAN is expected to provide the same or even a higher degree of safety.

The safety case and Human factors case processes are explained in Sub-chapter 3.1 and Sub-chapter 3.2.

#### 4.1.2 Capacity

An ATM system should ideally be geared towards providing the required capacity to satisfy airspace-user demands, while at the same time minimising restrictions on traffic flow. However, at times, demand exceeds runway capacity, and it is then that system support tools such as AMAN can assist in maintaining a high degree of capacity, while keeping restrictions to a minimum.

The implementation of an AMAN tool can be expected to provide the same or more capacity with at least the same level of safety, through improved controller efficiency and reduced controller workload.

In addition, the capacity level for a runway can often be maintained with better "environmental" consideration, because of the reduction in holding and low-level vectoring, achieved through AMAN-assisted metering and sequencing.



Figure 17: Benefit linkage

In terms of sector capacity, although part of the ATCO workload that revolves around arrival management and the AMAN moves to the upstream sectors, feedback received so far from previous implementers indicates that in most cases this is an acceptable increase. It is considered to be balanced by a bigger workload decrease in the approach sectors. Also the use of the AMAN is considered to have only a relatively small impact on the sector capacities. It should be noted, however, that this feedback comes from areas and ANSPs where usually only single-AMAN implementations have occurred and the workload/sector capacity issues might be different for En Route sectors dealing with several AMANs, serving

several TMAs.

#### **4.1.3 Efficiency**

For airlines, efficiency addresses the operational and economic cost of operating a flight or flights from gate-to-gate. Operators and airspace users ideally would like to operate their flights, departing and arriving at times that suit their business needs, and flying in a manner and on a trajectory that also best fulfils their needs.

However, when demand exceeds capacity in today's operations that type of operation is not always possible. Implementation of an AMAN still addresses the demand for efficiency by minimising arrival delays in as much as possible, and by providing operators improved profiles through reduced vectoring and holding.

Enhanced "predictability", combined with improved and consistent levels of performance and traffic management (another ICAO "expectation") is also addressed and fulfilled by the AMAN.

Efficiency and economic benefits linked with the implementation of an AMAN can be expressed in terms of money, time, fuel and/or resources for the following participants:

For ANSPs:

- Via a more efficient use of human resources

For Airspace Users:

- Through flight efficiency improvements (due to better predictability of aircraft trajectory/routing)
- Through a reduction in fuel consumption (due to reduction of airborne holding and vectoring)

For Airport authorities:

- Better predictions of arrival times, for turn-around time and related services on the ground

The Business case is previously covered in Sub-chapter 3.3.

#### **4.1.4 Environment**

The ATM system as a whole is responsible for addressing and reducing the environmental impact of aviation. Ambitious targets for fuel- and emissions-reductions are part and parcel of most current and future ATM strategies, such as SESAR.

AMAN can assist in reducing the environmental impact by providing a more efficient method for handling busy arrival streams over that employed in today's holding and vectoring.

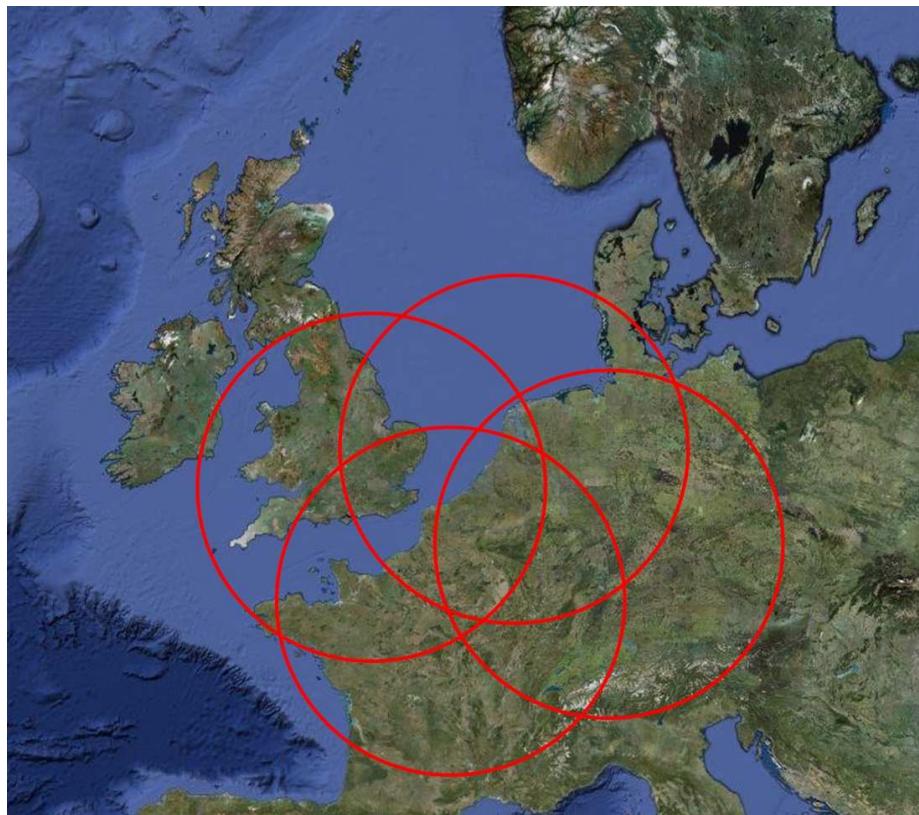
When aircraft are subject to an AMAN delay, the norm is to try to absorb the delay when the aircraft is still a considerable distance from the destination airport, and is at a high level. This can reduce the need for delay absorption later in the flight, when the options are normally reduced to holding, low-level path-stretching and/or vectoring.

Minimising these current "tactical" delay-techniques reduces fuel-burn for the flights, thereby having a corresponding reduction on emissions, and other environmental considerations, such as noise (an issue, usually below 10,000)

Environment is previously included in the Business case study covered in Sub-chapter 3.3.

#### 4.1.5 Interoperability

Although there are no AMAN INTEROP standards available to date, the arrival management process including the use of AMAN would benefit from a standardized approach to its use. This is specially the case if AMAN is envisaged to operate cross-border where systems will need to exchange AMAN information with each other (e.g. using AMA messages).



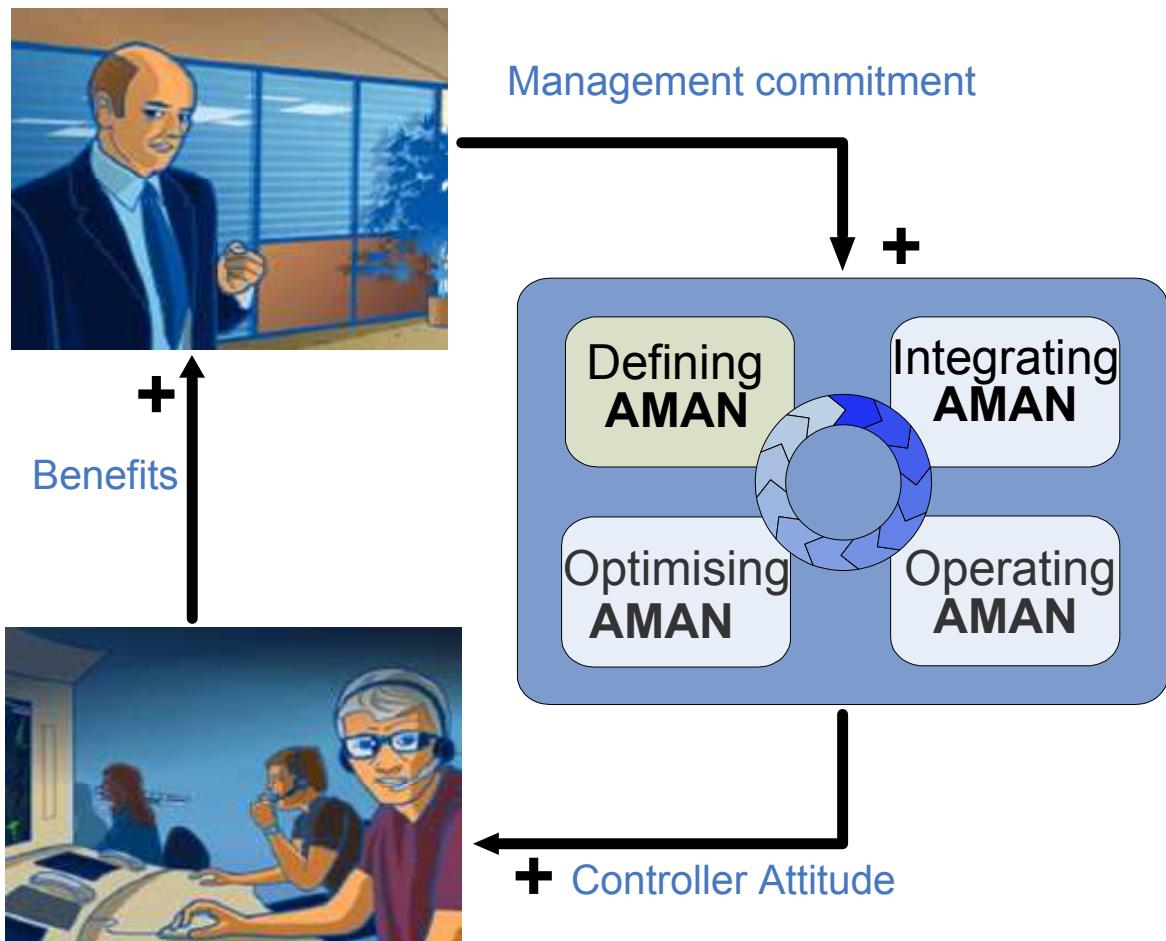
**Figure 18: Theoretical illustration of overlapping AMAN horizons in core Europe**

Figure 18: Theoretical illustration of overlapping AMAN horizons in core Europe above shows an illustration of 250Nm horizons extending from 4 of the top 5 busiest airports in Europe – London Heathrow, Paris Charles de Gaulle, Frankfurt and Amsterdam Schiphol.

As can be seen, there is extensive overlap of the horizons, with the area above Benelux being contained within all four horizons. This would mean that, if these horizons were all implemented, the Maastricht UAC would be involved in implementing and possibly coordinating the arrival sequences to each of these four airports. This would also require significant pan-European network coordination.

## 4.2 *Implementation Guidance*

The following drawing (Figure 19: AMAN implementation process) is a high-level representation of a process that might be followed when implementing an AMAN.



**Figure 19: AMAN implementation process**

The process is a revolving one, from definition to integration, operation and optimisation.

It also usually needs both a strong commitment from the management to support the process (from specification through to implementation), and also the involvement of technical and operation personnel during the entire process (from specification, through design and testing, to implementation) to ensure the success of the venture.

Below, in more details, the different phases of an AMAN implementation are covered.

#### 4.2.1 Defining AMAN

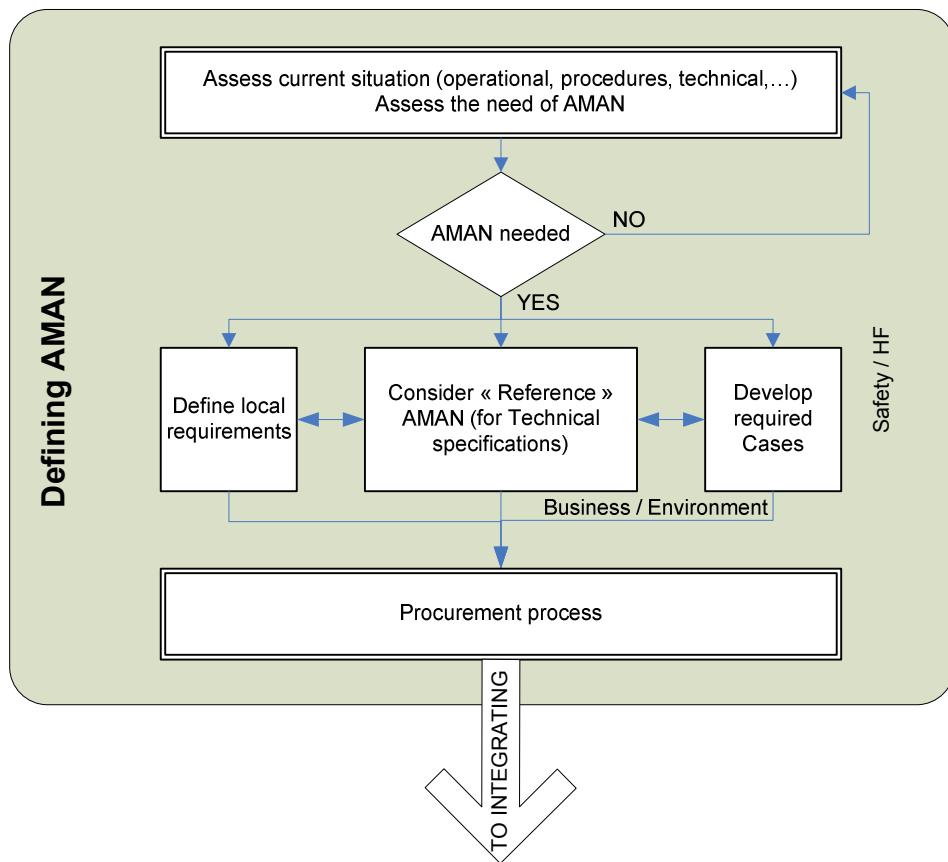


Figure 20: Defining AMAN

The “need for an AMAN” is usually the result of an operational assessment and the recognition that some form of automated support to ATCOS, to help controllers in reducing delays and low-level vectoring and holding, may be needed.

When an AMAN is considered it may be considered in isolation (just AMAN software), or it may be considered as part of a larger implementation or change, such as in a decision to upgrade the FDPS, or significant parts of it.

In the case of a decision to implement even just the AMAN itself a project manager, and a project team, to oversee the implementation process will usually be designated. Given the length of time that may be involved in the process, a dedicated project manager and a dedicated team is probably a must in any AMAN implementation project.

The team may be large or small, but would ideally comprise both operational and technical personnel who would be able to see the process through from start to finish, from specification to testing to training to implementation.

At the beginning of the definition phase for the AMAN (Figure 20: Defining AMAN) 3 different processes will generally be run in parallel:

- A study (by both technical and operational people) of commercially available products and their “specifications” may already help the potential user to better understand the workings of an AMAN, and may help to define the technical requirements that may be asked from their own AMAN.
- A study of the local operations will help define specific local operational requirements

(with ATCOs involvement)

- Some required studies will be launched. These will include Safety, Human factors and Business cases. (These processes are explained in CHAPTER 3 – "Required Studies")

The results of those three processes will largely determine the procurement process and will finally influence the choice of a COTS or self-developed AMAN solution.

It should be recognised that the resources (both human and financial) and the time needed may vary considerably between those two development solutions. Those requirements and considerations are also usually captured during this phase.



Figure 21: A humoristic view of AMAN definition phase (© Hindsight magazine)

#### 4.2.2 Integrating AMAN

When the chosen solution is a commercial product, the ANSP will normally contract and purchase an AMAN solution with a commercial supplier (possibly as a stand-alone unit or possibly integrated with a new/upgraded version of his FDPS).

When the chosen solution is self-development, the local engineering team will start the IT process. This solution supposes that the ANSP has the expertise available in-house to design/develop and implement the required functionalities.

An intermediate solution may be the purchase of the "core" of the AMAN system from a commercial developer, and the development of the local interfaces and dedicated HMIs by the ANSP itself.

All of these solutions have been applied in AMAN implementations in different locations in Europe.

As part of the contract with a commercial supplier a training package will usually be included, where generally, the supplier will “train the trainers”, providing basic training for the instructors who will teach the system to the ATCO end-users.

In the case of an internally developed system, dedicated ATCOs will normally be part of the implementation team. As part of their role they would normally be expected to be the trainers of the end-users since they will be familiar with the system from the beginning.

In all cases (Figure 22: Integrating AMAN), the initial version of the AMAN developed or purchased will usually need extensive customization and integration into the current/new FDPS.

The system will also need to be adapted/tuned/tested in light of the local operational and technical requirements, as defined in the definition phase; and lastly, updated or new local operational procedures will also need to be developed and tested prior to going to full operations.

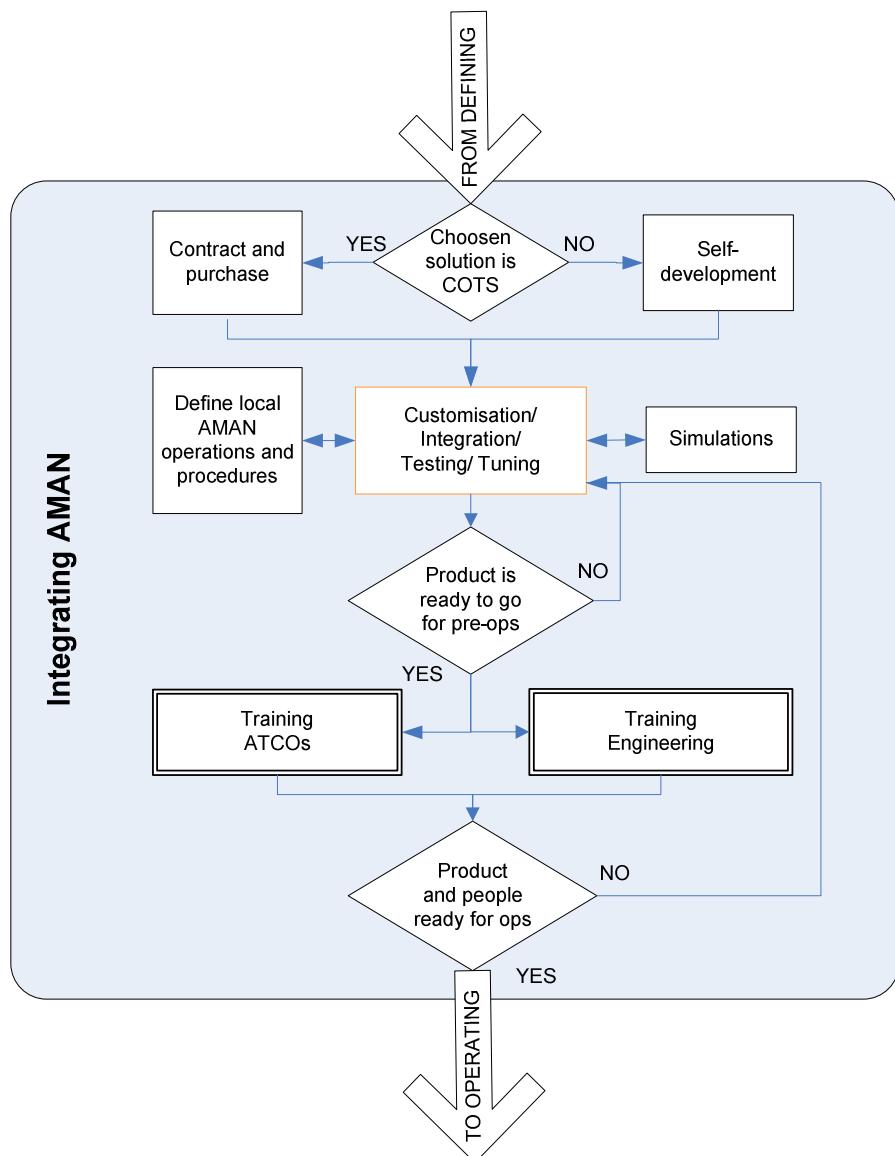
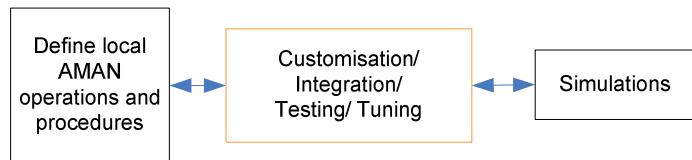


Figure 22: Integrating AMAN

Both technical and operational aspects will likely need extensive testing/simulations and fine-tuning before the next phase: the pre-operational phase.



**Figure 23: Kernel of the integration phase**

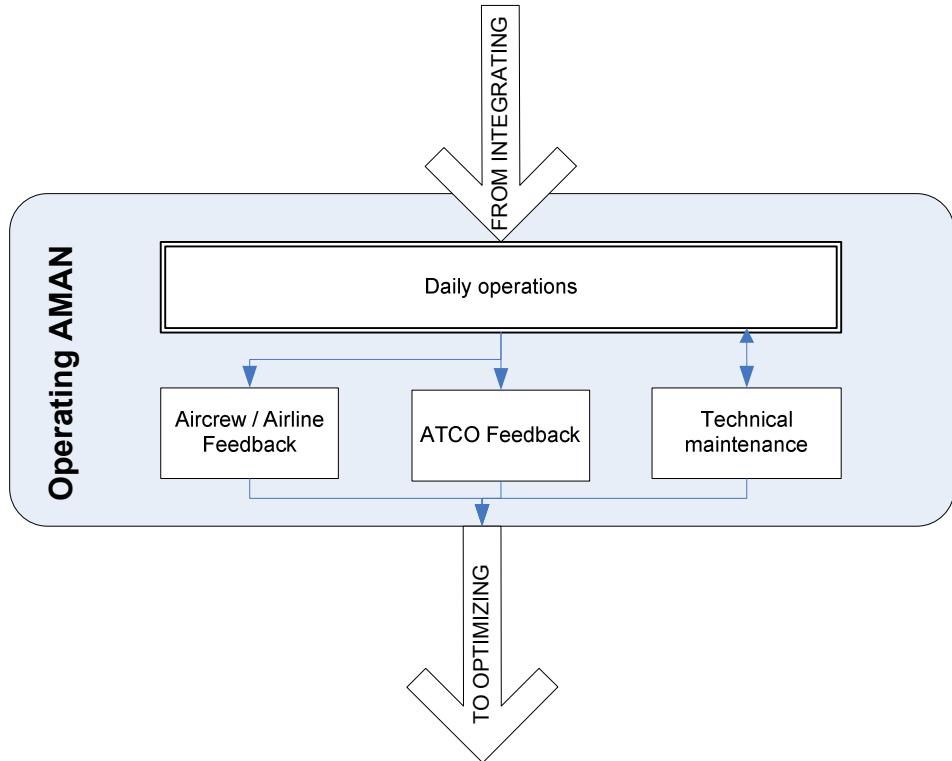
Although this process looks quite simple on paper, experience shows (as reported by previous AMAN implementers) that this phase can take 12 to 18 months or maybe even longer. The process at the centre of the Integration phase (Figure 23: Kernel of the integration phase) , the customisation, testing and tuning, is a central key in any successful AMAN implementation and is one that is normally underestimated in terms both of time and of resources.

The training phase begins with the training of the ATCOs and of the technical team that will support the implementation. There are usually several different types of training possible: short courses, information brochures, training within simulation environments, shadow mode with real system, computer-based training). Ideally, since the training will be part of the final preparation for operations, the training should take place with the final version of the product.

When all training, operational and technical, has been completed and when all tuning has been done to a satisfactory level, the decision is normally then taken to move to “operations” with the AMAN. This decision, of when precisely to move to operations, may also be affected by other factors such as the readiness of other tools/systems being implemented at the same time, or the readiness (publication) of the necessary accompanying procedures.

The introduction into use can be phased (initially “shadow-mode”, then “operational in low traffic”; or from “low traffic density” to “medium or high-density ops”) or it can be the result of a “big-bang” implementation approach (like the introduction of the AMAN together with a new FDPS system, which may be done in one single change, this is a local decision.

#### 4.2.3 Operating AMAN



**Figure 24: Operating AMAN**

During daily operation (Figure 24: Operating AMAN), the feedback from ATCOs using the system is essential. This will help greatly in optimizing the system, both technically and operationally.

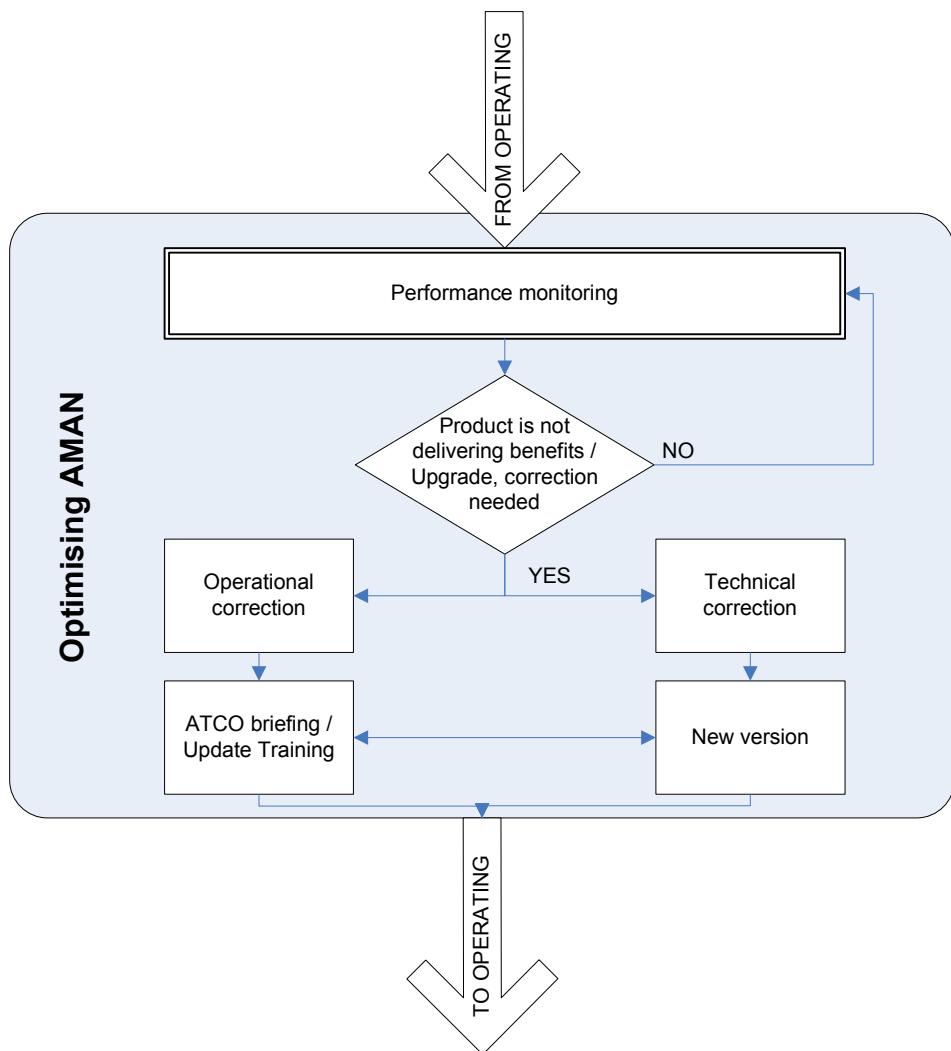
Feedback from others impacted by or using the AMAN the users (airlines and airports) may also help in assessing the benefits or identifying any issues arising from the AMAN implementation.

However, external users should be briefed on the basic functions of the AMAN and on what they can expect from it, to avoid misunderstandings in terms of their “interpretation” of AMAN times and sequences provided to them.

#### 4.2.4 Optimizing AMAN

Separate key performance indicators are not usually defined for AMAN system (see Sub-chapter 3.3: Business case).

Whether an AMAN meets the expectations set for it can be a matter of subjective opinion but is usually accurately reflected by the feedback received from ATCOs and other users. In this regard setting the correct level of expectations at the beginning of the process is critical. The AMAN, and what it should deliver (or has delivered), is sometimes seen very differently at management and at operational level.



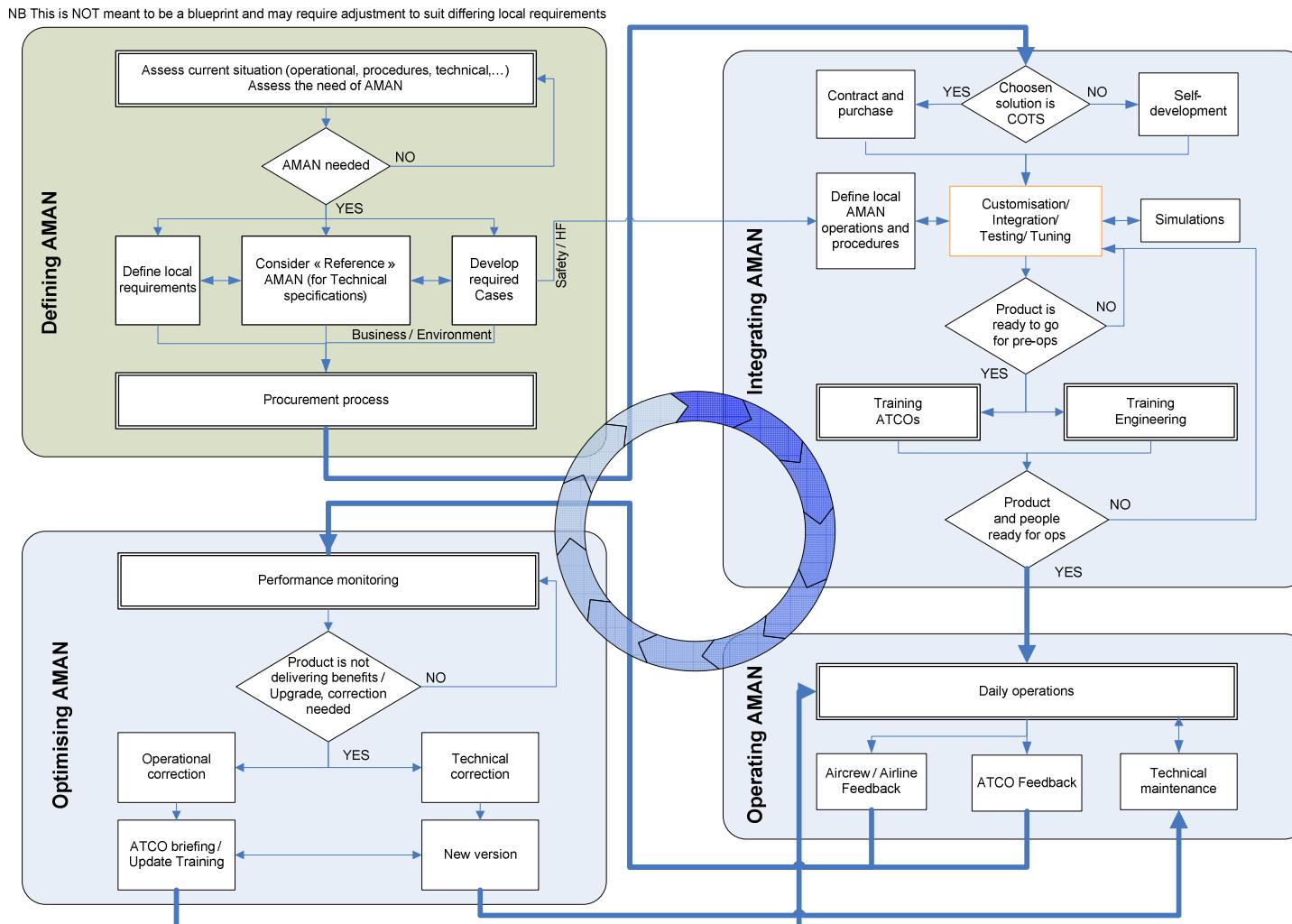
**Figure 25: Optimizing AMAN**

If the system is not delivering as expected (Figure 25: Optimizing AMAN), some changes may be required. These can be of 2 different types: operational or technical:

- Operationally: changes may be required in the procedures, in the airspace, in the proposed HMI.....
- Technically: changes may be required in the trajectory prediction, in the sector coordination or other related functionality....

Any changes arising from daily use need to be transmitted back into the overall process, to ATCOs (e.g. for training) and/or to maintenance personnel for technical issues.

## 4.2.5 In summary



#### 4.2.6 Alternative process

One of the commercial suppliers promotes a slightly alternative way for the deployment, by using simulators for initial assessment (GO/NOGO) from the functional perspective and to perform a first training on the concepts.

Then the operational and technical assessment continues using real life data for a smooth and successful use in the operational rooms. The supplier can deploy a mobile platform easily in the target airports/APP/ACC using a SCANSIM ATC simulator connected to MAESTRO.

The fine tuning and the optimisation of the use is a continuous process performed by the operational staff by adjusting the dataset and sometimes by identifying new evolutions.

It has been used by IAA for Point Merge System trials and by Paris Controllers for the Paris airspace reorganisation in Brétigny, with ESCAPE/MAESTRO.

This system integration method is currently used in Nice Côte d' Azur airport (in APP only for 2011):

- Simulations/tests in Nice with MAESTRO connected to SCANSIM platform: tuning and parameters setting with the planned re-organized airspace – “Nice V3”
- Simulations in Nice, using real traffic samples for fine tuning and possibly for shadow mode operations to prepare next operation steps.

In both tests, the controllers involved are the operational “Referents”, the Nice' s ATCOs in charge of revision of the airspace and of support to AMAN implementation. Their role is to check the product but also to be close to the operational ATCOs, to motivate them and identify their expectations.

# CHAPTER 5 – Lessons learned

## **5.1     *Sharing experience in a user community***

When researching AMAN implementation (and planning) in Europe for the AMAN Status reports, it quickly became apparent that little “common” or up-to-date information was available on AMAN, or on AMAN operations in general.

EUROCONTROL, as a neutral player in the ATM tools arena, felt it could adopt an educational and facilitation role in this regard, openly talking to different industry partners and to ANSPs involved with AMAN implementations, past, present and planned.

These dialogues enabled the authors to gather and (with the kind assistance and approval of those involved) to subsequently publish up-to-date information on AMAN implementations, some of which is contained in the AMAN Status Reviews (2009 and 2010), and some of which is contained in this document.

### **5.1.1    Sharing experience**

In trying to capture “experiences” from previous implementers, the authors deliberately did not seek to capture “minute” details of specific implementations or to capture the precise details of what might have been seen as possible “AMAN-related incidents”.

However, they did feel that there was still some significant value to be gained by capturing and publishing general “experiences” with regards to AMAN.

Thankfully, this view was also shared by many of the pioneer AMAN implementers themselves and nearly all previous/current AMAN implementers, when contacted, were willing to share their experiences (even at a high level) and so make this document a reality.

### **5.1.2    User community**

Also apparent in the dialogues with users was the fact that many of them felt that some form of AMAN User Community should be developed, preferably in the near future.

Although some degree of “sharing” does go on (in practice, different users of the same commercial product can sometimes work together to share the cost of system upgrades and also to share some experiences), there is no widespread sharing of information or experiences in relation to AMAN.

Also, with programmes such as SESAR seeking to place more and more emphasis on arrival management and on arrival management software, expectations for the tool now known as AMAN are expanding rapidly.

A User Group of current AMAN users and developers could not only broaden the information/experience base on AMAN amongst themselves, but it could also bring many years of AMAN-development and experience to the table, helping guide the next developments in a practical, realistic and coordinated manner.

As examples of what is already achieved and done in relation to “sharing”, below are a few small examples of the way that current suppliers work:

User group for a particular AMAN supplier: the example of BARCO:

- The changes/upgrades required by one ANSP are feedback in the other ANSPs systems, when those changes concern the core of the product, which remain the same for all the users
- When more guidance is asked by the ANSP from the supplier, the customers are presented different “users cases” (e.g. different types of slots in the process) resulting from the experience gathered from previous implementation

User group for a particular FDPS supplier: the example of Thales (Information source: THALES):

COOPANS is a cooperation group between 4 ANSPs (IAA - Ireland, Naviair – Denmark, LFV – Sweden and AustroControl – Austria) and Thales. This industry-ANSP partnership establishes a reference high-level ATM system and prepares for needed upgrades.

Through a dedicated process, the members of COOPANS share a common view to define priorities for necessary system evolutions, some of which are covering AMAN. For those system enhancements, the AMAN component is analysed both from a component point of view but also with regards to the interactions with other components of the system within the architecture defined by Thales.

COOPANS aims to capitalise on the shared experience of EUROCAT users in order to harmonise software upgrades, provide convergence with respect to architecture and meet new operational needs. The COOPANS initiative enhances financial sustainability for the benefit of the Service Providers and their customers."

## 5.2 **Issues and experiences**

**“Don’t kill the messenger” – “AMAN just makes the problems visible”**

(Gotthard Boerger, OSYRIS Product Manager)

The issues and experiences presented below are some of those derived from discussions held with Industry, discussions held with ANSPs, and are also derived from other documents and working papers on AMAN and on arrival management.

The issues and experiences are broken into two groups, and viewed from a “global” level, and also from a “local” level.

### 5.2.1 At a global level

<b>Topic</b>	<u>References and Key points</u> <u>(Issues and Experiences)</u>
<b>AMAN to En Route</b>	<p><b>Reference 14</b></p> <p>In some of today’s AMAN implementations AMAN information is passed upstream and routinely used by the ACC/En Route sectors concerned.</p> <p>A more widespread extension of AMAN information to the En Route sectors is currently the subject of an activity within FASTI.</p> <p>The aim of that activity is to promote, in as many locations as possible, the spreading of AMAN information into the En Route sectors, and so better realise the benefits of starting arrival management at an early stage of the flight.</p> <p>It is expected that this enhanced information-sharing will bring the following benefits, some of which are already seen and confirmed in current AMAN locations:</p> <ul style="list-style-type: none"> <li>• Early notification of arrival requirements and constraints to the airborne side should lead to an increase in flight efficiency and predictability</li> <li>• An optimised arrival traffic flow leading to a potential controller workload reduction and capacity increase</li> <li>• Earlier information sharing, and earlier action, should lead to more confidence in the predictability and stability of the arrival sequence</li> <li>• There should be a reduction in workload for the terminal area controller as a result of the rebalancing of tasks between TMA and En Route</li> <li>• Early notification of arrival requirements and action on them</li> </ul>

	<p>should reduce the need for severe sequencing measures later in the flight, leading to ATCO workload reduction.</p> <p>Some of the issues recognised with this extension of information and earlier action include:</p> <ul style="list-style-type: none"> <li>• An appropriate system messaging needs to be in place to support the AMAN concept, and AMAN information sharing concept, being used.</li> </ul> <p>In a relatively simple concept of just “information display” then a relatively simple display might be all that is needed. However, in a more complex concept, where instructions related to AMAN delays will be given by the En Route sectors, and where the arrival sectors (or AMAN manager) will need to know the status of any delay-actions, a more complex version of system-messaging might be needed.</p> <ul style="list-style-type: none"> <li>• Appropriate procedures need to be put in place, to support the use of the information provided.</li> </ul> <p>When an AMAN information or instruction is displayed to En Route every actor concerned needs to know and understand exactly what is displayed and exactly what is required to be done. Failure for everyone to follow “the game-plan” can lead to issues with aircraft from some sectors being unduly penalised, due to inconsistent behaviour from some of the controllers/sectors involved.</p> <ul style="list-style-type: none"> <li>• Working “for” another sector, or working to provide a benefit that will only be realized either by the aircraft, or by ATCOs in another sector, may involve a culture change (to a greater or lesser extent) in some units.</li> </ul> <p>This may require training to reinforce the notion of joint responsibility for all those handling the flight, rather than all operating in small, self-contained spheres of operation. While this is not a problem in much of today’s operations, where adjacent sectors are regularly called upon to conduct “arrival management” into nearby sectors, when it becomes part and parcel of the daily operations attitudes towards it may change, and may need to be reinforced through training and education.</p> <ul style="list-style-type: none"> <li>• Although workload for the TMA/APP sectors will most likely diminish in an AMAN environment, the very fact that ACC and En Route sectors will be taking earlier actions implies an almost automatic increase in the workload involved in these “earlier” sectors.</li> </ul> <p>Current implementers report that through training, and through being able to see/realise the benefits that arise in later sectors, this increase in workload – provided it is not too severe – can usually be accepted in the En Route/ACC sectors.</p>
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Cross-border issues	Reference 15
	<p>The issues associated with implementing an AMAN across national borders include not only the issues for implementing AMAN in En Route, but also more complex ones. These additional issues can include:</p> <ul style="list-style-type: none"> <li>• ANSP systems implemented at neighbouring locations are rarely, if ever, equipped to the same standard or with the same equipment.</li> </ul> <p>Even when it may be technically possible to transmit AMAN advisories to a neighbouring ANSP, the receiving unit may not have developed its systems or controller workstations which are capable of displaying the precise advisories to be transmitted. The neighbouring systems/workstations may only be configured/used to receive and display specific basic AMAN advisories or messages (Time-to-Gain/Time-to-Lose) while the AMAN in use may, in fact, be generating, or looking to generate, advisories of a different nature (speed advisories), or vice versa. It is possible that significant upgrades or even new equipment might be required if neighbouring ANSPs are to participate fully in complementary arrival management. This then raises an issue of <u>costs against benefits</u>, especially if the costs are to be borne in one location and the benefits are to be felt in the other.</p> <ul style="list-style-type: none"> <li>• When Arrival Management is implemented the benefits are mainly associated with the ANSP or with the unit responsible for delivering traffic to the airport concerned, or with the airport itself.</li> </ul> <p>However, in the context of a cross-border operation, the work to deliver these benefits in a cross-ANSP situation is also shared on a more widespread basis. The delivering ANSP may, as we have said, be taking on extra responsibilities without any perceived direct benefit. However, in addition to the normal "human" reaction to this work/benefit situation, in some cross-border situations this may, in fact, pose an additional political challenge in reaching agreement on the process. Genuine commitment to the "overall good" may need to be enforced as the requirement on both sides, rather than national or political self-interest prevailing.</p> <p>As well as having technical and operational differences, cross-border arrival management can also lead to more complex questions and concerns about issues surrounding <u>responsibility and legal matters</u>. These can include:</p> <ul style="list-style-type: none"> <li>• If the application of an AMAN advisory is a contributing factor to an incident in a neighbouring ANSP, where and how might liability and accountability be assigned?</li> </ul> <p>For a low-level incident this might simply be a question for local cross-border investigation and for refinement of procedures, but for a severe incident it might lead to more serious legal action, litigation and questions/issues about blame, responsibility, and especially how they might be handled under different</p>

	<p>jurisdictions.</p> <ul style="list-style-type: none"> <li>• If a neighbouring ANSP does not meet your AMAN requests what impact/redress might there be?</li> </ul> <p>It is usually an easier situation to deal with issues of impact/redress in an “in-house” context, where there is only one “authority” in place to arbitrate and determine solutions to a problem. Dealing with a second entity, or different ANSP, can complicate matters considerably in this regard.</p> <p>Additionally, if, for instance, a non-compliance, even with agreed AMAN “requests”, contributed to an incident or perhaps to overload in the receiving ANSP, the questions of liability and accountability mentioned previously may arise.</p> <ul style="list-style-type: none"> <li>• If a neighbouring ANSP receives AMAN-generated requests from different airports or for different flights, how should it prioritise between them?</li> </ul> <p>This could be “simple” prioritisation in relation to the sequential timing of the action(s) required, or more complex prioritisation, in relation to the impact of one request on other traffic, AMAN-constrained or otherwise.</p> <p>To ensure that responsibilities are clear there is a need for the acceptance of consistent regulations and procedures across different countries, and this may not be easy to achieve. This type of cross-border cooperation, and how many of these issues/responsibilities are to be handled, however, is very much a matter for the new Functional Airspace Blocks currently being set up in many areas.</p>
<b>Multiple AMANs</b>	<p>No reference</p> <p>An En Route sector in any particular ANSP may be dealing with several adjoining, adjacent or subjacent units, and with multiple-AMANs, all looking to employ their own version of AMAN-advisories early for their flights.</p> <ul style="list-style-type: none"> <li>• In some cases, as was detailed previously, systems may be quite different for each of any two adjacent units. When additional units are brought into the mix the possibilities of mismatched systems increases proportionately.</li> </ul> <p>An ANSP, especially one providing early arrival management services to many nearby locations, may be faced with both a technical and a procedural decision as to how best to accommodate, and display, AMAN messages and requests that are substantially different in nature, form or content, from several different units.</p> <p>In addition, the issues raised previously about workload, about priority and about responsibility between any two adjoining units are also magnified proportionately in these circumstances.</p> <p>Although there are no instances of multiple AMANs in place at the moment, this type of operation is currently being planned in Maastricht UAC, where shortly they will look at using AMAN into</p>

	several of the busy airports they serve.
<b>AMAN – DMAN integration</b>	<p><b>Reference 13</b></p> <p>Integrating a single type of tool/system such as an AMAN into a multiple-tool or cross-border operation has its own challenges. Other challenges also exist when considering integration of two different tools.</p> <ul style="list-style-type: none"> <li>• Sometimes, integration of systems which are considered by many to be “opportune for integration” may not be so easy.</li> </ul> <p>An example of this is the often proposed integration of AMAN and DMAN. These systems, proposing integrated runway management of arrivals and departures at the same location, would seem to be ideal “bed-fellows”.</p> <p>Yet, experience has shown that, as separate systems they have developed independently over the years and as such they have reached substantially different levels of maturity. Now, although some manufacturers are now offering “integrated” solutions, there are, in fact, other AMAN users who would tend to caution against this type of system integration.</p> <p>Nonetheless, issues such as the handling of arrival vs departure prioritisation, in integrated or associated systems, are now also being looked at operationally and technically in SESAR WPs 6 and 12.</p> <p>These WPs will also look at integrating runway management with other “airport” tools and processes, such as CDM.</p>

Table 4: Issues at global level

## 5.2.2 At local level

<u>Topic</u>	<u>References and Key points</u> <u>(Issues and Experiences)</u>
<b>Local Tuning</b>	<p>Tuning and correct configuration of the AMAN to suit and match local conditions and operations is a very complex operation, but is one that is critical to its success.</p> <p>When questioned about their AMAN experiences, many of the current AMAN implementers have reported that their tuning of the system was usually one area where the time, effort and complexity of the task were all very much underestimated.</p> <p>The correct configuration and fine-tuning of the local version of the AMAN has a tremendous impact on its acceptance, and therefore on its use. The “better” the fine-tuning, the configuration and adaptation is, usually the higher the controller acceptance and use of the AMAN will</p>

	<p>be. When the AMAN is not tuned or configured properly, or is not operating “well” the controllers often perceive it to operating “against” them rather than “for” them, and trust in the tool can be very quickly eroded.</p> <p>The exact length of time to allow for the tuning is not easily determined: it is really a site-specific variable. Values between 18 months to 2 years are given by suppliers. The required “tuning” and associated time, is also a factor of the complexity of the tool, and how it is intended to be used (e.g., with or without additional add-ons, such as coordination functions)</p> <p>It should also be remembered that the tuning of an AMAN does not stop on O-Day, the day it becomes “operational”. AMANs are under a continuous process of tuning/upgrading during the post-implementation phase as well. As such, it might be said that they are never really implemented in a definitive version.</p>
<b>Simplicity</b>	<p>Related to the tuning mentioned above, one of the “lessons learned” from previous implementers is the notion that things should be kept relatively simple in terms of what the AMAN is designed to do, or is asked to do, in its local implementation.</p> <p>There are defined limits to the complexity of the software that is used by and is incorporated into an AMAN, and these limits need to be fully understood by all concerned.</p> <p>It is also a recognised fact that there are also certain tasks and operations that are better carried out by the human rather than by an automated process.</p> <p>Ideally, an AMAN should not be “over-engineered”, nor should it try to replicate to the ultimate degree many of the more complex human tasks or cognitive processes carried out routinely by ATCOs. The AMAN operation ideally should take the best of the system’s technical competency at doing some tasks very well, and marry that to the best of human ATCO competencies, to produce a more efficient human/machine interaction and operation.</p>
<b>Complexity</b>	<p>Air traffic control is a complex operation in itself, and the AMAN system is usually only one of several tools that may be used by an ATCO in their normal day-to-day operations.</p> <p>As such, the AMAN, and its use should not be an overly dominant feature in its operation. It should fit as seamlessly as possible into the normal operation of the end-user.</p> <p>The ATCO must always be able and free to operate to the best of their ability, and to operate in complex situations, without unwarranted effort or distraction emanating as a result of their use of the AMAN tool.</p>
<b>Keep controllers involved</b>	<p>To fit as seamlessly as possible into an operational context the AMAN needs to be moulded into that operation by the people who are routinely involved in it.</p> <p>Successful AMAN implementations have invariably involved the end-users, the ATCOs, not only from an early stage in the process, but also</p>

	<p>throughout the entire process.</p> <p>This implies the implementation team for AMAN should have, and should endeavour to keep controllers involved at all stages, from the specification phase, to the tuning phase, to the training phase, and right into its daily use.</p> <p>It is often difficult in many operational companies/providers to guarantee the same operational personnel throughout a project. However, chopping and changing the operational personnel at various stages throughout the lifecycle of the project should be avoided as much as possible, as complete understanding of the system is a long and sometimes difficult process, and it is not always easy for people to arrive midway through the process and simply “pick things up”.</p>
<b>Keep software people involved</b>	<p>Most implementation teams set up to oversee implementations such as those for an AMAN should (and do) involve a mixture of operational and technical people.</p> <p>As important as involving controllers is in the complete process, it is also equally important to involve the appropriate technical people. Technical people who have a good grasp of operational matters, and who can readily translate operational requirements into technical, and then operational reality, can greatly assist in a successful implementation.</p> <p>Also similar to the case with controllers, it is important to try to maintain continuity of technical personnel throughout the project.</p>
<b>Dedicated teams vs end-users</b>	<p>While dedicated teams are an essential element in a successful implementation, it should be remembered that the focus, motivation and sometimes the enthusiasm of the implementation team can be very different to the focus, motivation and enthusiasm of the end-users for the same product or tool.</p> <p>The ultimate aim of an implementation team often revolves around the single goal of achieving a successful implementation for the particular tool – in this case, the AMAN. The members of implementation teams can sometimes almost live, breathe and dedicate themselves completely to that goal. “Successful implementation” for the team members can often be related to specific elements, such as achieving operations in a specific timeframe, or achieving it within a budgetary constraint, or training constraints.</p> <p>For the everyday end-user the AMAN will usually represent just a single piece of their daily operations. They, the ATCOs, will always have other tools and other considerations to deal with, and the priority and enthusiasm given to the project by the dedicated implementation team may not always be matched by the end-users, especially if the tool is not working to their expectations.</p>
<b>Understanding Arrival Management</b>	<p>One of the “experiences” reported to EUROCONTROL in relation to a particular AMAN implementation concerned the way that controllers viewed and handled arrival management, especially in contrast to the way that an AMAN is seen to handle arrival management.</p> <p>Although controllers conduct “arrival management” every day, there are</p>

	<p>aspects of arrival management as handled by the AMAN that can be regarded as markedly different to the way they do things.</p> <p>This can lead to some confusion, and sometimes ultimately to mistrust, especially when the controllers do not understand exactly what the AMAN is doing in relation to sequencing, or why it should be doing things apparently so different from the way they would do things.</p> <p>“Equity,” “Delay Sharing” and other elements of the sequencing algorithms routinely employed by AMAN may not be fully understood by ATCOs. Likewise, they may not match the way that the ATCOs regularly operate, where First-Come-First-Served, or where even slight relative differences (in relative spacing or speed of aircraft) can often be dominating factors for the controller.</p> <p>This “difference” or perceived difference in operations and/or methods of working, along with several of the other aspects mentioned in this table, needs to be considered and addressed in the training for the ATCOs prior to implementation.</p>
<b>Expectations</b>	<p>One element in particular that needs to be carefully managed in an AMAN implementation is the expectations that the controllers have for the tool.</p> <p>In some instances the controllers expect the AMAN to be so sophisticated that it <u>never</u> provides them with an inappropriate sequence.</p> <p>Likewise they often expect the system to routinely and consistently provide them with the “easiest” arrival management solution to implement every time.</p> <p>Irrespective of the “advanced” or “sophisticated” nature of the tool being used, these expectations are not really based on reality. AMANs operate on sophisticated but still “basic” principles, with software and “rules” that simply cannot operate to that level of desired “perfection” across the board.</p> <p>The AMAN is a system “support” tool. It is NOT intended as a replacement for the controllers, nor is it as sophisticated in its design and operation as the normal ATCO.</p> <p>Neither is the AMAN the ultimate “one-shot” solution to all arrival management issues. ATCOs will always still need other tools and techniques, procedures and processes, in order to achieve high levels of effective arrival management on a routine basis.</p> <p>These expectations, and these details about what the AMAN is, and can/cannot do, need to be carefully managed in the training given to the ATCOs.</p>
<b>Interacting with the AMAN</b>	<p>An aspect that also needs to be well explained and equally well understood by the controllers using an AMAN is what happens when the controller interacts correctly with the AMAN and what happens if they fail to interact correctly.</p> <p>In a recent “AMAN simulation” it was interesting to note the initial</p>

	<p>difference that the controllers experienced when operating with a human in the arrival management chain, and what they experienced when operating with a machine in the chain (the AMAN).</p> <p>When operating with another human, the ATCOs involved felt comfortable communicating with, and interacting with, the other human in the chain. They understood completely the need to respond to the other person's requirements or wishes, and they also understood the need to correctly feed the other person with information, or to respond to their operational wishes correctly.</p> <p>When an AMAN was introduced in the simulations, however, the controllers initially felt much less "obliged" to respond to the needs of the AMAN (in implementing a delay management requirement), or to the need to feed the AMAN with information if they themselves made a change that affected the system (e.g. a change in order). After some further training the controllers came more to understand the need to react correctly with, and feed the AMAN when necessary.</p> <p>Controllers need to fully understand what happens when they do, and don't interact correctly with the system, and the implications of their action/non-action on the system, the sequence and the accuracy of the operation.</p> <p>This is another item that needs to be considered for ATCO training.</p>
<b>Transition</b>	<p>The transition from a non-AMAN environment to one where AMAN is routinely used is reported as one that requires careful consideration and handling.</p> <p>Controllers need to fully understand how their operations will change when the AMAN is introduced into operation. These changes can be different depending on which sectors are being considered, and to ease the transition into the new operation the controllers involved in all affected areas need to understand exactly what the implications for their particular work-area are.</p> <p>As discussed previously, there may be several options to consider in how the AMAN is introduced into service, background use prior to shadow-mode prior to full ops, or big-bang introduction, or even something in between these options. In any case, the impact of the AMAN introduction and the changes that <i>will</i> occur need to be thoroughly explained to the controllers during training and implementation.</p>
<b>Flexibility issues</b>	<p>Since the AMAN is a software driven tool it operates to a prescribed (and limited) set of rules, which are programmed into it.</p> <p>This inevitably means that the AMAN is ultimately never as "flexible" in its operation as the human is. It does not, nor cannot, operate to the same level of sophistication as a human ATCO, who can nearly always respond "flexibly" as any particular situation demands</p> <p>This difference in flexibility (or inflexibility), with its associated constraints, also needs to be highlighted in controller AMAN training prior to its implementation.</p>

<b>Flexible use</b>	<p>The “need” for an AMAN is directly related to the amount of traffic involved. When traffic is light, the “need” to follow AMAN instructions or advisories may not be that critical. In these cases, some implementers advocate a more “laissez-faire” approach with their controllers, determining that the ATCOS themselves know when they need to use/not use the tool support.</p> <p>This flexibility in use is also one which some controllers have reported as being beneficial, allowing them to continue to remain “in control” and enhancing their view of using the tool as a “support”, and not as a “master”, telling them what they must do at all times.</p>
<b>Benefits workload increases</b>	<p><b>vs</b></p> <p>For some controllers, typically the ACC or En Route controllers feeding a TMA, using the AMAN, and providing arrival management at an early stage of flight, may actually involve an increase in their workload.</p> <p>Not only that, but these ACC controllers will likely never really see the benefits that their use of the AMAN will actually introduce, such as the decrease in work experienced by the relevant TMA controllers, or the reduced flying time/reduced fuel-burn that might be experienced by the flights being handled under the AMAN.</p> <p>Controllers need to have this benefit mechanism fully explained to them, and possibly reinforced at regular intervals, so that they fully understand the way that their actions are fitting into a wider picture.</p> <p>Responses to the EUROCONTROL AMAN questionnaires have indicated that in ongoing implementations, once explained to them, the workload increase that the En Route controllers experience is usually considered acceptable, provided it is not too significant.</p> <p>Again, this is an aspect for training prior to implementation.</p>
<b>Simulation training</b>	<p><b>/</b></p> <p>As can be seen from the amount/detail of the “training” issues mentioned above adequate preparation and training is essential for a successful AMAN implementation.</p> <p>Several of the current implementers have used simulation as a vehicle for preparing for AMAN operations. Simulations can also assist greatly in de-bugging the system, in spreading familiarity throughout the operational and technical workforces, and in determining and refining the correct procedures and methods of operation to be used when the system actually goes live.</p>
<b>Relative importance Time</b>	<p><b>of</b></p> <p>Although the AMAN is a system that is configured for, and operates on “time”, time is usually not an over-riding or critical element in ATC operations as they currently exist.</p> <p>When AMAN is used today it usually provides what is considered to be a general timeframe for the controller to operate within, both in terms of sequence and of time.</p> <p>However, at some stage of the operation, the physical management of the sequence and the “correct” presentation of the traffic, especially in the latter stages when the flight may be passing from ACC to APP/TMA, often becomes “more important”, at least as far as ATC are concerned.</p>

	<p>In some current implementations, as well as providing a metering function, one of the main aims of the AMAN is to get a sequence established towards the IAF. If, for some reason, this is not the precise sequence that will be followed between the IAF and the runway (i.e. the sequence needs to be changed to better reflect the actual traffic situation) then changes to the order of traffic can be, and are, made.</p> <p>However, since changes to the sequence made by one controller can affect the AMAN sequencing of the traffic further away, in these implementations changes that are to be made are usually only allowed when the aircraft is within the area of the responsibility of the APP controller, and the changes are not allowed to affect traffic that is further away.</p>
<b>Wind/Weather information</b>	<p>One of the crucial aspects for the acceptance of the AMAN is the accuracy of its predictions, viewed in terms of the required accuracy of its predictions.</p> <p>One of the factors that directly affect the prediction capability of the AMAN, or in fact the prediction capability of any ATC predictive tool, is the wind input that is used.</p> <p>All other factors being equal, usually, the better the wind modelling used, the closer it is to the reality of the wind that the aircraft are flying through, the more accurate the resulting predictions.</p> <p>This will help the accuracy, and the perceived “accuracy” of the system, which is also important to the overall acceptance by the ATCOs.</p>
<b>AMAN Management</b>	<p>AMANs are not completely autonomous, and each implementation needs a human manager at some stage.</p> <p>The AMAN is usually operated from a central AMAN position with a dedicated ATCO (TMA supervisor or coordinator) in charge. In this case, the AMAN manager is the only one having the right to manipulate the sequence or make required inputs (such as changes to the sequence spacing).</p> <p>One AMAN implementation however reported that it allows different ATCOs to change the sequence.</p> <p>In this case, any changes of sequence must be well coordinated to avoid that the change issued by one ATCO impacts negatively the work of the other ATCOs.</p>
<b>Coordination assistance</b>	<p>One of the notable extensions of the “AMAN functionality” in current operations seems to revolve around the provision of a coordination facility along with the AMAN.</p> <p>In some AMAN implementations, the AMAN has had significant coordination facilities integrated into the system and operation. The AMAN screen/s in these implementations is routinely used, not only to pass AMAN sequence information, but also for transmitting and receiving some coordination messages, especially messages related to hand-over conditions between ACC and APP.</p>

	<p>Implementations that report the use of coordination with the AMAN have reported it as being a highly successful addition to the operation, which is well received by the controllers involved in its daily use.</p>
<b>Pop-up flights (and asymmetric airspace)</b>	<p>The problem of aircraft “popping up” late in the system is a common problem to all current AMAN implementations.</p> <p>This usually happens when aircraft take off from an airport in the vicinity of their destination (a very short flight) or when the route of this aircraft as “seen” by the system is short (on a cross-border flight with a short leg in the destination country). If the arrival sequence is already built and either full or stabilised when a pop-up flight occurs the flight concerned can be delayed substantially.</p> <p>When a short-route flight is known in advance, there may be the possibility to keep it on the ground until it fits in a pre-reserved slot in the AMAN system. This offers an economical solution, but requires deep collaboration with the ATC unit controlling the aircraft start-up.</p> <p>In one AMAN implementation report aircraft from nearby airports are reserved slots in the sequence, on request from the departing airport. Subsequently, when the aircraft is airborne and captured by the AMAN the position of the aircraft within the sequence is fine-tuned. Alternatively, the system might allow the controller to choose the best position for the short-route flight and to re-sequence the flow accordingly.</p> <p>Having issued a slot for the pop-up, if the AMAN system predicts that an aircraft cannot physically enter in the reserved slot, it can automatically re-sequence the traffic, and the pop-up flight, according to agreed rules. This usually involves automatically delaying the short-route flight to the first available slot in the sequence after a given length of time.</p>

Table 5: Issues at local level

**“On ne peut prévoir les choses qu'après qu'elles sont arrivées.”**

(Eugène Ionesco - Extrait de Le rhinocéros)

# CHAPTER 6 –AMAN and SESAR

## 6.1 AMAN in the SESAR/ATM Master Plan

Arrival Manager systems/tools are included in several of the “Queue Management” and system projects detailed in the SESAR (now ATM) Master Plan (**Reference 3**).

The scope of AMAN and its envisaged development path/use can be seen across the full SESAR timescale, although it should be remembered that the focus of this document is more on the shorter-term development and implementation of AMAN.

The charts displayed in this section are extracted from the original ATM Master Plan – 2009 (**Reference 3**) and the updated information supplied by the ATM Master Plan Update Working Group Report – 2010 (**Reference 4**).

The 6 different Service Levels are displayed on Figure 26: SESAR - Master Plan overview (2009 data) and the updated version for Service Levels 0 and 1 is visible on Figure 27: ATM Master Plan Update for Service Levels 0 and 1 (2010 data).

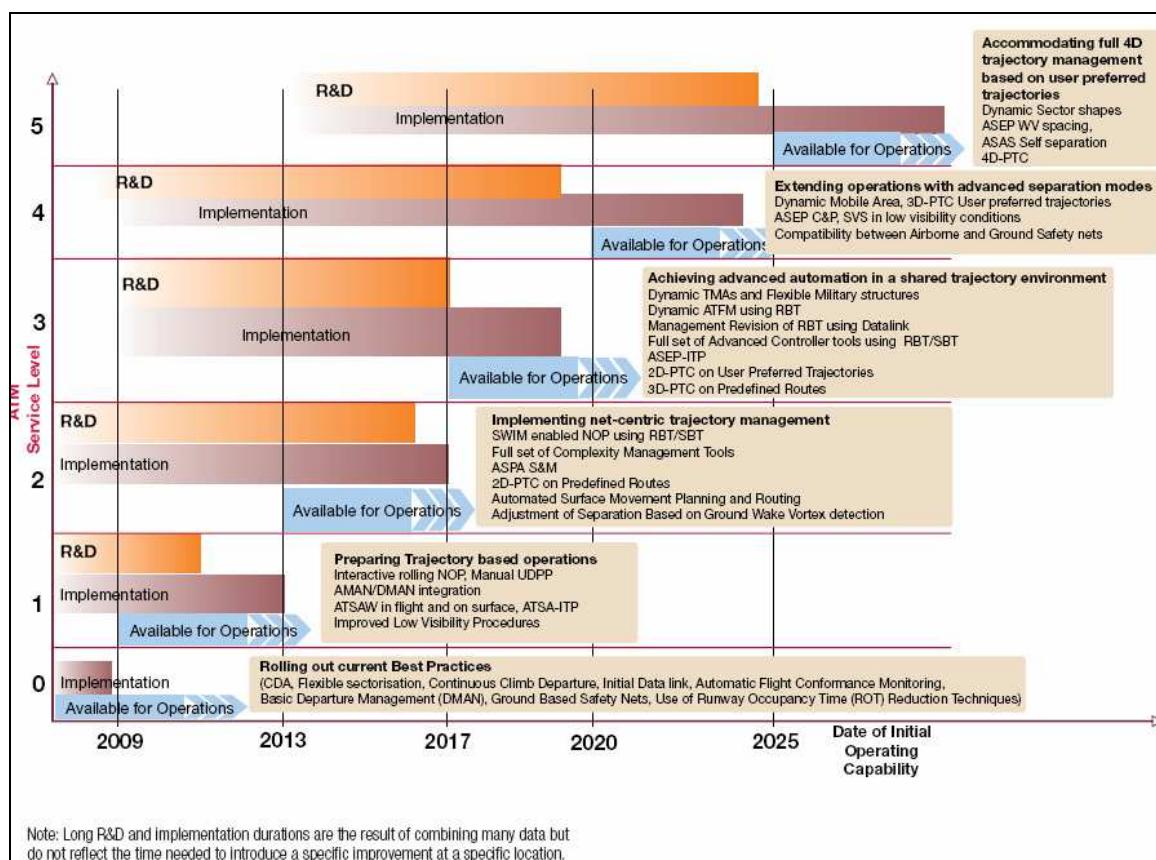
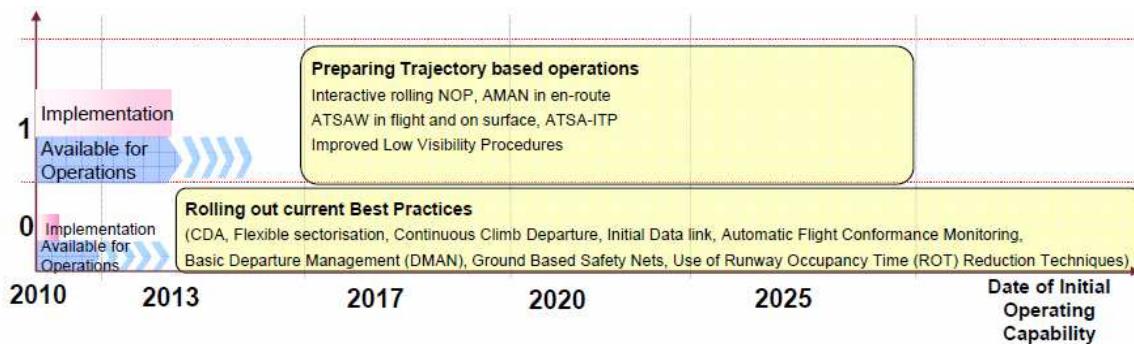


Figure 26: SESAR - Master Plan overview (2009 data)



**Figure 27: ATM Master Plan Update for Service Levels 0 and 1 (2010 data)**

#### AMAN in ATM Service Level 0 (data 2010)

Arrival Management is already mentioned in the “foundation” level, ATM Service Level 0, the building block for the entire SESAR development. It is stated as being applicable to the ongoing deployment of Best Practices:

- Basic Arrival Management Supporting TMA Improvements (incl. CDA, P-RNAV)

The AMAN capability is also seen as a key enabler, and “Basic AMAN” is seen as supporting Queue Management activities in Line of Change (LoC) #7, in the shorter-term.

#### AMAN in ATM Service Level 1 (data 2010)

The AMAN is expected to extend its range of operations beyond its current “normal” use at this stage, and by including its use in En Route airspace, to begin the “Arrival Management” process much earlier in the flight:

- AMAN extended in En Route: Introduce Arrival Management Extended to En Route Airspace

#### AMAN in ATM Service Level 2 (data 2009)

Yet further enhancements are considered in Service Level 2, including development of AMAN systems to cater for more complex operations, and even greater integration with other tools and applications, including integrating the AMAN with the use of Controlled Time of Arrival (CTA) for the aircraft:

- Integrated Queue Management Step 1: Integrate Surface Management Constraint into Arrival Management; Integrate Surface Management Constraint into Departure Management; Departure Management from Multiple Airports; Surface Management Integrated With Departure and Arrival Management
- Integrated Queue Management Step 2: Integrate Arrival Management into Multiple Airports; Optimised Departure Management in the Queue Management Process; Integrate Arrival / Departure Management in the Context of Airports with Interferences (other local/regional operations)
- CTA Optimisation through Use of Datalink: All ATM partners work towards achieving Controlled Time of Arrival (CTA) through the use of Datalink to optimize arrival sequence

#### AMAN in ATM service level 3 (data 2009)

For Service level 3 multiple CTOs are anticipated, and although some of these may come from airspace entry/exit requirements, it is also expected that some of these will come from the AMAN or “arrival management” requirements.

Multiple CTOs: Introduce multiple Controlled Times Over (CTOs) through use of Datalink. The CTOs are ATM-imposed time constraints set on successive defined merging points for queue management purposes. The CTOs are computed by the ground actors on the basis of the estimated times provided by the airspace user.

## 6.2 SESAR Stakeholder Deployment Roadmap

Again, the “development” of AMAN can be seen in relation to the ATC System Roadmap, covering airport, En Route and TMA system applications.

### TMA and En Route ANS Providers – ENR/APP ATC System

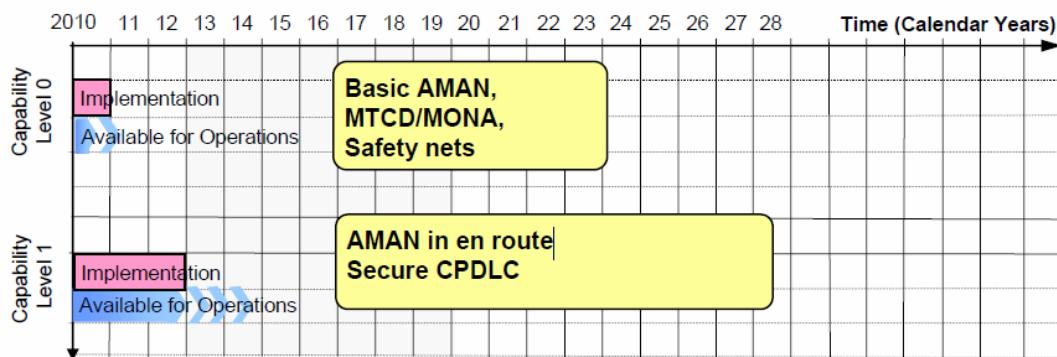


Figure 28: SESAR - Roadmap for ENR/APP ATC Systems

### Airport ANS Providers – Aerodrome ATC System

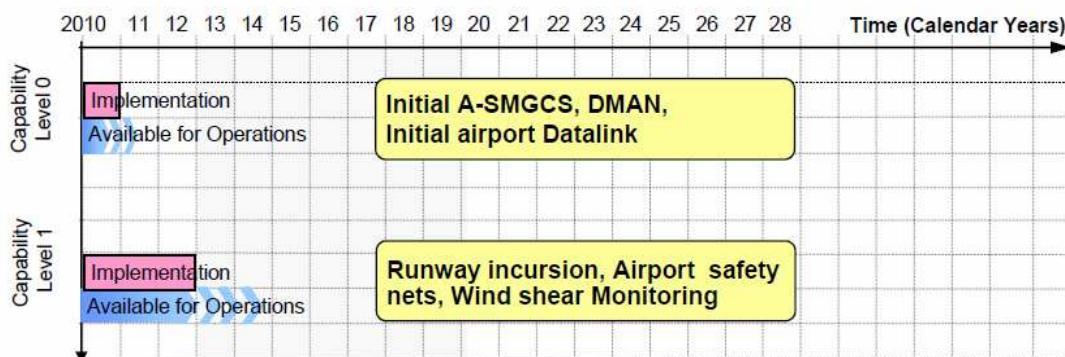


Figure 29: SESAR - Roadmap for Aerodrome ATC Systems

In the updated version of the plans for Service Level 1, “DMAN and pre-departure” and “AMAN/DMAN Integration” operational evolutions are postponed.

### 6.2.1 Current SESAR Project progress

Many of the operational and technical projects related to AMAN are already underway (Q4/2010). These include two of the main “operational” projects related to AMAN and AMAN developments, Projects 5.6.4 (TMA operations – “Tactical TMA and En-route Queue Management”) and 5.6.7 (TMA operations – “Integrated Sequence Building / Optimisation of Queues”).

These projects work in close cooperation with various other work-packages, sub-work

packages and projects within SESAR, including technical work packages and projects, such as those in 10.9. (En-route and approach systems – “Queue Management and route optimisation”)

To provide the reader with a flavour of what is being worked on in relation to AMAN the following section contains a short extract from WP5 description from SESAR SJU internet site (<http://www.sesaru.eu/>).

“WP5 TMA Operations is one of the five operational Work-packages defined in the Work Programme for 2008-2013 elaborated during the SESAR Definition Phase (D6). The SESAR operational concepts will be further defined and validated for the arrival and departure phases of flight, i.e. from top of descent to landing and from take-off to top of climb.

The main concepts to be studied include, Trajectory Management Framework, Trajectory and Separation Management, Co-operative Planning, Controller Team Organisation, Queue Management and Usability Requirements for Controller Working Positions. Significant co-ordination will be required with other Work-packages, specifically WP 4 (En-Route operations), WP 6 (Airport operations) and WP10 (En-route and Approach ATC Systems). Indeed, some projects have been planned to be progressed on a collaborative basis with WP 4.

WP 5 will aim at:

- Refining the concept of TMA Operations
- Defining and undertaking the necessary validation activities including the assessment of operability, safety and performance at all levels
- Demonstrating the operational feasibility of the TMA Operations concepts in a complete ATM environment (including systems)”

From “*The Controller*” magazine (June 2010)

“In the 60s and 70s, very successful flight data processing, radar data processing, short-term alert systems were successfully implemented.

**What has happened since?**

**TCAS (...), ATFM (...), Arrival Managers.”**

**Jean-Marc Garot**

(Former Director EUROCONTROL Experimental Centre)

# CHAPTER 7 – Conclusions

## **Conclusions from the guidelines and lessons learned.**

Several important conclusions can be drawn from the research conducted for the AMAN Status Reviews, and for these “AMAN Guidelines and Lessons learned”.

The major AMAN implementations cross Europe, although having some local differences, are by and large quite similar.

Nearly all

- have an AMAN manager responsible for the system in operation,
- operate within about 150 miles from touchdown,
- use some form of timeline in their operation,
- use similar HMIs to display the flights and their AMAN information, and
- are reasonably well accepted by the controllers involved.

The correct adaptation, configuration and tuning for the implementation are crucial for its success, and all these elements have usually been underestimated by previous implementers. If many of them were to be given an option to “do it all again” this aspect is the one that most of them would address differently.

Implementation of an AMAN **will** have an affect on the ops room, in terms of procedures, working methods and also on HMI. Human factors are affected, and studies to assess human factors, safety and other aspects of implementation need to be conducted beforehand to assess the impact in the local environment.

Simulations are considered to be a good method of determining the best working arrangements and they also provide a chance for the implementers to “de-bug” the system in a realistic representation of the expected environment.

The training for an AMAN implementation is probably more extensive and requires more “depth” than many implementation team members realise. The system, although “relatively” simple, operates somewhat differently to the way controllers can and do operate, and the differences in operating methods between the human and the machine need to be well understood by those operating the system, otherwise it can lead to mistakes, misunderstanding, mistrust and ultimately a possible rejection of the tool.

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The tool, when used within its design parameters, and when used within its limitations is

generally regarded as a “good tool”. When used for metering, and for assisting in delivering traffic in a reasonable manner and in a reasonable sequence, it is quite effective.

The AMAN is not the “ultimate tool” in ATM. It cannot and will not solve all arrival management problems. Neither is it a replacement for the human ATCOs. It is a “support tool” and should be seen in that light, and in that light, only. When the principles, and operating methods, are kept “simple” AMAN works well as an efficient support for the ATCOs.

Some implementations have found the AMAN to be an ideal vehicle to host additional functionality, such as coordination functionality and messaging, especially for use between ACC and APP.

Although some research is planned to investigate integration of AMAN with other systems such as DMAN, the AMAN is currently not extensively integrated with other FDPS systems.

Although the prediction times for an AMAN are usually calculated all the way to the runway, most AMAN implementations use a fix position, such as the IAF, as the metering point/s for the system users to target and to operate to.

Short duration, or pop-up flights, consistently provide perhaps the most “operational” (and technical) difficulty or issues in nearly all AMAN day-to-day implementations.

On a general level, most AMAN implementers, and also AMAN system providers, have been quite happy to discuss their implementations and products with the project team responsible for this and other AMAN documents. They have also usually been happy to pass on their “general” issues and experiences relating to AMAN. Additionally, they report themselves as happy and willing to find out more from other people’s implementations, issues and plans with regards to AMAN.

Currently, there is no AMAN-users group, similar to the kind of group that operates for other systems and products, in existence. **All current and some planned implementers that were approached during the last two years for these projects have reported their desire for such a group to be established.** They have also reported their willingness to participate and support such a group.

Several of the implementers see the formation of an AMAN-user group as becoming a more important requirement, especially given the focus that AMAN is coming under in the SESAR work packages, and the expectations that are being considered for the system in the future.

# ANNEX 1 – Inventory

## **A1.1 *Inventory of AMAN products***

Note: the information below is supplied by industry or compiled from publicly available commercial data; EUROCONTROL has not validated any of the information included in this chapter. (Info dated Dec. 2010).

Note: SARA (considered to be used in conjunction with IBP) is currently not a commercial product; it is still under LVNL internal development.

### **A1.1.1 MAESTRO (Supplier: Egis-Avia)**

Website: [www.egis-avia.com/products/ATC-Systems](http://www.egis-avia.com/products/ATC-Systems)

MAESTRO is a sequencing tool which encompasses the arrival and departure management function. AMAN and DMAN features can be deployed in a single system or in two separate systems.

AMAN Arrival Management module (further down referred as MAESTRO) is providing an arrival sequence for up to 5 independent TMAs. This sequence is displayed to all relevant air traffic controllers in Approaches, En Route sectors and possibly in the Towers in order to help them to handle the arrival traffic in an efficient way. A delay to be absorbed is computed for each flight and is managed by upstream sectors (En Route) to feed the approach area with a smooth traffic preventing the use of holding pattern.

The system enables an optimum utilisation of airspace and runway capacity by distributing the workload associated to arrival and departure control among En Route, Approach and ground-based controllers involved, thus minimising delays and excessive fuel consumption.

In this perspective, the system provides En Route, Approach and Tower controllers with graphical views of the computed sequence and the control actions which have to be taken accordingly. Throughout this process, controllers keep the sequence operations well in hand as MAESTRO enables them to make manual changes in order to test sequencing options.

## MAESTRO:

- Keeps record of arrival flight plans from the local Flight Data Processing System (FDPS) and possibly of radar tracks from the local Radar Data Processing System (RDPS) if the FDPS estimates (ETO) are not accurate enough.
- Allocates each incoming aircraft to a destination runway in accordance with geographic runway allocation rules, runway restrictions associated with noise reduction procedures, selected Terminal Control Area (TMA) configuration and runway separations and flight priorities.
- Calculates the optimum scheduled time of arrival at the TMA entry fix and at the runway threshold and the delays to be absorbed to abide by this scheduled time.
- Optimises the overall sequence in order to minimise the delays and holding pattern situations.



Figure 30: MAESTRO HMI – Runway view



Figure 31: MAESTRO HMI - IAF views

### AMAN/DMAN integration.

Arrival and Departure management functions share:

- the same hardware, middleware, supervision, connexions to external systems, recording/replay, data management making easier the integration of the departure function.
- the same TMA configuration to synchronise the change of the runway orientation or the closure of the runways (e.g. runway inspection) for the both flows.
- possibly the same timeline on the air traffic controller HMI for the runway views.

Departure sequence takes into account the arrival flows to compute the managed take off time (MTOT).

### **A1.1.2 OSYRIS (Supplier: BARCO)**

Website: <http://www.barco.com/en/product/1229>

The general objective of OSYRIS AMAN is to manage the flow of arriving aircraft in order to make best use of the available ATC resources, such as runways and airspace. This must be achieved without increasing workload; in practice the planning features of the AMAN will decrease controller workload, particularly in unusual circumstances such as recovery from events such as runway closures.

To achieve these goals, OSYRIS AMAN provides sequencing and scheduling of arrivals and advice generation for all controllers involved. In addition, planning functionalities like automatic runway allocation are provided.

The current **traffic situation** is continuously reported to AMAN by radar and flight plan data. OSYRIS monitors the traffic situation and (re)calculates **trajectory predictions** in cases of a mismatch between actual and predicted positions. An arrival traffic sequence is planned based on this input and the current **spacing requirements**. The plan results in a set of **advisories** that are presented to the controllers.

The controllers set up their **planning** using the advisories from OSYRIS as a starting point. The controller could decide at any time to modify the sequence (e.g. by a manual change in the arrival sequence) or introduce additional constraints into the calculations. When the controllers have made their decisions they send the corresponding instructions to the pilots. Depending on how arrival traffic evolves, AMAN monitors the situation and adapts the planning results and advice generation accordingly.

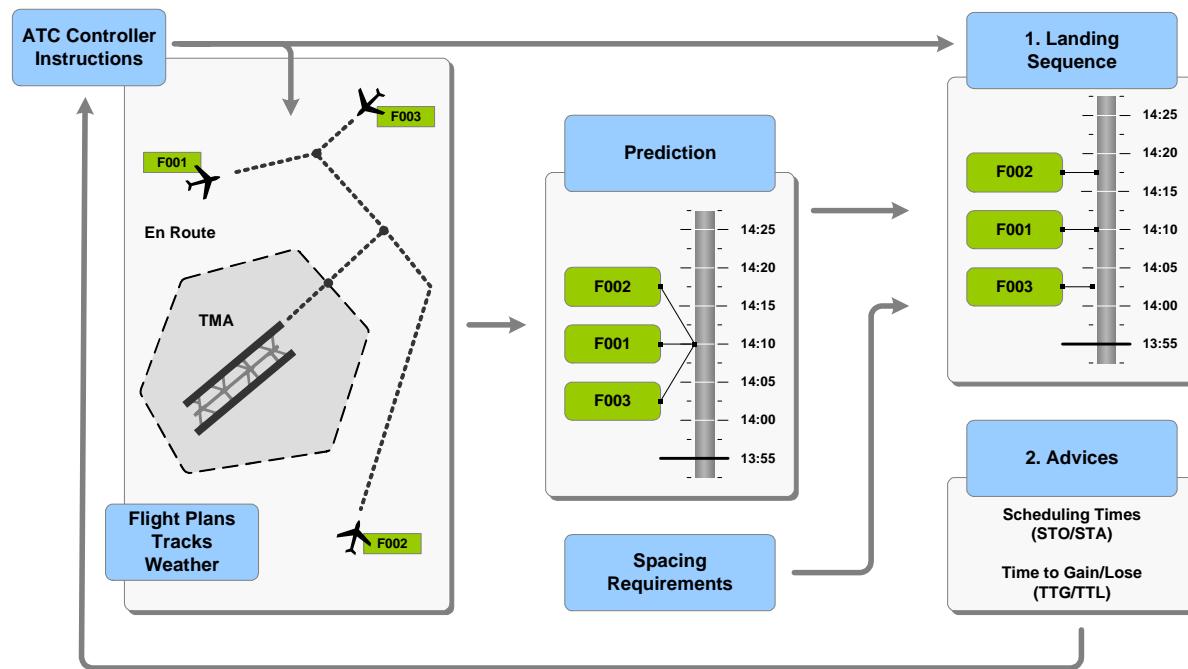


Figure 32: OSYRIS - High level representation

The generated advisories are optimized according to different selectable goals (for example minimum average delay or minimum deviation from preferred profile).

The results of the sequencing and planning process are primarily presented in the form of traffic sequences for a configured set of reference points or runways together with requested times over these reference points or runways.

These requested arrival times can be used directly to guide flights, e.g. as goals to be achieved with the help of the on-board Flight Management System (FMS). They can also be regarded as a suggestion to the controller to be achieved via different measures (rerouting, holding, vectoring, speed changes) that are at the disposal of the controller.

In addition, AMAN generates specific advice (e.g. speed advice, route allocation, turn to point) that indicates how a given planning time can be reached. The calculation of speed advice exploits the OSYRIS Trajectory Predictor's capability of varying the flight profile while the time at the final point is treated as a constraint.

AMAN supports an early planning of the arrival sequence over an extended time/distance horizon and calculates a precise arrival time for every flight as soon as radar data is available. Before radar data becomes available, planning relies on the flight plan, and is updated once surveillance data is provided. The pilot can be informed about this arrival planning when entering the operational horizon.

The system will sequence and meter the arrival traffic for a target airport when it is still far outside the TMA. Traffic streams from different En Route sectors are organized to enter the TMA in a way that fits the plan for the final approach sequence. The natural peaks and troughs in traffic are smoothed in order to make efficient use of constrained resources such as certain runways.

The OSYRIS AMAN provides true optimization of the arrival sequence and takes account of wake turbulence categories (WTC) and flight profile characteristics. Thereby it makes best use of constrained resources while allocating delay fairly and with a clear audit trail.

A very important aspect of the AMAN concept is the ability to centralize the planning of the arrival traffic and to organize the distribution of the results to all related sectors and workstations. This means that all controllers are informed about the global planning and can avoid contradictory advice from successive sectors due to differing local perceptions of air situations and sector load.

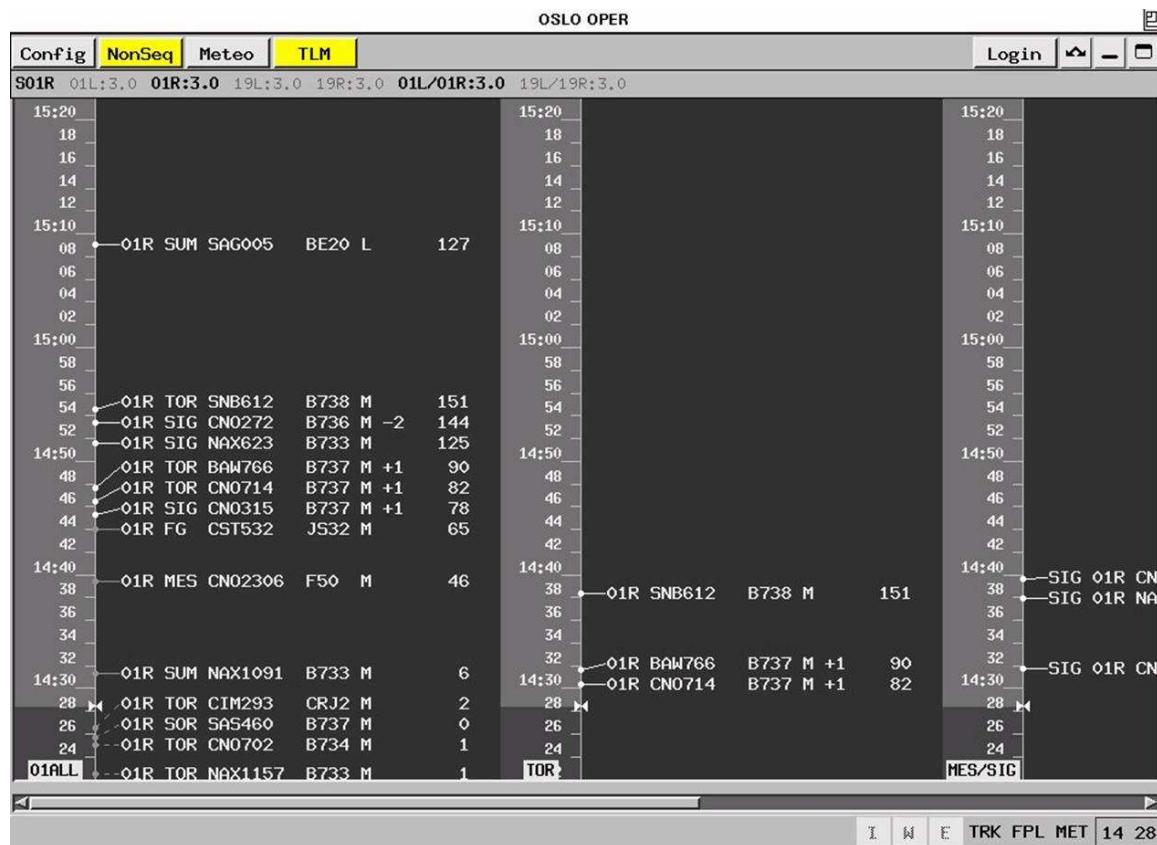


Figure 33: OSYRIS - HMI view

### AMAN/DMAN Integration

The OSYRIS queue management tool suite includes a **Departure Manager (DMAN)**. Both tools AMAN and DMAN share the same technical framework and could operate separately or combined. The integrated solution supports mixed mode runway operation for arrival and departure traffic to optimise airside resources.

The OSYRIS queue management suite is completed by the **Collaborative Flow Management (CFM)**. CFM enables airlines to jointly agree on priority flights and reschedule their services by matching demand to capacity. It exchanges data with the AMAN system and uses it to control traffic in the most efficient manner possible.

**A1.1.3 4D Planner (Joint Suppliers: DFS and DLR)**

Website:[http://www.deutscheflugsicherung.de/dfs/internet\\_2008/module/worldwide\\_solutions/englisch/worldwide\\_solutions/systems/4d\\_planner/index.html](http://www.deutscheflugsicherung.de/dfs/internet_2008/module/worldwide_solutions/englisch/worldwide_solutions/systems/4d_planner/index.html)

The DFS product 4D Planner is the first operational second-generation arrival manager. It maximises the use of the limited resources of airspace and runway throughput, thereby achieving maximum flexibility and a lower workload for the controller.

The 4D Planner operates in four dimensions; apart from the normal dimensions of horizontal position x-y and altitude z, the fourth dimension "time" is integrated into all calculations. This fourth dimension improves the accuracy of the arrival management system while maintaining the high safety level. Using all relevant data, the system generates an overall plan for all approaches, derives the appropriate management information from this plan and displays this information to the controller. The 4D Planner continuously compares the planned with the real traffic situation in order to update the optimum approach sequence. The controller is thus able to precisely control approaching air traffic with respect to the timing and adjust the separation distances at the runway threshold for optimum efficiency. The system considerably reduces the effects of interfering factors on the separation accuracy. This applies to both external factors, such as wind, and inaccuracies resulting from human shortcomings on the ground and in the air. The new planning system also ensures more precise compliance with the times over metering fixes and the runway threshold.

Main points:

- No Freezing of Sequence and Target Times, Updates permanently allowed
- Permanent Estimate Calculation based on Radar Data
- Sector Sequences with slow Adaption in ACC for Planning Stability
- Final Sequence with fast Adaptation in the TMA for Flexibility
- Knowledge about operational Procedures included
- Possible participation of upstream Centres (OLDI Message AMA) with display of TTL or Target Time in the Radar Label
- New silent level coordination function between ACC and APP (2009)
- Statistic Function e.g. "landing per hour" and "average separation on final"
- Functions "miles to fly" (Oct. 2011) and "load balancing" (Oct.2011)

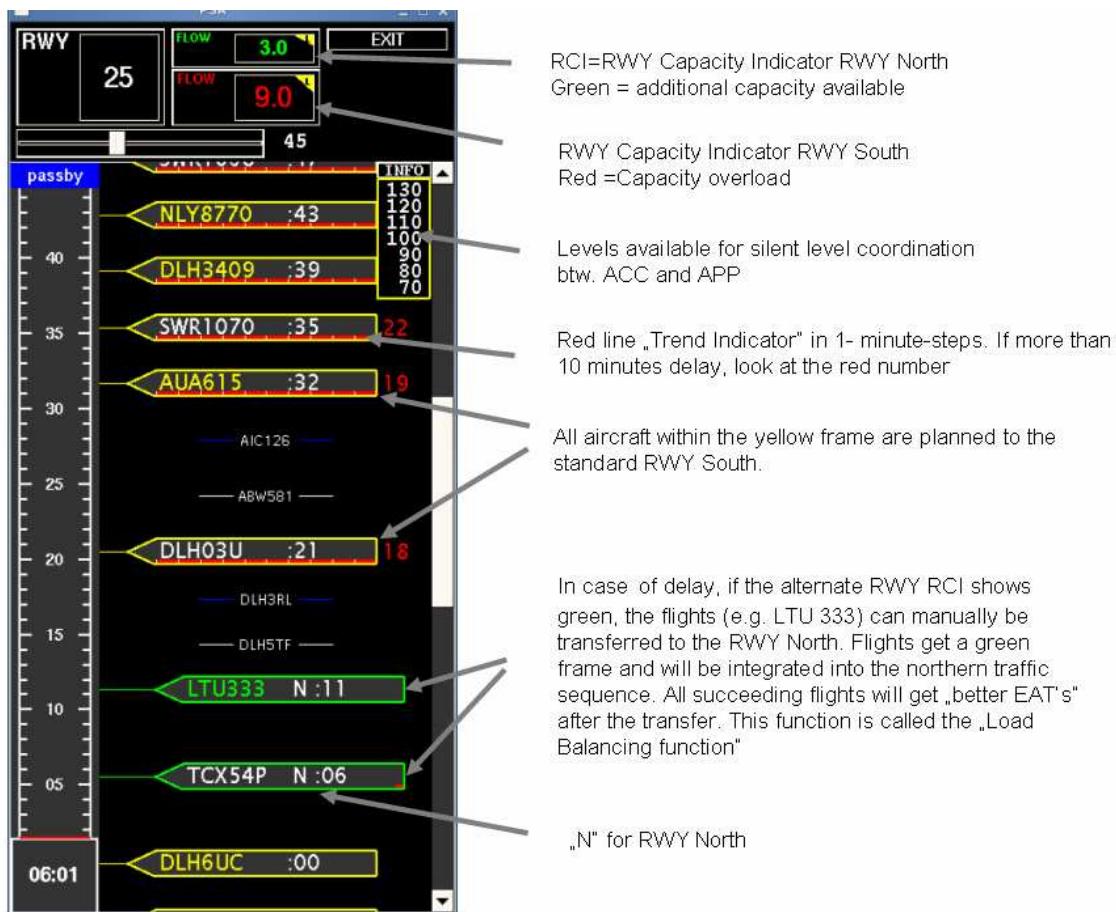


Figure 34: 4D PLANNER - ACC display (EDDF Oct.2011)

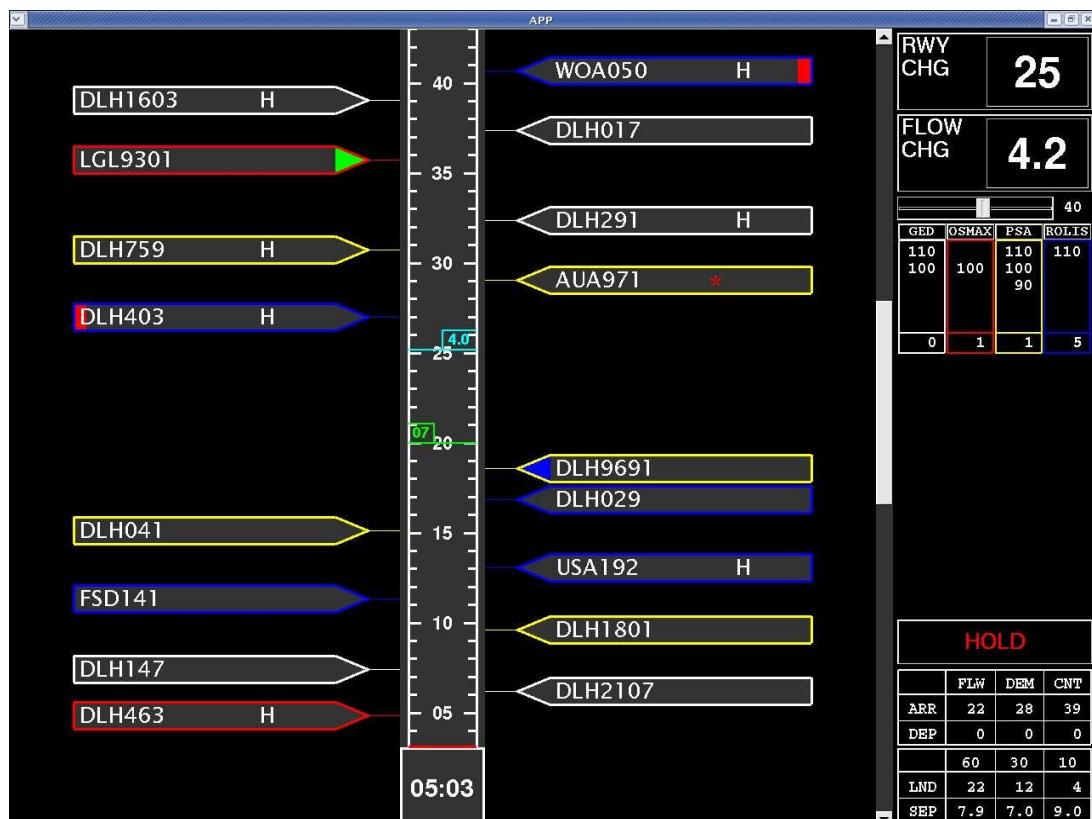


Figure 35: 4D PLANNER - APP display (EDDM)

**AMAN/DMAN integration:**

There is no information available on integration with DMAN.

**A1.1.4 IBP and future SARA extension (Developer: LVNL)**

Website: <http://www.kdc-mainport.nl/> (Search “SARA”).

**IBP: Inbound Planner.**

IBP is a planning tool, to support APP (Approach) operations and to regulate the flow of traffic to Amsterdam Schiphol airport.

A default main landing runway is defined per IAF. The traffic to a main landing runway is regulated through the introduction of a landing interval between each aircraft in sequence. The landing interval is either calculated from the minimal WTC radar separation between two flights or a fixed value.

The result of the IBP process is the computation (and display) of landing slots for each inbound flight to a main runway and the computation (and display) of its EAT. This result is manually tuned by the approach planner for optimal runway usage.

The computed EATs are used by ACC controllers as time reference for the aircraft to pass the IAF and be transferred to APP. There is currently an allowed margin of 2 minutes on this reference time.

The automatic IBP tool can be switched on or off and has different planning states: unplanned, slot requested, planned, reserved or manual. A flight becomes “planned” 14 minutes before the IAF (horizon). As a result flights further from their IAF but closer to the landing runway will become “reserved”. IBP is based on the principle of “first come first served” with manual override.

**SARA extension to IBP**

SARA is being developed as an ACC (area control) tool. It will start working with a flight before TOD. It will calculate a descent speed and route that will put the aircraft at the IAF according to plan. The aim is that the accuracy over IAF will be high enough to allow for fixed route operation in the TMA.

It was realised from the outset of the project that SARA will generate advice relevant to more sectors. For the Amsterdam situation this means that adjacent ATC centers will be involved.

SARA is an integral part of the ATC system:

1. The flight appears to the ATM system and is entered in the AMAN planning
2. Once the planning is considered stable, SARA starts working
3. SARA reads the Expected Approach Time (EAT) for the flight
4. SARA contacts the TP and collects the current position of flights. It also uses the TP to calculate the flights Estimated Time Over (ETO) the IAF
5. SARA compares the EAT and ETO. If the difference is outside a set bandwidth (+/- 30 seconds at IAF), it will initiate the process to generate advisories
6. An iterative process is started where SARA uses the TP to calculate a speed and route combination that will bring the aircraft to the IAF such that the EAT and ETO is below the threshold value
7. Once a solution is found, it is communicated to the controller

SARA is used to develop and validate a Concept of Operation that will give:

- Traffic delivered with high accuracy at IAF
- Lower workload for controllers
- More predictability for airlines

SARA will:

- Reduce planning deviations to enable Fixed P-RNAV routes in the TMA
- Shift executive workload to planning domain
- Implement the global Tailored Arrivals Concept in high-density airspace



Figure 36: IBP/SARA – HMI view Approach Planner

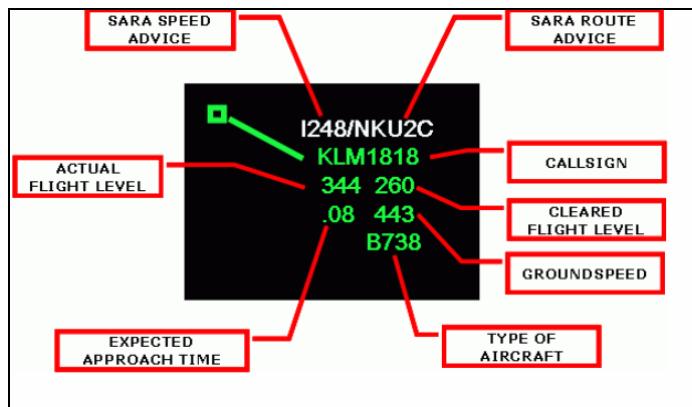


Figure 37: IBP/SARA - HMI view ACC controller label

#### AMAN/DMAN integration:

There is no information available on integration of IBP/SARA with DMAN.

### A1.1.5 OPTAMOS (Supplier: AVIBIT)

Website: <http://www.avibit.com/Solutions/OPTAMOS.htm>

OPTAMOS automatically creates optimized arrival sequences and advisories (time over waypoint and route selection) to achieve the sequence.

As OPTAMOS sends the time-to-lose and time-to-gain advisories via an AMA message directly to cooperating adjacent units, the traffic in the TMA and thus the controller workload can be reduced.

The OPTAMOS user interface is typically installed both at the APP and ACC units. While the ACC unit can work to provide the planned sequence at the metering fixes, the APP can guide the flights via FMS transition route advisories.

Finally the planner can dynamically adjust the total capacity by changing the DLI (determined landing interval) at the runway.

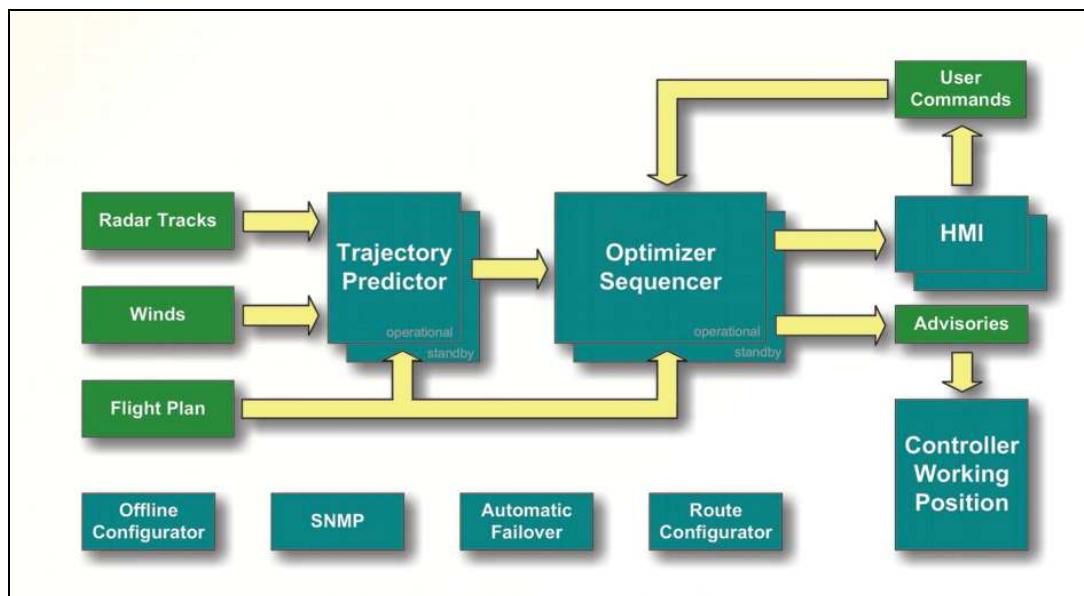


Figure 38: OPTAMOS - Functional Diagram

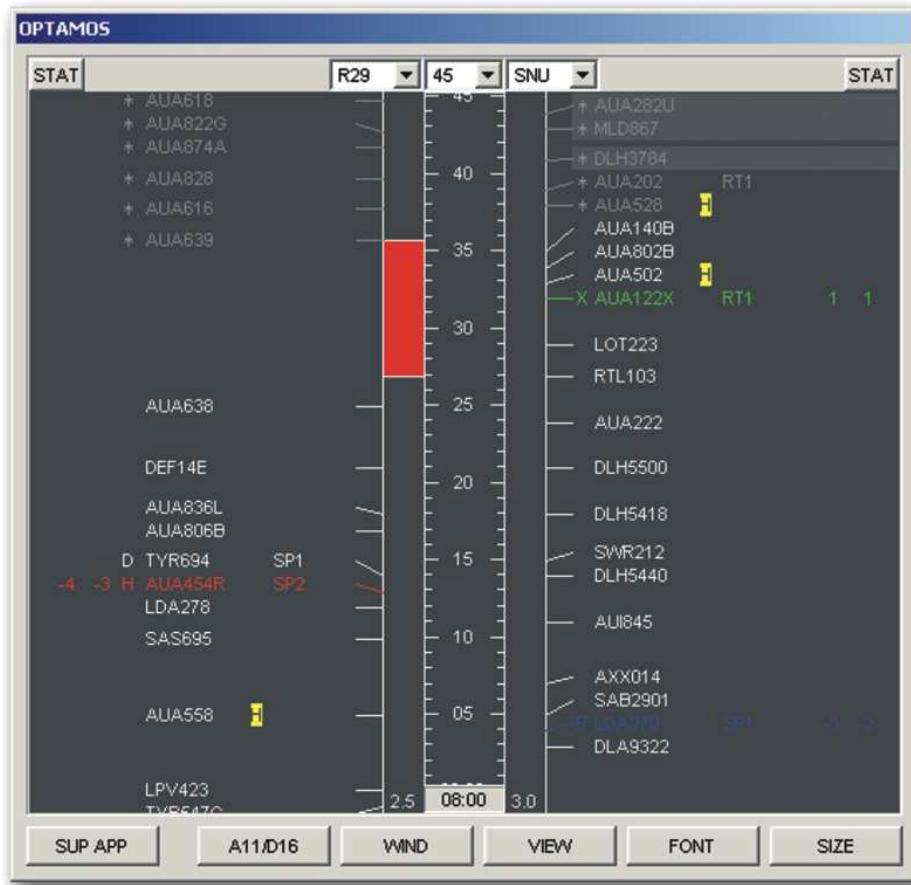


Figure 39: OPTAMOS - HMI view

#### AMAN/DMAN integration:

OPTAMOS can easily be linked to a departure management system either by sending planned runway occupancy time to the departure manager or by considering departure aircraft in the arrival sequence.

#### **A1.1.6 SELEX AMAN (Supplier: SELEX Sistemi Integrati)**

The AMAN assists the Controllers in the sequencing activity of arrival flights on a given airport. AMAN distributes the workload by improving coordination between ACC and APP and between sectors in ACC and between APP and TWR. AMAN provides a list of SFPLs (Arrival Sequencing List - ASL) in order to ensure a safe separation between two consecutive landings on a constraint point (Initial Approach Fix, aerodrome or runway) and ensures optimum runways utilization and the quickest landing time for aircraft. The AMAN takes into account the SFPL Trajectory, the Environment Data provided by the FDP and the controller orders and provides the **Arrival Sequencing List**.

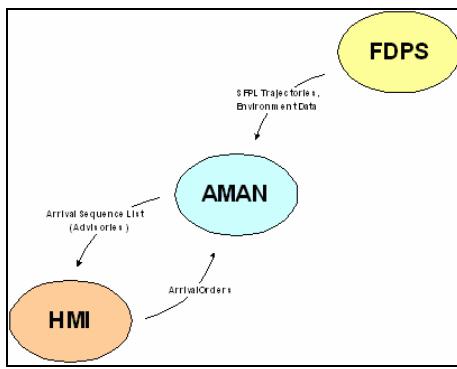


Figure 40: SELEX - High level representation

The AMAN computes the optimised times over the Sector Exit Fixes or TMA Entry Fixes and Scheduled Time of Arrival (STA). An Arrival Sequencing List includes all flights whose Expected Time Over (ETO) on a constraint point is less than T minutes (Operational Horizon – between 0 and 300 minutes; typically 60 minutes) from the actual time. Several ASLs can be defined for different constraint point within the Area of Responsibility.

In order to assure the right separation among arrival flights, within a given operational horizon, ASL can be automatically or manually updated and automatic advisory are also performed. When a flight lands (reach the constraint point) or is re-routed to another airport it is automatically deleted from the Arrival Sequencing List.

An SFPL is “eligible” for AMAN if:

- it's within the operational horizon
- its state is greater than “pending”

If ETA (or ETL) does not meet predefined time separation constraints, the AMAN will propose a different Scheduled Time (STA or STL) for each flight, assuming  $|STA-ETA|$  is minimum.

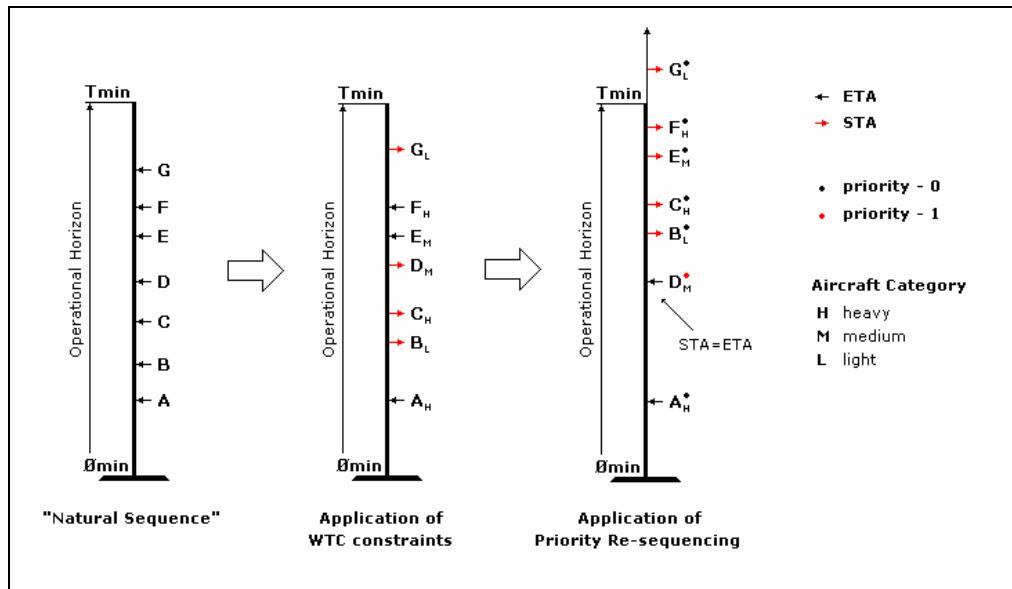


Figure 41: SELEX - Working method

The order of the optimised sequence (ASL) may change in consequence of:

- the input of the operative order
- the change of the priority class of the flight

- the change of the flight trajectory (re-calculation)

For establishing and maintaining the arrival sequence, AMAN uses the Wake Turbulence Category (WTC) of the flight to define the separation minima in approach phase of flight.

The AMAN provides to the controller the following operational advisories:

- **if** STA=ETA
  - “No Delay”
- **if** STA>ETA
  - **“Delay on Airway”**, the system suggests a new speed beginning from a given application point regarding to the obtainable maximum delay from that point to the Top of Descent (TOD)
  - **“Delay on feeding fix”**, the system suggests the holding procedure on the basis of the number of flights in holding phase (<MAX) and the obtainable maximum delay from the application point to the Top of Descent (TOD)

AMAN will be triggered for automatic sequence re-computation when the SFPL modifications occur and then the trajectory is re-computed.

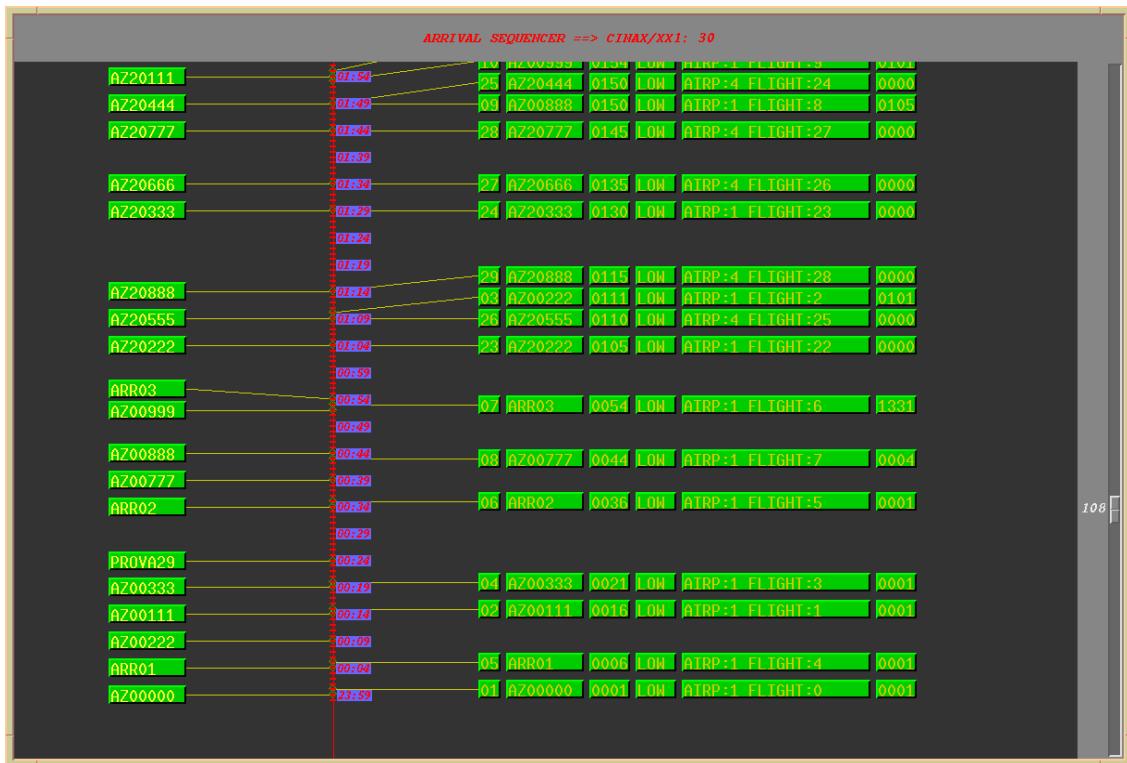


Figure 42: SELEX - HMI view

#### AMAN/DMAN integration:

There is no information available on integration with DMAN.

## A1.2 *Inventory of AMAN per country*

Please refer to “AMAN Status Review 2010” (**Reference 2**) for a more detailed description/feedback of the countries that have deployed or planning to deploy an AMAN system.

### A1.2.1 Deployment at major European Airports

Below is the ranking of the top 25 European airports (including: all-cargo, Business Aviation, Low-cost, non-scheduled, traditional scheduled, military and undefined segments as identified by EUROCONTROL/STATFOR Statistics and Forecast Service for the year 2009).

A colour coding for countries with **multiple** airports in the ranking is also included:

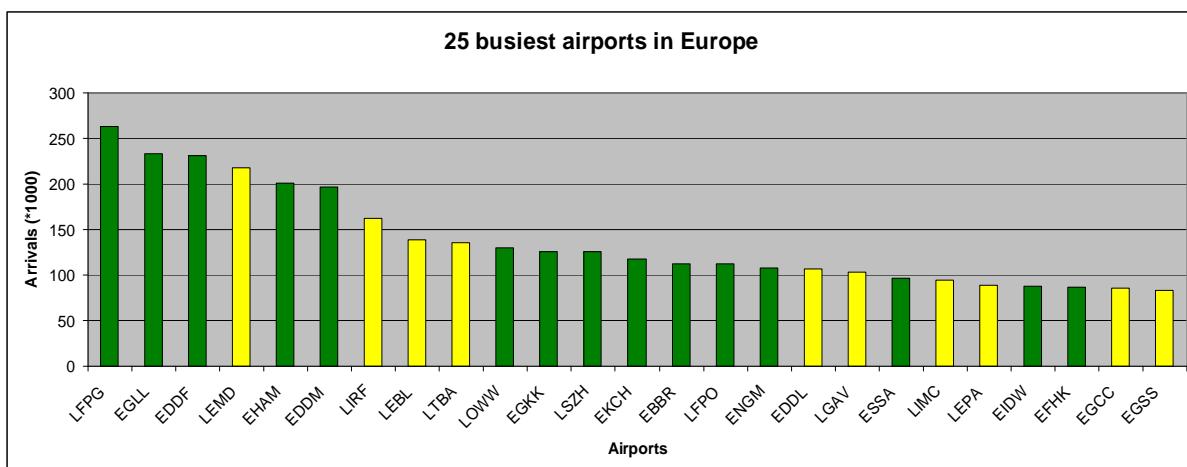
<u>Using AMAN:</u>	<u>Not using AMAN:</u>
France	Spain
UK	Italy
Germany	

	<u>AIRPORTS</u>	<u>AMAN</u>	<u>Used</u>
1	PARIS CH DE GAULLE	MAESTRO	X
2	LONDON/HEATHROW	OSYRIS	X
3	FRANKFURT MAIN	4D PLANNER	X
4	MADRID BARAJAS		
5	SCHIPHOL AMSTERDAM	IBP (SARA)	X
6	MUENCHEN 2	4D PLANNER	X
7	ROME FIUMICINO		
8	BARCELONA		
9	ISTANBUL-ATATURK		
10	WIEN SCHWECHAT	OPTAMOS	
11	LONDON/GATWICK	OSYRIS	X
12	ZURICH	CALM (OSYRIS)	X
13	COPENHAGEN KASTRUP	MAESTRO	X
14	BRUSSELS NATIONAL	MAESTRO	
15	PARIS ORLY	MAESTRO	X
16	OSLO/GARDERMOEN	OSYRIS	X
17	DUESSELDORF		
18	ATHINAI E. VENIZELOS		
19	STOCKHOLM-ARLANDA	MAESTRO	X

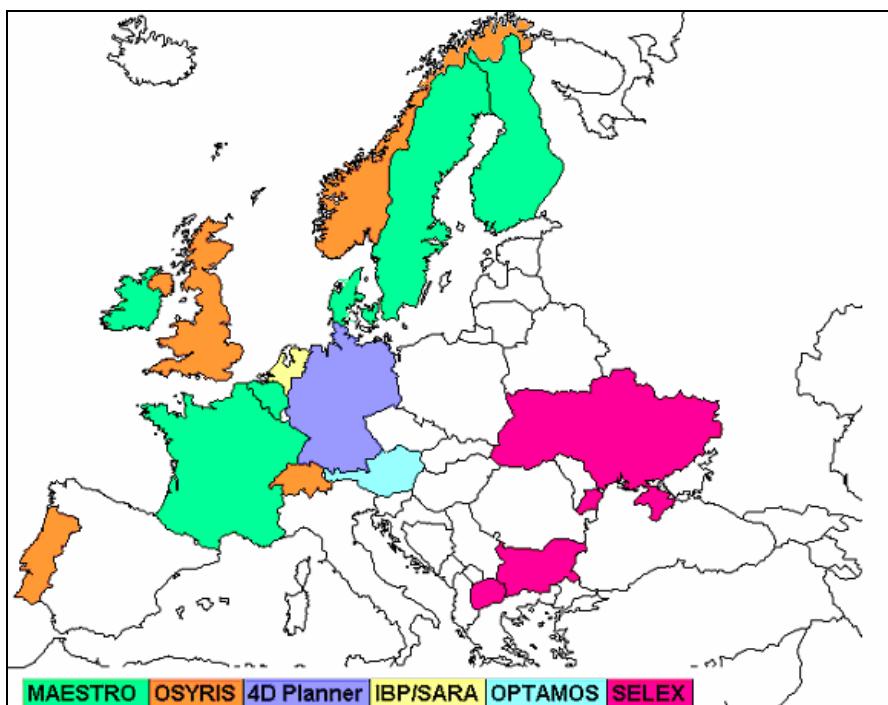
20	MILANO MALPENSA		
21	PALMA DE MALLORCA		
22	DUBLIN	MAESTRO	X
23	HELSINKI-VANTAA	MAESTRO	X
24	MANCHESTER		
25	LONDON/STANSTED		

**Table 6: AMAN Deployment at major European Airports**

The traffic volume is represented in the following figure (Figure 43: Arrival Traffic at major European Airports).

**Figure 43: Arrival Traffic at major European Airports**

The airports that have implemented or plan an implementing of AMAN are in green. The airports without AMAN are in yellow.

**A1.2.2 Geographical distribution of AMAN Suppliers/Users****Figure 44: Distribution of AMAN Suppliers/Users**

Source: information supplied by ANSPs. When one airport in a country reports using an AMAN, the full country is coloured.

There is a widespread dispersion of AMAN products across Europe (as on Figure 44: Distribution of AMAN Suppliers/Users), as there is a widespread dispersion of FPDS products.

# ANNEX 2 – General issues in ATC automation

The following is an extract from “Human Factors in the Design and Evaluation of Air Traffic Control Systems. FAA – Final Report 1995 (Reference 7)

## A2.1 *Expected benefits of automation in ATC*

- Increased capacity (traffic throughput)
- Improved human and system performance
- Reduction in perceived workload
- Reduced training requirements
- Expanded capability to perform functions beyond human capabilities
- Enhanced safety
- Reduced staffing
- Improved management control
- Better integration of data from multiple sources
- Enhanced services
- Lower task complexity

## A2.2 *Potential drawbacks of automation in ATC*

- Loss of control skills and readiness to respond
- Unexpected negative interactions between human performance and computer performance
- Inability of automated systems to resolve complex, critical problems
- Perception of automation as replacing operators
- Overconfidence and lack of trust in the automation
- Changes in the source and patterns of workload, with possible increases in integration operational workload
- Unforeseen changes in human roles
- Introduction of new forms of human error
- Perception of full autonomy for what is really semi-autonomy

- Brittle computer performances (failure to degrade gradually)
- Increased boredom and loss of job satisfaction
- Reduced efficiency and lack of productivity

### **A2.3 *A user-centred approach to automation***

A user-centred approach is applied by systematically mapping user requirements to technical solutions (e.g., hardware and software that will satisfy requirements). A user-centred approach also requires attention to evaluating the usability and acceptability of the design products. Such an evaluation benefits controllers by ensuring that the tools and capabilities provided by the computer system are the ones needed by controllers to do their jobs.

- Humans must remain in command of flight and air traffic operations. Automation can assist by providing a range of planning and control options
- Human operators must remain involved in the task. Automation can assist by providing better integrated and more timely information
- Human operators must be fully informed about the purposes and functioning of automated processes. At no time should the controller be wondering, “What is the automation doing or why is it doing that?” (as pilots sometimes have). Automation should assist users by providing explanations of its intentions, recommendations and actions
- Human operators must have the information needed to anticipate and resolve problems. Automation can assist by monitoring trends, providing decision support and making required information accessible when it is needed

There are 3 high-level objectives for ATC automation: usability, operational suitability and workforce acceptance.

- Usability. (ease of navigation through a menu structure, ease of remembering data-entry requirements, ease of locating specific items on a visual display)
- Operational suitability. (It must support the controller's effective and efficient planning, maintenance of situational awareness, separation of aircraft and performance of other ATC tasks)
- Workforce acceptance. (From a design's reliability, usability and operational suitability

Other characteristics/objectives:

- Transparency of underlying operations
- Error tolerance and recoverability
- Consistency with controllers' expectations
- Compatibility with human capabilities and limitations
- Ease of reversion to lower levels of automation
- Ease of handling abnormal situations and emergencies
- Ease of use and learning

# ANNEX 3 – AMAN: possible next steps

## A3.1 *Advanced version*

To cater for ever-changing needs, ATM and AMAN developers constantly propose upgraded functionality, to meet more ambitious economic and environmental targets, to cater for advances in technology and in procedures (Point merge system PMS), while increasing capacity and safety targets.

In addition to functionality already available new functionality for AMAN is currently being considered and developed in some areas. AMANs that can consider a new or alternative arrival route are now being considered, as well as functionality that can consider how to facilitate Continuous Descent Approaches (CDA) from a higher level than today, such as from cruising level (Top of Descent to Glide Slope interception).

In moving to the future SESAR concept of 4D operations, tomorrow's AMANs would likely also need to include additional functionality, such as CTA/RTA negotiation capabilities, enabling the mix of sequenced aircraft (under ground arrival management) with CTA/RTA aircraft (employing self-management to AMAN constraints). This too is being considered in some areas.

Likewise, the downlink of the aircraft trajectory is also being considered in some areas, since this could also be included (or even possibly "required") in future AMAN operations.

Although not yet a feature of these systems, in developing more advanced systems the need for integration of AMAN Controller Support tools with other monitoring and conflict detection tools (Monitoring Aids – MONA and Medium Term Conflict Detection - MTCD) is also now recognised. In effect the ultimate goal might possibly be the delivery of conflict free arrival management advisories.

These concepts of Advanced AMANs and the greater acceptance of system advisories by the controllers/pilots are under investigation in projects such as SARA ("Speed and Route Advisories" project - Ref in Annex 1), and in research work that is to be undertaken within the remit of the SJU.

Below one possible AMAN development or step, the inclusion of an RTA/CTA negotiation within an AMAN operation, is described in some more detail. The sequence depicted is from work that was conducted under the previous EUROCONTROL TMA2010+ project, and

involves CTA/RTA negotiation capability that was being tested by the project at the time. It should be noted, that although the experiment is similar to some “enhancements” being investigated in SESAR at the moment, current AMAN system suppliers are not at the moment planning such an enhancement in the shorter-term...

### A3.1.1 RTA/CTA negotiation

As an example of a possible AMAN development, below is depicted a typical sequence of events for a “future” AMAN conducting a CTA exchange. The sequence involves:

1. Around 150-200nm from touchdown, around AMAN horizon, the aircraft is captured by the system
2. On the ground, the ATC system sends the STAR and Runway in use (via Datalink)
3. The aircraft computes its trajectory (non-time constrained) for optimization and (possible) downlink
4. ATC initiates CTA/RTA negotiation by requesting (via Datalink) the ETA of the flight for a certain point along its trajectory
5. The aircraft sends the ETA/O and also possibly a time-window (Min/Max time) for the requested point
6. On the ground, the AMAN system sequences the aircraft at the preferential time (ETA) or within the time-window transmitted by the aircraft and sends a CTA to the flight
7. Aircraft uses on board RTA functions to meet agreed CTA

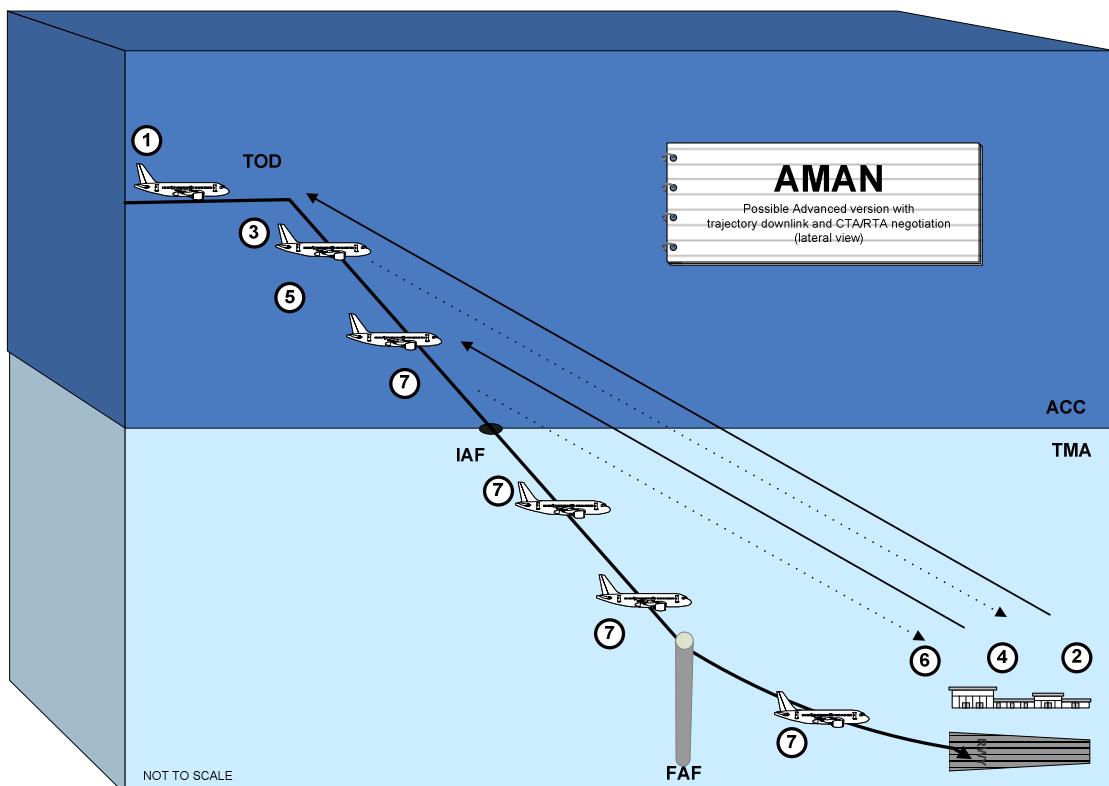


Figure 45: AMAN with downlink of trajectory (vertical view)

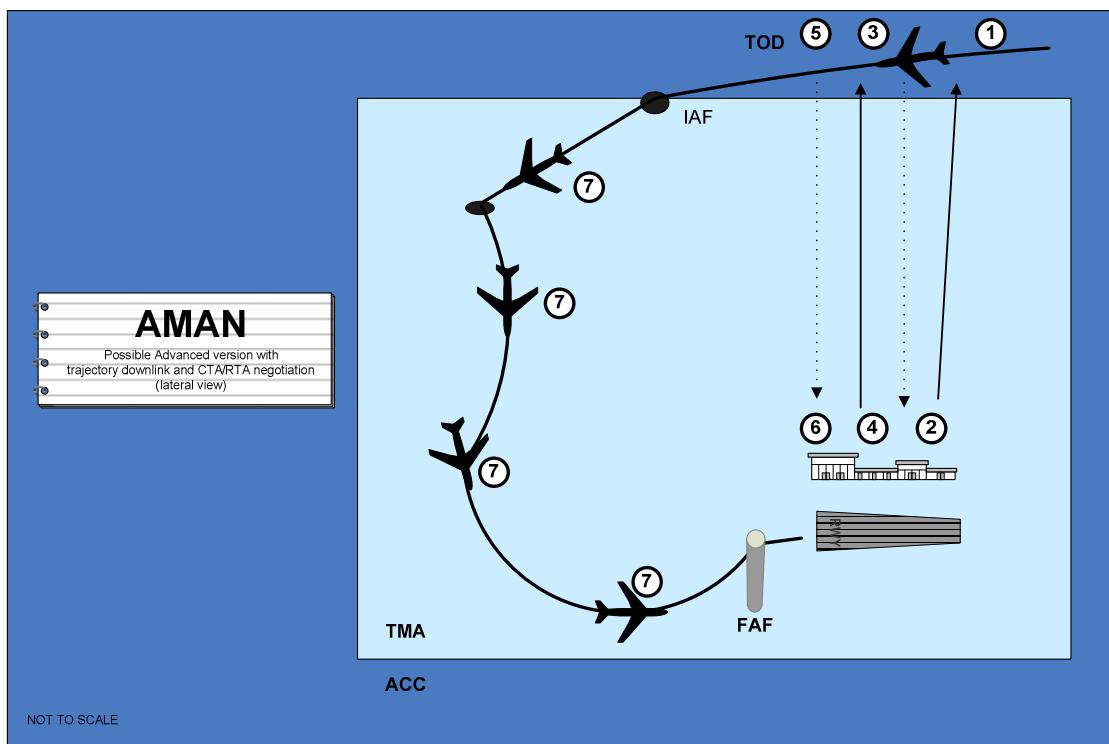


Figure 46: AMAN with downlink of trajectory (lateral view)

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**Reference 2:** EUROCONTROL – AMAN Status Review 2010. Edition: 0.X. Date: 17<sup>th</sup> December 2010. Status: Proposed Issue.

**Reference 3:** European Air Traffic Management Master Plan. Edition: 1. Date: 30<sup>th</sup> March 2009. [www.atmmasterplan.eu](http://www.atmmasterplan.eu)

**Reference 4:** ATM Master Plan Update Working Group Report. Edition: 0.14. Date: 27<sup>th</sup> March 2010. [www.atmmasterplan.eu](http://www.atmmasterplan.eu)

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