

# **CONCEPT OF OPERATIONS**

## **Mode S in Europe**

### **(Mode S CONOPS)**

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### Abstract

The Concept of Operations Mode S in Europe (Mode S CONOPS) Document specifies the employment criteria for the operational use of Secondary Surveillance Radar (SSR) upon the introduction of a Mode S Enhanced Surveillance capability.

### Language

The English Language has been used in preparing the original text of this document.

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Operational Requirements	Concept Application	Operational Objective	Operational Benefits
Downlink Aircraft Parameters	Policy and Procedures	Operational Principles	Airborne Equipment
Exemption Arrangements	Transition Guidelines	Interoperability	Recommendations

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## FOREWORD

**This version of the Concept of Operations Mode S in Europe Document (Mode S CONOPS) supersedes Mode S CONOPS, Version 1.0, which was produced by the EUROCONTROL Mode S Civil/Military Task Force and published on 15 February 1995.**

**Mode S CONOPS, Version 2.0, represents the culmination of the work of the Mode S Operational Use of Enhanced Surveillance (MOUSES) Task Force established in June 1995 by the Operational Requirements and Data Processing Team (ODT). The MOUSES Task Force has been charged to develop further the operational concept for Mode S in the Core Area to the level necessary to achieve Enhanced Surveillance. This tasking is an essential element of the Surveillance Domain Strategy for the Initial Implementation of Mode S Enhanced Surveillance (IIMSES) which includes the extraction and transmission to the ground of downlink aircraft parameters (DAPs) within the design of the proposed ground system surveillance function. The definition and employment of DAPs in association with the carriage and operation of Mode S transponders therefore distinguish IIMSES from Elementary Surveillance and that which may result from future development of both the Mode S Subnetwork and the Aeronautical Telecommunications Network (ATN).**

**Mode S CONOPS, Version 2.0, has been developed to reflect the evolutionary introduction of Air Traffic Services (ATS) based on SSR Mode S. IIMSES will be phased in over a number of years and will require the clustering of ground sensors due to the limited number of Interrogator Identifier (II) codes available for operational use.**

**The Document also includes the principles and guidance for the maintenance of civil-military IFF/SSR interoperability. However, much of the specific technical implementation will need to be decided upon by the appropriate international and military organisations in consultation with the necessary national authorities.**

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# **1. INTRODUCTION**

## **1.1 Purpose**

The Concept of Operations Mode S in Europe Document (Mode S CONOPS) specifies the employment criteria for the operational use of Secondary Surveillance Radar (SSR) following the introduction of a Mode S surveillance capability. It provides detailed information concerning the operational elements involved; the requirements of the users, airborne equipment functionality and the measures needed to ensure continued safe and efficient Air Traffic Management (ATM) in a mixed Mode S and non-Mode S secondary radar environment.

Mode S CONOPS also provides information on the operational benefits to be obtained from the implementation of Mode S based Air Traffic Control (ATC) radar surveillance services.

## **1.2 Background**

### **1.2.1 Secondary Surveillance Radar System Development**

The provision of ATS in Europe has placed increasing reliance on SSR based radar services and applications. Almost all states comply with the requirement for the carriage and operation of transponders using civil Mode A, military Mode 3 (Mode 3/A) together with Mode C altitude reporting for aircraft flying in controlled airspace. In addition, harmonisation measures have been published governing the carriage and operation of SSR transponders in other categories of airspace. SSR provides data on the position, identification and altitude of the aircraft, permitting individual flights to be tracked in three dimensions.

Within the last decade, increasing traffic growth has stretched the capacity and capability of the ATC infrastructure and, in particular, has highlighted the inherent limitations of existing SSR based ATS. To ensure the efficient handling of increasing traffic volumes in a safe, orderly and expeditious manner, progressive implementation of SSR Mode S, in conjunction with other system improvements, is necessary to satisfy the medium to long term surveillance requirements in Europe.

Existing SSR systems are approaching the limits of their capability in certain parts of the Core Area; whereas Mode S installations, when implemented, will be at the beginning of their operational capability.

## 1.2.2 Limitations of Existing SSR

Deficiencies associated with SSR Mode 3/A and C include:

- Interference due to overlapping replies from two or more transponders (garbling).
- Interference at one interrogator caused by replies from a transponder in response to interrogations from another interrogator (FRUIT).
- Interference at one transponder caused by over-interrogation resulting in transponder dead time and consequent unavailability.
- Reflections from obstacles or high terrain causing ghost targets to be displayed.
- Availability of only 4096 codes in Mode 3/A for identification purposes.

## 1.2.3 Adoption of SSR Mode S

To overcome these deficiencies, SSR Mode S has been developed which incorporates a selective and individual aircraft address and datalink capability. Furthermore, it is able to transmit certain aircraft parameters automatically with the potential for system development to full air/ground/air datalink applications. It has been specified by ICAO to be interoperable with Mode 3/A and C and will progressively replace it where required. A system overview is at Annex A.

## 1.3 Document Context

### 1.3.1 Rationale

The European Civil Aviation Conference (ECAC) strategy for the 1990s was established on 24 April 1990 at the inaugural meeting of ECAC Transport Ministers in Paris. The requirement for Mode S to be implemented, in a central area, from 1998 onwards was one of six operational objectives in what was later defined as the ECAC En-Route Strategy and which additionally stipulated that monopulse radars shall be progressively upgraded to Mode S capability.

The ECAC Transport Ministers at their 4th meeting (MATSE/4, Copenhagen - 10 June 1994) reaffirmed their support for the ECAC En-Route Strategy and their commitment to developing the future European Air Traffic Management System (EATMS) for the early years of the next century. In calling for enhanced civil-military cooperation, the ministers agreed the measures necessary for the successful introduction of SSR Mode S. Consequently, a civil/military task force was charged to develop:

- A concept of operations.

- A transition plan to ensure a consistent approach.
- Exemption principles for certain categories of State aircraft.
- Airborne equipment carriage requirements for civil and military aircraft.

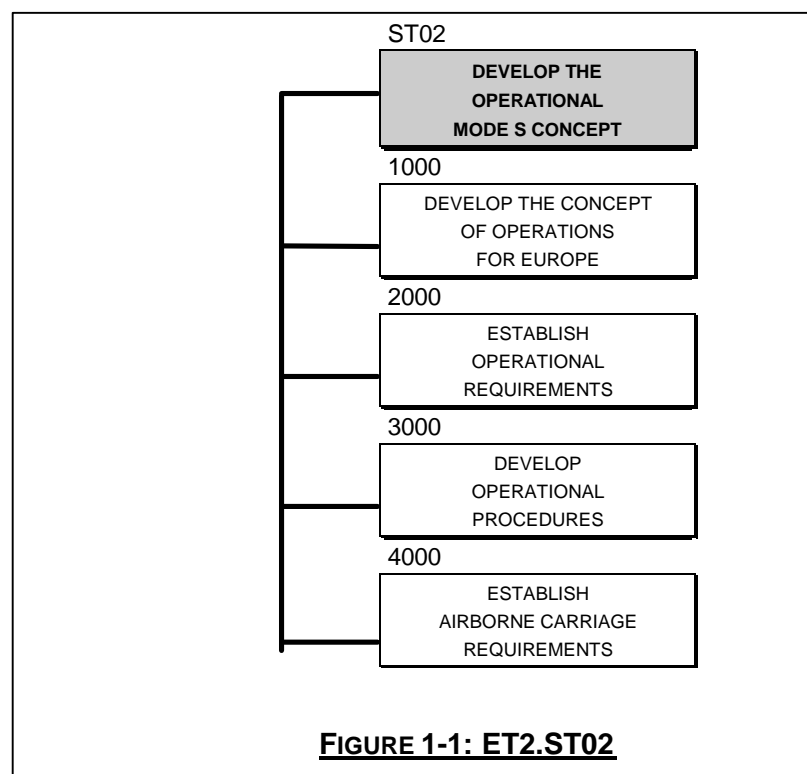
This resulted in the production of Mode S CONOPS, Version 1.0, which could address the issues required only in very broad terms.

Achievement of the ECAC strategy objectives is being accomplished through a phased action plan as part of the European ATC Harmonisation and Integration Programme (EATCHIP) coordinated and managed by the EUROCONTROL Agency. Mode S CONOPS is an early explication of the high-level description concerning improvements to the surveillance elements of the ATM system described in the EATCHIP Operational Concepts Document (OCD) for the period 1998 - 2005.

### 1.3.2 The EATCHIP Context

The Mode S CONOPS, Version 2, Document is a deliverable of Specialist Task 02 (ST02) of the EATCHIP Surveillance (SUR) Domain, Executive Task (ET) 2, Initial Implementation of Mode S Enhanced Surveillance. ST02 has been delegated to the Operational Requirements and Data Processing Team and forms part of the Domain Executive View of System Design and Harmonisation (DEV1), of IIMSES.

ET2.ST02 embraces the tasking components shown in figure 1-1.



This version of Mode S CONOPS has been developed by the Mode S Operational Use of Enhanced Surveillance (MOUSES) Task Force, under the direction of the ODT. It supersedes Mode S CONOPS, Version 1.0, prepared by the former Mode S Civil/Military Task Force, upon which it is based.

Mode S CONOPS is complementary to the EATCHIP Document, Strategy for the Initial Implementation of Mode S Enhanced Surveillance in the Core Area, which is maintained under the responsibility of the SURT. A detailed breakdown of the IIMSES Business Plan Working Structure is set out at Annex B. This depicts the introduction of IIMSES as a phased process commencing in the year 2000 and completing in approximately 2003/04.

### 1.3.3 The ICAO Context

The ICAO SSR Improvements and Collision Avoidance Systems Panel (SICASP) was established in 1983 and is responsible for the development of International Standards and Recommended Practices pertaining to ground and airborne SSR equipment. SARPS progression relevant to Mode S is as follows:

- **Annex 10 to the Convention on International Civil Aviation - Aeronautical Telecommunications**
  - Introduction of technical specifications for SSR Mode S. Material on allocation to states and assignment to aircraft of SSR Mode S aircraft addresses. (Adopted 27 July 1987).
  - Amendment No. 69 concerning sensor-transponder protocols. (Adopted 23 March 1993).
  - Draft Mode S Subnetwork SARPS and Guidance Material; draft Manual on Mode S Specific Services (SICASP/5).
  - Future work under consideration includes Mode S extended squitter formats and the possible extension of interrogator identifier (II) code sets.
- **Rules of the Air and Air Traffic Services (PANS/RAC Doc. 4444-RAC/501/12)**
  - SSR Mode S operating procedures approved with an application date of 10 November 1994.
  - Proposed amendments to Primary Surveillance Radar (PSR) and SSR operating procedures for an envisaged applicability date of 7 November 1996.

### **1.3.4 The NATO Context**

The official NATO military position on Mode S is stated in a NATO International Military Staff document (IMSM-KEC-382.95 dated 16 Oct 95). It supports the view of the Major NATO Commanders (MNCs) that Mode S, as a civil ATC surveillance system, does not satisfy the NATO Operational Requirement for an improved IFF capability which is secure and resistant to jamming (hostile electromagnetic interference). Therefore, the MNCs saw no NATO military requirement for procurement of Mode S as a military IFF system.

NATO also recognises that the carriage and operation of Mode S transponders in military aircraft will be necessary to facilitate access to the airspace in which ATC is provided by civil ATS units and to enhance flight safety. In addition, NATO military authorities have stated a requirement for the acquisition and distribution of Mode S data for the safe coordination and control of aircraft and to assist Air Defence authorities in the compilation of the Recognised Air Picture. Discussion within NATO as to the extent of data to be derived from civil sources as opposed to that obtained from military interrogators are still ongoing.

A NATO appraisal of the military implications of Mode S implementation is at Annex D.

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## 2. SCOPE

Mode S CONOPS describes the concept for the employment of SSR Mode S by the identified users. As Mode S CONOPS only covers the applications relevant to IIMSES, its scope is limited by:

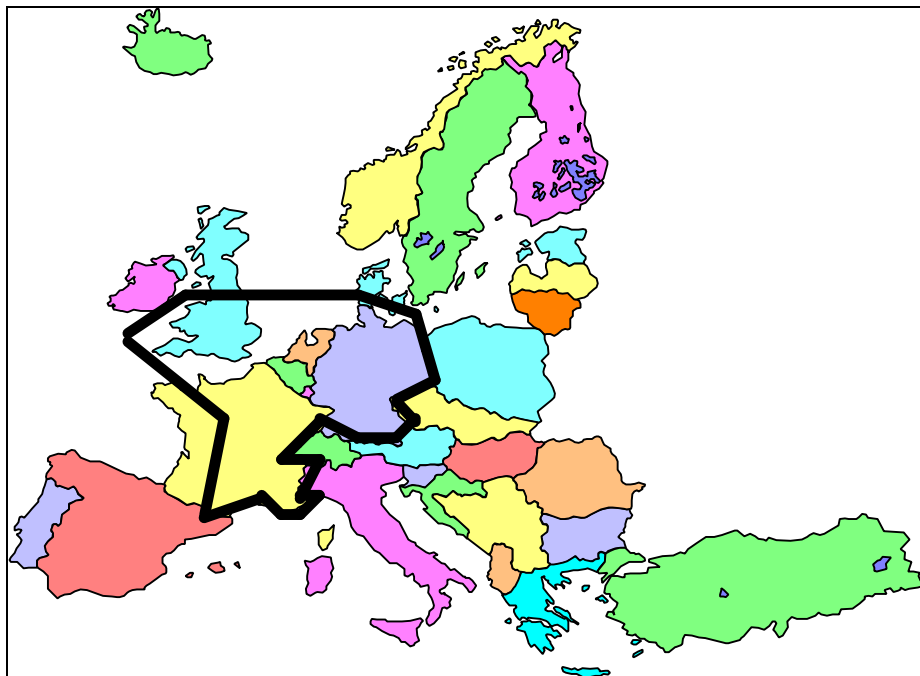
- The geographic area and airspace considerations.
- The elements of the system to be implemented.
- The identified users.
- The identified user requirements.

The scope of Mode S CONOPS in each of these areas is set out below.

### 2.1 Geographic Area and Airspace Considerations

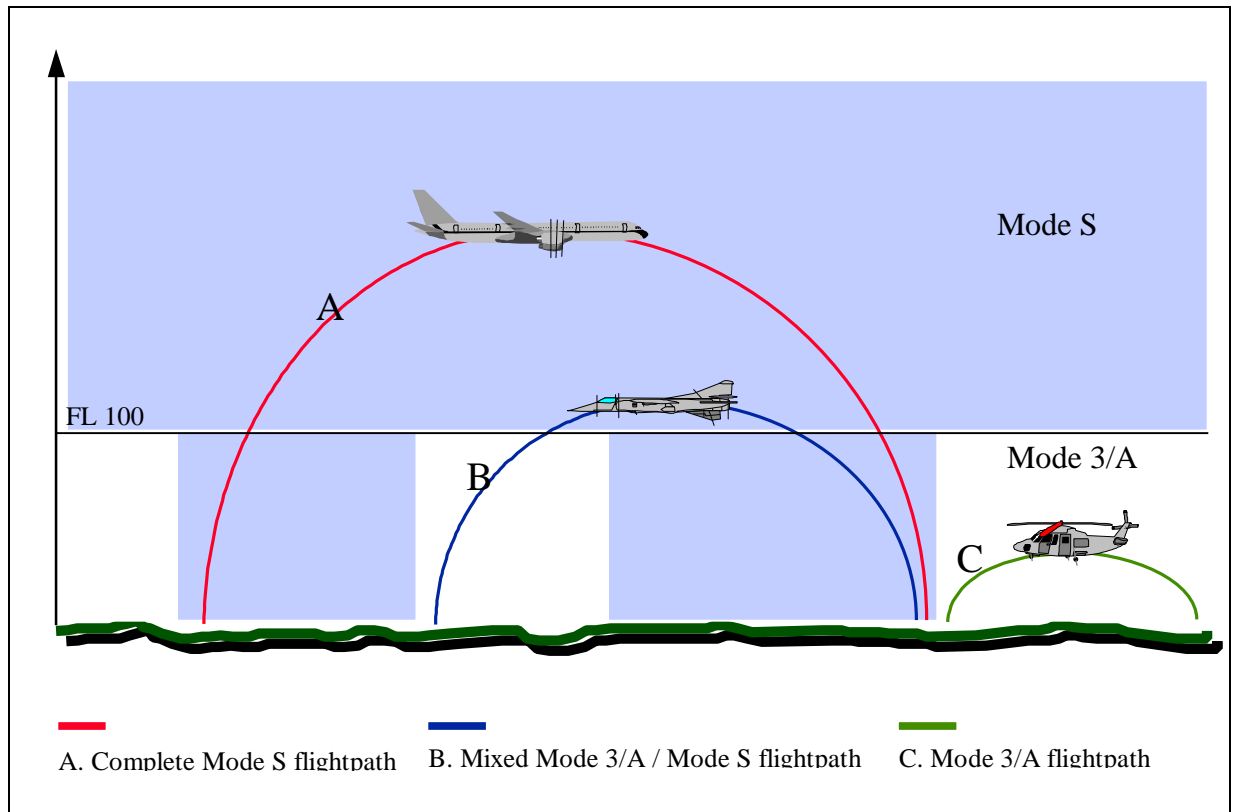
Mode S CONOPS describes a concept of operations which takes account of the geographic area defined in the Strategy for IIMSES as the Core Area. This covers the spheres of responsibility of the ATC centres for Belgium, Luxembourg, the Netherlands, France, Germany and the United Kingdom (London ACC). Figure 2-1 depicts the Core Area of IIMSES applicability.

Any extension to this area should maintain geographic continuity for the provisions and requirements contained in Mode S CONOPS to remain valid.



**Figure 2-1: Applicable area of IIMSES**

Mode S CONOPS also takes account of the lateral aspects of the airspace applicable to the introduction of Enhanced Surveillance as defined in the IIMSES Strategy. This should consist of at least duplicated Mode S radar coverage at and above FL100 and in major TMAs. Figure 2-2 depicts an illustrative cross section of IIMSES airspace.



**Figure 2-2 - Illustrative Cross Section of Mode S Airspace**

It will be necessary for each state participating in IIMSES to define the volume of airspace in which an ATS using Mode S is provided. This is to enable issues such as Mode 3/A transitional arrangements and exemption provisions to be properly addressed and promulgated in accordance with the principles set out in Chapter 4 of Mode S CONOPS.

## 2.2 Elements of the System to be Implemented

Mode S CONOPS describes a concept of operations for the SSR system which will be in place on completion of Mode S Enhanced Surveillance implementation and validation (Annex B; IIMSES Business Plan Work Structure). In addition, Mode S CONOPS addresses in Chapter 4 the interfaces and procedural requirements for Mode S equipped and non-Mode S equipped users.

## 2.3 Users

Mode S CONOPS describes a concept of operations which has implications for all current and future users of SSR, including military Identification Friend or Foe (IFF) systems operating in 1030/1090 MHz. In this context, the term 'users' refers to the organisations, people, automated systems, infrastructure procedures, rules and information involved in the operation of IFF/SSR and the data derived from the ground and airborne elements concerned.

### 2.3.1 Civil Users

In general terms, Mode S CONOPS applies to civil users as follows:

- Aircraft operating IFR as General Air Traffic (GAT) in the airspace where the carriage and operation of Mode S transponders has been prescribed by the appropriate ATS authority.
- Aircraft operating VFR within class B and C airspace; also aircraft operating in defined portions of class D, E, F and G airspace where the carriage and operation of SSR transponders has been prescribed by the appropriate ATS authority.
- Appropriate Air Traffic Service Units (ATSUs).

### 2.3.2 Military Users

In general terms, Mode S CONOPS applies to military users as follows:

- Military aircraft operating in accordance with the rules pertaining to General Air Traffic (GAT) e.g. transport, Airborne Early Warning (AEW), Maritime Patrol (MPA) and tanker aircraft.
- Other military aircraft, including helicopters, normally operating in accordance with the rules pertaining to Operational Air Traffic (OAT). These aircraft would on certain occasions require to operate as GAT.
- Appropriate Military ATSUs.
- Air Defence (AD) and AEW units, including static, mobile and deployable units land, sea or air operated, within or adjacent to Mode S radar coverage.

## 2.4 Operational Requirements

Mode S CONOPS describes a concept of operations which has been developed to meet the operational requirements of the users of IFF/SSR systems on the introduction of IIMSES.

### 2.4.1 General Requirements

The overall user requirement is to overcome the inherent limitations of existing SSR systems and to:

- Facilitate the efficient handling of increased traffic volumes in a safe, orderly and expeditious manner.
- Permit the eventual alleviation of SSR (4096) code shortage.
- Allow for a progressive reduction in R/T workload per aircraft.
- Provide continued access to SSR Mode 3/A and C through sustained backwards compatibility.
- Ensure that displayed radar target accuracy remains at least equal to or superior to that provided by existing SSR monopulse systems.

In order for these requirements to be realised, a sufficiently uninterrupted and contiguous area of airspace must be made available in which Mode S Enhanced Surveillance can be effectively employed.

### 2.4.2 Specific Military Requirements

Specific military requirements are:

- Permanent, uninterrupted and reliable access to real-time SSR data including Mode S information both for flight safety reasons and in support of the compilation of the Recognised Air Picture (RAP).
- Maintenance of operational flexibility.
- Provision for the continued use of military IFF.
- The ability to employ ground selectable Mode S aircraft addresses.
- The ability to disable selected Mode S functions on military platforms when demanded by the operational situation.

### **3. CONCEPT APPLICATION**

#### **3.1 Operational Objective**

The purpose of SSR Mode S development is to overcome the inherent limitations of Mode 3/A and C whilst providing the means to benefit from an improved ATC surveillance capability with a corresponding augmentation in safety. This, in turn, facilitates the process towards easing controller workload and increasing system capacity consistent with the Operational Requirements listed under paragraph 2.4.

#### **3.2 Operational Benefits**

The operational benefits attributable to the introduction of Mode S Enhanced Surveillance derive from the improvements afforded in the use of the Mode S transponder (Elementary Surveillance) by the ground system and by the employment in IIMSES of a minimal Downlink Aircraft Parameter (DAP) capability. Together these will enable:

- Unambiguous aircraft identification.
- Improved integrity of surveillance data.
- Improved air picture and tracking (horizontally and vertically).
- Alleviation of Mode 3/A code shortage.
- Improved controller situation awareness.
- Progressive reduction of R/T workload per aircraft.
- Improvements to the Safety Nets (e.g. STCA).

##### **3.2.1 Unambiguous Aircraft Identification**

The availability of almost 17 million unique aircraft addresses, in conjunction with the automatic reporting of flight identity, permits the unambiguous identification of aircraft independently of any Mode 3/A code assignment.

*This eradicates the risk associated with erroneous/duplicate SSR (4096) code settings.*

##### **3.2.2 Improved Integrity of Surveillance Data**

Selective interrogation and the superior resolution ability of Mode S over existing SSR and MSSR installations will:

- Eliminate synchronous garble.
- Resolve the effects of over interrogation.
- Simplify aircraft identification in the case of radar reflections.

*The effects of these problems are experienced, to varying degrees, throughout the EUR Region.*

### **3.2.3 Improved Air Picture and Tracking**

The radar controller can be presented with a better current air picture through system acquisition of flight identity, ready access to downlink aircraft parameters and enhanced tracking techniques. The greater accuracy of Mode S Enhanced Surveillance i.e. less random or systematic errors together with the production of more stable speed vectors will result in an improved horizontal and vertical tracking capability over current in-service SSR installations.

*High integrity track monitoring will be an essential prerequisite to exploiting, to their full potential, closely spaced parallel Required Navigational Performance, RNP-1, routes, should these be brought into operational use.*

### **3.2.4 Alleviation of Mode 3/A Code Shortage**

The situation concerning SSR code shortage in the EUR Region is reaching a critical stage. The unique aircraft address ability of Mode S will solve the predicament of European SSR code shortage permanently.

*Whilst alternative strategic devices can be employed to extend the useful life of the available 4096 codes, these have cost implications and operational limitations and can only be considered as short term palliatives.*

### **3.2.5 Improved Situation Awareness**

A clearer air picture, enhanced tracking and access to pertinent information direct from the aircraft will enable the controller to benefit from quicker and more accurate recognition of airborne events.

*The controller will have access to data, not readily available today, which would allow for improved decision taking where currently information required from the aircraft has to be either estimated or requested from the pilot.*

### **3.2.6 Progressive Reduction of R/T Workload per Aircraft**

There is scope for R/T usage between controller and individual aircraft under service to be reduced following the progressive introduction of Mode S Enhanced Surveillance. It applies in particular to the current requirement for SSR code verification procedures and also where system enhancements

and/or the display of downlink aircraft parameters obviate the need for certain voice communication exchanges.

### 3.2.7 Improvements to Safety Nets (e.g. STCA)

The ability of Mode S to eliminate synchronous garbling, to produce a more stable speed vector and to acquire aircraft altitude reporting in 25ft increments, (if supported by compatible barometric avionics) provide valuable improvements to the quality of safety nets. In addition, access by the ground system to actual values downlinked from the aircraft, and specifically that of vertical rate, will afford early and accurate knowledge of manoeuvring information.

*These improvements should reduce the number of nuisance alerts and enhance the integrity of separation assurance.*

Note Whilst the ground system will benefit from altitude reporting in 25ft intervals, there is no intention to change the existing practice of displaying altitude information to the controller in increments of 100ft intervals.

## 3.3 Downlink Aircraft Parameters (DAPs)

### 3.3.1 IIMSES Requirements

Airborne equipment recommended for the IIMSES programme comprise a Mode S transponder and the ability to transmit to the ground system, DAPs which promote the realisation of the operational benefits. Parameters identified for IIMSES are set out in the table below, indicating the benefits supported.

#### a. Basic Functionality

Parameter	Benefit
Automatic Reporting of Flight Identity (callsign used in flight)	3.2.1, 3.2.3, 3.2.4
Transponder Capability Report	Technical requirement for IIMSES
Altitude Reporting in 25ft intervals (subject to aircraft capability)	3.2.7

Note Use of Flight Status (airborne/on the ground) is also envisaged; initially as a requirement for ACAS/TCAS and, in the future, for its association with system applications beyond the current IIMSES programme. This parameter is a standard feature in Mode S replies.

**b. Enhanced Surveillance Functionality**

Parameter	Benefit
Magnetic Heading	3.2.3, 3.2.5, 3.2.6, 3.2.7
Speed (IAS / TAS / Mach No)	3.2.3, 3.2.5, 3.2.6, 3.2.7
Roll Angle (system acquisition of start and stop of turn)	3.2.3, 3.2.5, 3.2.6, 3.2.7
Track Angle Rate (system acquisition of start and stop of turn)	3.2.3, 3.2.5, 3.2.6, 3.2.7
Vertical Rate (barometric rate of climb/descend or, preferably baro-inertial)	3.2.3, 3.2.5, 3.2.6, 3.2.7
True Track Angle/Ground Speed (track initialisation only)	3.2.3

The categories of DAPs above, Basic Functionality and Enhanced Surveillance Functionality are proposed to meet the operational and added safety benefits which are to be expected from the IIMSES programme. These two categories of functionality can be supported by a Level 2 (standard message length) Mode S transponder(□) and have been included in the airborne equipment carriage requirements and installation timescales set out in Chapter 4.

It should be noted that transition arrangements will accommodate varying degrees of compliance according to aircraft capability following on from IIMSES introduction.

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1. Levels of Mode S Transponders

It is stipulated in ICAO Annex 10, Part I para. 2.5.5, that Mode S transponders shall conform to one of four Levels of capability as follows:

Level 1 This is the basic transponder. Level 1 permits surveillance based on Mode A/C as well as on Mode S. With a Mode S aircraft address it comprises the minimum features for compatible operation with Mode S interrogators. It has no datalink capability and will not be used by international air traffic.

Level 2 Level 2 has the same capabilities as Level 1 and permits standard length datalink communication from ground to air and air to ground. It includes automatic aircraft identification reporting. This is the minimum level permitted for international flights.



Level 3 Level 3 has the same capabilities as level 2 but permits extended datalink communications from the ground to the aircraft.

Level 4 Level 4 has the same capabilities as level 3 but allows extended datalink communications from the aircraft to the ground.

(SARPS for an additional level, Level 5, are being processed for inclusion in ICAO Annex 10 in 1996 to provide enhanced datalink capability in an environment of several interrogators).

### 3.3.2 Future Expansion of Mode S Surveillance Services

In anticipation of further expansion of Mode S surveillance services in the direction depicted in Annex A (Figure A-1), consideration needs to be given to the downlinking of additional aircraft parameters. Those which indicate aircraft intention (selected parameters) offer the greatest potential benefit to the ATM system and in particular the safety nets in terms of enhanced tracking and anticipated knowledge of aircraft manoeuvres. They would be used to considerable advantage in ground systems with ARTAS<sup>1</sup> or ARTAS-similar surveillance data processing. However, the resolution of certain technical and institutional issues associated with the downlinking of these aircraft parameters is essential before they can be introduced for operational use in IIMSES.

Therefore, once these issues have been resolved, the following parameters are recommended for inclusion:

- Selected Flight Level / Altitude.
- Selected Magnetic Heading.
- Selected Course.
- Selected IAS / Mach No.

Other candidate DAPs are also under active consideration for inclusion in the further development of Mode S Enhanced Surveillance. Therefore, it is particularly important that aircraft operators and equipment manufacturers are made aware as early as possible of planned ground infrastructure developments which could impact on future airborne equipment carriage requirements.

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<sup>1</sup> ARTAS EUROCONTROL ATC RADAR TRACKER AND SERVER

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## **4. OPERATIONAL POLICY AND PROCEDURES**

The introduction of IIMSES in Europe is the first stage in the progressive implementation of a Mode S surveillance and associated datalink facility with upgrade capabilities to the full Mode S subnetwork. As such, operational policy for the employment of IIMSES will provide for expansion of the system both in terms of equipment upgrade and extended airspace coverage. Operational policy matters together with the consequences for modification to rules and procedures cover:

- Airborne equipment.
- Transition guidelines.
- Exemption arrangements
- Civil-Military interoperability.

### **4.1 Airborne Equipment**

#### **4.1.1 Carriage and Operation of Mode S Transponders**

Requirements for the mandatory carriage and operation of Mode S transponders in the EUR Region have been incorporated in ICAO Regional Supplementary Procedures Doc. 7030 and are reproduced at Annex C.

States upgrading their SSR systems to a Mode S capability would normally be expected to include the provisions of Doc 7030 within national regulations. However, because of revised timescales regarding the introduction of IIMSES in the Core Area, most of the States concerned have not yet amended their existing SSR carriage requirements to embrace Mode S.

Those States which have already incorporated requirements for Mode S transponders in national regulations have been considering the issue of supplementary amendments. This is to take account of revised scheduling within the IIMSES programme.

#### **4.1.2 Airborne Equipment Requirements for IIMSES**

The Doc 7030 requirements for the carriage and operation of Mode S transponders were initiated in 1992. This was to afford aircraft operators seven years notice in accordance with the provisions of ICAO Annex 10 and consequently, it was not possible at that time to include the onboard extraction and transmission to the ground of aircraft parameters. The two categories of DAPs; Basic Functionality and Enhanced Surveillance Functionality, set out in 3.3.1.a. and 3.3.1.b., together with a Mode S

transponder, are therefore proposed as the basis for revised airborne equipment requirements in the EUR Region.

#### 4.1.3 **Eurocontrol Specimen Aeronautical Information Circular (AIC)**

In order that States can adopt a harmonised response in addressing the requirements of airborne equipment carriage, it has been agreed (CE 182) that the EUROCONTROL Agency will oversee the development of a specimen AIC to explain the needs of IIMSES. In addition, it is envisaged that work will proceed towards initiating an amendment to the Doc 7030 requirements for the carriage and operation of Mode S transponders.

The following information is considered relevant:

- Validation of the IIMSES operational concept to be completed by the end of 2000\*.
- First limited operational use of IIMSES from 2001\* Therefore, 1 Jan 2001 could be considered as the IIMSES Operational Date (O-Date).
- A contiguous volume of airspace, within which ATS employment of Mode S Enhanced Surveillance is feasible, should be available from 2003\* onwards [O-Date +2(years)].
- Operational accomplishment of IIMSES requires Mode S transponder carriage and operation at Level 2 capability (3.3.1, last paragraph).
- Operational use of IIMSES requires the extraction and downlink of aircraft parameters as specified in 3.3.1.a. and 3.3.1.b.
- Specimen AIC on the Airborne Collision Avoidance System (ACAS) issued by the Agency on 21 Dec 95 to the EATCHIP Liaison Officers. This implies the installation of Mode S transponders of at least level 2 capability in designated aircraft from 1 Jan 2000 and from 1 Jan 2005 (Full schedule reproduced in 4.5.1).

\* Mode S CONOPS, 1.3.2, last paragraph and Annex B, IIMSES Business Plan Work Structure.

##### 4.1.3.1 **Airborne Equipment Carriage Recommendations**

It is recommended that the EUROCONTROL Specimen AIC, in amplification of Mode S airborne equipment carriage and operation in the EUR Region, should include requirements for IIMSES as proposed in (i) to (iv) below, together with the guidance contained in the accompanying notes 1 and 2.

- (i) For IFR Flight, in the airspace designated by the appropriate ATS authority, a level 2 Mode S transponder as a minimum, together with a DAP capability (Basic and Enhanced Surveillance Functionality),

required by new aircraft on O-Date(□) and by all aircraft on O-Date +2(years).

- (ii) For VFR Flight, existing provisions of Doc 7030 apply, subject to installation timescales relevant to IIMSES requirements together with a DAP capability (Basic Functionality), from O-Date +2(years) onwards.
- (iii) Specific requirements relating to State aircraft to remain the sovereign responsibility of the States concerned.
- (iv) Provisions for the granting of exemptions, harmonised on a Regional basis(□).

Note 1. DAP capability; Basic Functionality and Enhanced Surveillance Functionality as specified in 3.3.1a and 3.3.1b.

ICAO Doc 7030 currently refers to Level 3/4 transponders for IFR flight. Whilst the operational concept for IIMSES does not warrant this level of Mode S data communications capability, the AIC should highlight the intention to extend the degree of ground and airborne capability in the future. Therefore, it may well be in the interests of Airline Operators, economically, to equip initially to the higher standard.

Additionally, due to the technical link between ACAS and Mode S Enhanced Surveillance, it may also be in the interests of Airline Operators to install the necessary equipment at an earlier stage.

Note 2. In developing the AIC, due account should be taken of Mode S CONOPS, Sections 4.2, 4.3, 4.4, concerning Transition Guidelines, Exemption Arrangements and Civil-Military Interoperability.

Additionally, it is recommended that the Specimen AIC contains a full technical description of the DAPs required for Mode S Enhanced Surveillance.

## 4.2 Transition Guidelines

The phased implementation of Mode S will be achieved over a period of time and will necessitate the development of a comprehensive transition plan. This is required for essential management throughout the period to maintain operational effectiveness and to accommodate varying degrees of aircraft equipment compliance according to platform capability. It is estimated that by the IIMSES Operational Date some 20% of the aircraft customers will be compliant to Enhanced Surveillance capability. As Mode S is progressively introduced within the EUR Region, the degree of benefit will increase correspondingly, together with a reduction in the need to accommodate non-Mode S equipped elements. Equally, the expected benefits of the use of airborne parameters will increase with the number of capable aircraft. However, throughout the transition period, planning and execution shall be consistent with the principles set out below.

## 4.2.1 Operational Principles

- 4.2.1.1 The ability to assimilate mixed Mode S and classical transponder equipped aircraft within the initial area of Mode S operations and adjacent airspace will be supported by harmonised arrangements. These arrangements will ensure the provision of surveillance services to categories of aircraft which are exempt or partially exempt from the Mode S airborne equipment carriage requirements. At the end of the transition phase the level of service to those exempted aircraft may differ from that provided to aircraft which comply fully with Mode S airborne equipment carriage requirements.
- 4.2.1.2 Procedures are to be developed that maintain interoperability between Mode S equipped ground stations and those which are not. These will be particularly important to accommodate the needs of airfields and other airspace user interests within the developing Mode S structure. Furthermore, the procedures must ensure that safe and effective coordination can take place between the control agencies concerned.
- 4.2.1.3 A systematic re-allocation and notification of Mode 3/A codes in accordance with a pre-planned Mode S/ORCAM rationalisation scheme will be implemented in accordance with agreed transitional arrangements.
- 4.2.1.4 Transition planning must be made which has as an objective the earliest possible realisation of Mode S derived benefits to suitably equipped users, whilst at the same time avoiding the possibility of increased controller and aircrew workload, particularly with regard to Mode 3/A code changes. Furthermore, the planning must ensure that no ATS provider is disadvantaged by these transitional arrangements.

## 4.2.2 Continued Use of Mode 3/A Codes

Principles for the continued use of Mode 3/A codes, once IIMSES has been established in the Core area, are as follows:

- (i) Flights which are contained wholly within an IIMSES ATM service may be required to display a Mode S Conspicuity Code(□) provided that the State(s) concerned can ensure interoperability between Mode S and non-Mode S users.
- (ii) Flights which are not contained wholly within an IIMSES ATM service shall display a Mode 3/A code assigned in accordance with the provisions of the EUR Region SSR Code Allotment Plan.

Correlation of surveillance data with system flight plan activation is necessary and requires to be addressed(□). It should be noted that expansion of Mode

S airspace, in the future, could lead to modifications to the continued use of Mode 3/A codes.

Note 1 A Mode 3/A Special Purpose Code is to be defined by the ORCAM Users Group for the purpose of conspicuity in Mode S radar coverage.

Note 2 It is recommended that work in this area is undertaken within the DPS Requirements delegated by the SURT to the ODT (Annex B, IIMSES Business Plan Work Structure).

## **4.3 Exemption Arrangements**

### **4.3.1 Application Policy**

With respect to the carriage and operation of Mode S transponders, ICAO Doc 7030 calls for the application and extent of exemptions, in the interests of harmonisation, to be coordinated on a regional basis. This is particularly important during the phased introduction of IIMSES and should form an essential element in the development of the EUROCONTROL Specimen AIC.

### **4.3.2 Application Principles**

The granting of dispensations and exemptions from SSR transponder carriage and operation is a sovereign state responsibility. However, in order to satisfy the Doc 7030 coordination requirements, states should endeavour to comply with the exemption application principles set out below, subject to specific flight safety considerations and any significant penalty which might otherwise be incurred.

Additionally, State authorities should make every effort, within the airspace under their jurisdiction, to accommodate, in that airspace, aircraft which have been granted an exemption by another State participating in the IIMSES programme.

#### **4.3.2.1 Exemptions may be granted for VFR flights conducted by aircraft:**

already equipped with non-Mode S transponders having Mode A 4096 code capability and Mode C altitude reporting,

or, when the carriage of a transponder is impracticable,

or, when an exception to the requirement is authorised for a specific purpose.

#### **4.3.2.2 Exemptions should be granted to the operators of older aircraft where airframe life remaining is shown to be less than 3 years from O-Date +2.**

#### **4.3.2.3 Exemptions should be granted for IFR flights conducted by State (military) aircraft required to occasionally(□) operate as GAT, subject to the availability of a Mode 3/A transponder with 4096 code capability and Mode C altitude**

reporting. This concession should also apply, in the same circumstances, to State (military) aircraft equipped with a Mode S transponder but without the capability to downlink the full set of prescribed DAPs.

Note 1 In this context 'occasionally' is taken to mean an average total flying time of 30 hours annually in the airspace subject to the mandatory carriage and operation of Mode S transponders.

4.3.2.4 Aircraft operators who are granted exemptions should be advised that it will not be possible to provide the same level of ATM service as that applied to aircraft which comply with the Mode S transponder carriage and operation requirements.

4.3.2.5 Aircraft operators who are granted exemptions should be advised that the policy pertaining to exemptions will be subject to periodical review and, in the first instance, should be for a period not exceeding 3 years.

### **4.3.3 Partial Compliance for Older Aircraft**

Operators of older aircraft which are equipped with Mode S transponders but where the avionics do not permit the extraction and transmission of the full set of prescribed DAPs, should be granted ATS to the maximum extent possible without penalty. However, this dispensation should be subject to review as in 4.3.2.5, above.

## **4.4 Civil-Military Interoperability**

There are several levels of civil/military interoperability. The highest level of interoperability are those jointly shared ATC facilities wherein civil and military personnel employ a commonly derived air picture using shared primary and secondary radar equipment. At the opposite end of the spectrum are fixed civil and military facilities and mobile air, land and sea based military facilities without direct landline communications, and that share a common surveillance area. They must adhere to strict interrogation protocols to effect independent maintenance of a comprehensive air picture for civil and air defence use respectively.

### **4.4.1 Operational Principles**

The employment of Mode S following the introduction of IIMSES shall be in compliance with coordinated and agreed civil and military procedures and regulations.

Civil and military authorities have varying requirements for, and applications of, SSR information. Common to both is safety. In addition to the well known problem of sharing the same frequency bands, the method of usage of the limited number of II codes to support civil and military operations following IIMSES introduction has still to be jointly determined within the programme



system engineering design. It is essential that II code allocation principles are developed to ensure that flight safety is not compromised while maintaining the AD RAP commensurate with NATO Alliance and individual national defence requirements. Options for Mode S active interrogation data acquisition by the military are as follows:

- **Zero II code** (with restricted use of lockout)- for all types of interrogators using;
  - stochastic lockout override, or,
  - optimum procedure to minimise FRUIT.
- **Geographically permitted non-zero II code** - allocated in cooperation with civil authorities for military fixed interrogators.
- **Military reserved non-zero II code** - for all types of interrogators.
- **Shared II codes** - subject to civil/military agreed conditions on use.
- **SI codes** - if and when these become available.

#### 4.4.2 Specific IIMSES Military II Code Requirement

Further work within ICAO may in the future result in an expanded set of interrogator codes in the form of Surveillance Identifier (SI) codes (Annex A, paragraph 1.4). Nevertheless, to accommodate, in IIMSES, specific military requirements as set out in 2.4.2, it is recommended that one non-zero II code, under NATO operational management, be reserved exclusively for military purposes.

### 4.5 Airborne Collision Avoidance Systems

Airborne Collision and Avoidance Systems (ACAS) SARPS were adopted by ICAO in 1995. However, since December 1993, the Traffic Alert and Collision Avoidance System (TCAS II), which is currently not compliant with these SARPS, has been mandated for use in US airspace by aircraft of more than 30 passenger seats. Consequently, evaluation of TCAS II operations has been ongoing in European airspace over a number of years. These systems, which imply the use of a Mode S transponder of at least level 2 capability, interrogate the SSR transponders of other aircraft. They process the information received to provide, where appropriate, collision avoidance advice in the vertical plane of traffic in the vicinity of ACAS equipped aircraft.

#### 4.5.1 European ACAS Policy and Implementation Schedule

European ACAS policy is to require the mandatory carriage and operation of an ACAS conforming to ICAO SARPS in the airspace of ECAC member States. An implementation schedule has been adopted, in principle, as follows;

- (i) with effect from 1 January 2000, all civil fixed-wing turbine-engine aircraft having a maximum take-off mass exceeding 15,000 kg or maximum approved passenger seating configuration of more than 30 will be required to be equipped with ACAS II, and,
- (ii) with effect from 1 January 2005, all civil fixed-wing turbine engine aircraft having a maximum take-off mass exceeding 5,700 kg or maximum approved seating configuration of more than 19 will be required to be equipped with ACAS II.

However, aircraft operators are encouraged to equip with ACAS II compatible equipment as soon as possible.

#### **4.5.2 Mode S/ACAS Inter-relationship**

ACAS has the potential to affect 1030/1090 MHz frequency band utilisation. Common characteristics between Mode S and ACAS are:

- The receipt of Mode S squitter transmissions.
- Interrogation of Mode S air-to-air formats.
- ACAS to ACAS coordination via Mode S air-to-air datalink.

## 5. RECOMMENDATIONS

For ease of reference, recommendations included in Mode S CONOPS are indicated by the relevant paragraph headings and reproduced below.

### 5.1 Downlink Aircraft Parameters Required for IIMSES

#### Paragraph 3.3.1

The following downlink aircraft parameters are recommended as requirements for the operational use of IIMSES:

#### a. Basic Functionality

Automatic Reporting of Flight Identity (callsign used in flight)  
Transponder Capability Report  
Altitude Reporting in 25ft intervals (subject to aircraft capability)

Note Use of Flight Status (airborne/on the ground) is also envisaged; initially as a requirement for ACAS/TCAS and, in the future, for its association with system applications beyond the current IIMSES programme. This parameter is a standard feature in Mode S replies.

#### b. Enhanced Surveillance Functionality

Magnetic Heading  
Speed (IAS / TAS / Mach No)  
Roll Angle  
Track Angle Rate  
Vertical Rate (barometric rate of climb/descend or, preferably baro-inertial)  
True Track Angle / Ground Speed (track initialisation only)

#### Paragraph 3.3.2

The following selected aircraft parameters are recommended to be included for future consideration in respect to the envisaged expansion of Mode S services in Europe:

Selected Flight Level / Altitude.  
Selected Magnetic Heading.  
Selected Course.  
Selected IAS / Mach No.

### 5.2 Airborne Equipment Carriage

#### Paragraph 4.1.3.1

It is recommended that the EUROCONTROL Specimen AIC, in amplification of Mode S airborne equipment carriage and operation in the EUR Region, should include requirements for IIMSES as follows:

- (i) For IFR Flight, in the airspace designated by the appropriate ATS authority, a level 2 Mode S transponder as a minimum, together with a DAP capability (Basic and Enhanced Surveillance Functionality),

required by new aircraft on O-Date(□) (*O-Date, currently 1 January 2001*) and by all aircraft on O-Date +2(years).

- (ii) For VFR Flight, existing provisions of Doc 7030 apply, subject to installation timescales relevant to IIMSES requirements together with a DAP capability (Basic Functionality), from O-Date +2(years) onwards.
- (iii) Specific requirements relating to State aircraft to remain the sovereign responsibility of the States concerned.
- (iv) Provisions for the granting of exemptions, harmonised on a Regional basis(□).

Note 1. DAP capability; Basic Functionality and Enhanced Surveillance Functionality as specified in 3.3.1a and 3.3.1b.

ICAO Doc 7030 currently refers to Level 3/4 transponders for IFR flight. Whilst the operational concept for IIMSES does not warrant this level of Mode S data communications capability, the AIC should highlight the intention to extend the degree of ground and airborne capability in the future. Therefore, it may well be in the interests of Airline Operators, economically, to equip initially to the higher standard.

Additionally, due to the technical link between ACAS and Mode S Enhanced Surveillance, it may also be in the interests of Airline Operators to install the necessary equipment at an earlier stage.

Note 2. In developing the AIC, due account should be taken of Mode S CONOPS, Sections 4.2, 4.3, 4.4, concerning Transition Guidelines, Exemption Arrangements and Civil-Military Interoperability.

Additionally, it is recommended that the Specimen AIC contains a full technical description of the DAPs required for Mode S Enhanced Surveillance.

### **5.3 Continued Use of Mode 3/A Codes**

#### Paragraph 4.2.2

Correlation of surveillance data with system flight plan activation is necessary and requires to be addressed. It is recommended that work in this area is undertaken within the DPS Requirements delegated by the SURT to the ODT (Annex B, IIMSES Business Plan Working Structure).

### **5.4 Specific Military II Code Requirement**

#### Paragraph 4.4.2

It is recommended that one non-zero II code, under NATO operational management, be reserved exclusively for military purposes.

## Annex A IIMSES System Overview

### 1 FUNCTION OF MODE S

- 1.1 Mode S, SSR Mode Select, is a co-operative surveillance and communication system for ATC. It employs ground-based interrogators and airborne transponders. Ground-air-ground datalink communications can be accommodated integrally with surveillance interrogations and replies. Mode S has been designed as an evolutionary improvement to the existing SSR system operating in Modes 3/A and C to provide the necessary improved surveillance and communication capability required for air traffic automation. To facilitate the introduction of Mode S into the existing SSR system, both ground and airborne Mode S installations will be fully backwards compatible. Mode S interrogators will provide surveillance of aircraft equipped with Mode S and Mode 3/A/C transponders. Mode S transponders will reply to existing SSR and Mode S interrogations. In addition, the datalink potential of Mode S permits the employment of transponders for a number of ATC and aircraft separation assurance functions (ACAS, TCAS, ADS/B).
- 1.2 The monopulse technique used in Mode S surveillance allows improved position determination of SSR targets while reducing the number of required interrogations. This reduction of SSR interrogations and replies is greatly beneficial to the radio frequency (RF) interference environment.
- 1.3 A principal feature of Mode S that differs from existing SSR systems is that each aircraft is assigned an individual 24-bit Aircraft Address. Using this unique address, interrogations can be directed selectively to a particular aircraft and replies unambiguously identified. Channel interference is minimised because a sensor can limit its interrogations to targets of interest. In addition, by proper timing of interrogations, replies from closely spaced aircraft can be received without mutual interference. The unique address in each interrogation and reply also permits the inclusion of datalink messages to or from a particular aircraft.
- 1.4 Another key factor of the system is the limited number of Interrogator Identifier (II) codes, 15 for operational use, which by system design is to allow unambiguous data exchange between ground unit and aircraft and to reduce the problems of fruiting and over interrogation. After acquisition of the aircraft address, lock out protocols suppress transponder replies to certain interrogations of a ground unit. Additional Surveillance Identifier (SI) codes are foreseen to overcome the II code shortage limitations and could come about as a result of the current work being undertaken in the SICAS Panel of ICAO. Interrogation units that do not need to use the multisite communications protocols could be supported by these 'surveillance only' identifier codes.
- 1.5 As the introduction of Mode S in Europe is being planned as an evolutionary process, 'Enhanced Surveillance' is one step towards fulfilment of the Mode S subnetwork and later incorporation within the Aeronautical Telecommunications Network (ATN). Figure A-1 depicts the phased evolution of Mode S implementation).

- 1.6 IIMSES is effected by the use of a transponder with a downlink aircraft parameter capability in the aircraft, or alternatively by an Airborne Data Link Processor (ADLP), together with additional data processing capability in the ground equipment. The term Enhanced Surveillance applies to the use of certain datalink protocols such as Ground Initiated Comm-B (GICB) to extract aircraft derived data (e.g. state vector or aircraft inertial data) for use in surveillance related applications. This early use of datalink would require a small subset of the functionality of Mode S.

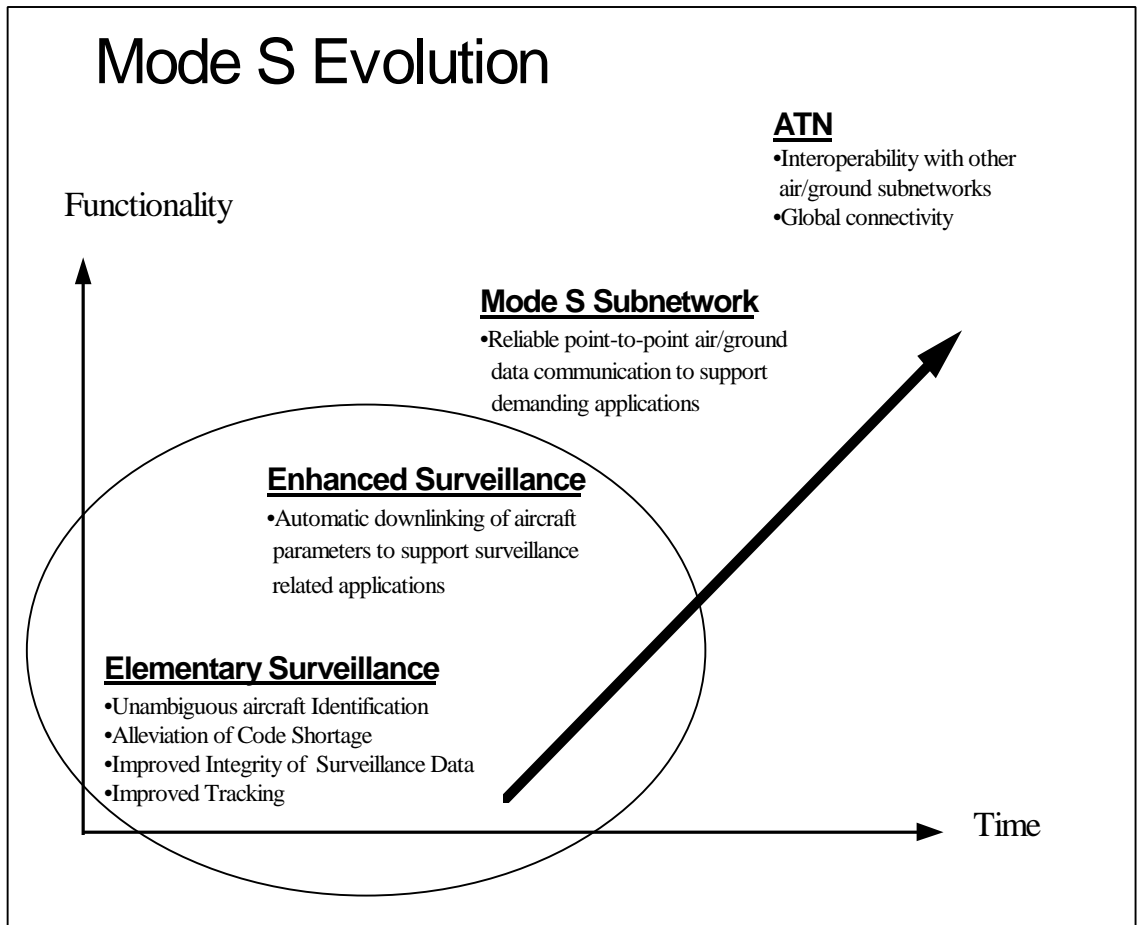
## **2. MAJOR OPERATING CHARACTERISTICS**

- 2.1 In order to facilitate a smooth transition from existing SSR systems, Mode S uses the same frequencies for interrogations and replies as currently employed for IFF/SSR (1030 and 1090 MHz respectively). The Mode S waveforms (modulation techniques) have been chosen to reduce interference between current SSR systems and Mode S. The Mode S interrogation is transmitted using binary Differential Phase Shift Keying (DPSK). The modulation of the downlink transmission from the transponder is Pulse Position Modulation (PPM). The information content of both uplink and downlink transmissions is further protected by parity check bits generated by a cyclic coding algorithm.
- 2.2 Each selective Mode S interrogation contains the unique 24-bit Aircraft Address which will accommodate traffic growth in the ATC environment without occurrence of a duplicate aircraft address.

## **3. SYSTEM PERFORMANCE**

- 3.1 The Mode S interrogator provides surveillance of all Mode 3/A/C and Mode S equipped aircraft within line-of-sight coverage. The nominal maximum range is 256 NM. The Mode S interrogators can provide surveillance of a large number of aircraft with better accuracy than current SSR systems. With the capability to interrogate a target within one interrogation cycle, the overall surveillance reliability of Mode S will be at least 99 percent.
- 3.2 In addition to surveillance, Mode S can provide ground-to air, air-to-ground and air-to-air data communications. The critical nature of many of the messages carried by the Mode S datalink medium will require a high degree of message integrity. Error detecting codes in both interrogations and a limited error correcting ability in replies are designed to ensure the necessary quality of data transmissions.

/Figure A-1 Mode S Evolution



**Figure A-1**

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## **Annex B IIMSES Business Plan Working Structure**

**EATCHIP PLANNING DIVISION**

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## Annex C ICAO Regional Supplementary Procedures

### Extract from ICAO Doc. 7030 Regional Supplementary Procedures, EUR/RAC Part 1, Paragraph 7.

#### 7.5 Carriage and Operation of Mode S Transponders

7.5.1 With effect from 1 January 1999 the carriage and operation of Mode S transponders shall be mandatory for all IFR flights in the ICAO European Air Navigation Region in accordance with the following requirements:

a) for IFR flights conducted with aircraft capable of automatic provision of projected flight path information by means of appropriate flight management system and data communications systems;

- Level 4 transponder with 16 linked segment downlink extended message (ELM) capability

*Note* The full exploitation of Level 4 transponders and associated flight management systems is specified for the Future European Air Traffic Management System (FEATS) for implementation towards the turn of the century.

b) for IFR flights conducted with all other aircraft;

- Level 3 transponder as a minimum

c) Mode S equipped aircraft shall report automatically aircraft identification (call sign used in flight):

*Note 1* The aircraft identification required above is not provided by the 24-bit aircraft address.

*Note 2* Level 1 transponders are not prescribed for use in the European Region.

d) Mode S equipped aircraft with a maximum mass in excess of 5,700 kg or a maximum cruising true airspeed in excess of 324 km/h (176 kt) shall operate with antenna diversity.

7.5.2 With effect from 1 January 1999 the carriage and operation of Mode S transponders shall be mandatory for all VFR flights in the ICAO European Air Navigation Region in accordance with the following requirements\*:

a) For VFR flights conducted in Class B and C airspace

b) for VFR flights conducted in defined portions of Class D, E, F and G airspace, where the carriage and operation of SSR transponders has been prescribed by the appropriate ATS authority.

\* Level 2 transponder as a minimum

Note 1      *This requirement is intended to ensure the widespread installation of Mode S transponders with Level 2 capabilities in preference to Mode A/C transponders, in order to meet the requirements for air traffic management.*

Note 2      *Exemptions from these requirements may be granted by the appropriate ATS authority for VFR flights conducted by aircraft already equipped with non-Mode S transponders having Mode A 4096 code capability and Mode C Altitude Reporting, or when the carriage of a transponder is impracticable, or when an exception to the requirement is authorised for a specific purpose.*

*In the interests of harmonisation, the application and extent of exemptions should be coordinated on a regional basis.*

Note 3      *The provisions of paragraph 7.5.1, c) and d) also apply to VFR flights.*

## Annex D NATO Appraisal

### Military Implications of Mode S Implementation

*(Although prepared by NATO this appraisal may well be applicable to all national military authorities within the scope of European Mode S implementation)*

#### 1 OPERATIONAL CONSIDERATIONS

- 1.1 Mode S does not meet NATO military requirements for a military IFF system in that it is neither secure nor jam resistant. However, it is recognised that military carriage of Mode S airborne equipment will facilitate access to the civil air traffic system, enhance air safety and will support Air Defence (AD) in the compilation of the Recognised Air Picture (RAP).
- 1.2 Military ATC and AD control agencies, as well as civil ATM/ATC agencies, currently rely on the use of dedicated Mode 3/A and Mode C interrogations to provide real-time surveillance data on both civil and military air traffic. This data is used by military and civil controllers to identify the agency providing control of air traffic and is an essential tool in the determination of actions between the control agencies involved. With the introduction of Mode S, new agreements and procedures have to be established to continue safe air operations/air traffic services.
- 1.3 The current availability of only 15 interrogator identifier (II) codes to access the Mode S data is the driving factor for a strict and enforced coordination of interrogation and may limit the number of interrogators deployed in a certain area or the actual level of interrogator activity. In the longer term, possible expansion of the II code sets would significantly reduce the need for complex coordination arrangements between civil and military authorities. Hastening continuation of this, and related extended squitter, work within the SICASP by states would lead to early consideration by ICAO to approve additional SARPS both for expanded II code sets and extended squitter formats.
- 1.4 Under normal circumstances, static military ATC/AD units should receive all required Mode S information in a timely manner from civil stations or networks. In the event of required information not being available from civil sources, Mode S interrogation from military stations may be necessary. In these circumstances, it will be essential for strict and agreed protocols and procedures to have been defined between the state authorities concerned, taking account of the local situation and limitations placed on electromagnetic interference.
- 1.5 Sea-based mobile military systems, most frequently associated with aviation capable and/or AD ships, will not have direct access to the civil data network. Ship-shore-ship data links will have the ability to pass the RAP as compiled by the land-based facilities when within data communication link reception range. It is envisaged that active Mode S interrogations by maritime units operating within interference range of civil ATS units will be infrequent. When active Mode S interrogation by maritime units is required, however, it will be conducted in accordance with agreed regional procedures and protocols.
- 1.6 Depending on the degree of data exchange between military and civil agencies/organisations, the Mode S data gained through military systems can be made available to civil users via the data communication networks.

- 1.7 Airborne military systems, including sea-based airborne early warning (AEW), fixed and rotary wing aircraft, operate under many of the constraints reflected in sea-based systems. AEW systems operating with fixed land-based systems normally function as an extended detection platform of the ground facility with which they are working. As such, they will actively interrogate in Mode S only when directed by their controlling facility, following coordination with civil authorities. AEW platforms operating in support of maritime forces will only interrogate in Mode S when directed to by their controlling authority, in coordination with the appropriate civil and/or military ATS authorities. However, it is recommended that ACAS-type air-to-air formats should be applied in preference to ground-to-air interrogation formats.

## 2 OPERATIONAL REQUIREMENTS

- 2.1 Military tactical and transport (fixed and rotary wing) aircraft require unrestricted access to airspace for operational employment, training, and deployment (transit) to operational and training areas. Military aircraft must be able to integrate fully into the Mode S environment when operational requirements demand that the mission:
- originates in a non-Mode S environment and then enters a Mode S environment for normal ATM service;
  - departs a Mode S environment and terminates outside of the ATC system;
  - departs a Mode S environment for mission requirements and then re-enters the ATC system for mission completion and flight termination.
- 2.2 Military aircraft must be able to operate freely within the confines of a military operating area embedded within the Mode S environment without detriment to civil air traffic operation. Procedures and equipment must be capable of providing essential information to both civil and military aircrew and controllers without compromising safety, efficient air traffic flow, or the value of the military training or operation being conducted in adjacent areas. It is recognised that whilst one of the essential functions of civil ATC is to ensure the prescribed separation minima are effected between aircraft, it is an inherent fact of many military air operations (e.g. air-to-air refuelling (AAR), multi-aircraft rendezvous for formation flight, air interceptor control for aircrew and controllers, etc.) that military aircraft must operate in close proximity. Additionally, during certain military training and operational manoeuvres, such as air intercept training, it is essential that neither participating aircrew is given artificial cueing of where the 'opposing' aircraft is located other than the information provided by the intercept controller or through own aircraft sensors.
- 2.3 The current practice of military aircraft flying in close formation within the ATS system will remain unchanged.
- 2.4 Since the Mode S system is not designed to operate in a jamming (hostile electromagnetic interference) environment, a separate, independent military IFF system or Mode will be utilised by military authorities, if necessary, to meet military operational requirements for jam-resistance and security. Recent changes in the world order have meant that a crisis or war situation, whereby civilian air traffic would significantly decrease or cease altogether, is unlikely. Instead, the possibility has increased of military involvement in 'out of area' conflicts whereby ATC Mode S and military IFF systems would operate in parallel. Therefore the ability to disable

selected Mode S functions, dependent on the operational situation, is a military requirement.

- 2.5 The use of one permanent ICAO 24-bit aircraft address allocated to a military aircraft could inadvertently compromise the order of battle. As a minimum, selectable address codes will be required for military aircraft. A block of aircraft address codes needs to be allocated for military use. Nations and multinational forces need to request certain blocks to be used for their respective aircraft. The management and control of these addresses will be the responsibility of the nations/forces who must ensure that duplicate aircraft addresses are never assigned to aircraft airborne at the same time.
- 2.6 Military air defence authorities require real time access to Mode S transponder response information as a contribution to the compilation of the AD RAP.
- 2.6.1 Military AD, ATC and air surveillance facilities must have a Mode S interrogation capability. Such interrogations will only be conducted in accordance with strict protocols and procedures. There is, therefore, a requirement for integration of several classes of military interrogators comprising:
- Fixed long range interrogators; all fixed sites with a range of greater than 110 nm.
  - Fixed short range interrogators; all these sites have a maximum RF range of less than 110 nm.
  - Deployable interrogators; these would have fixed positions but would be designed to be transported to a new site if required.
  - Mobile interrogators; these comprise ship-based helicopter-based and AEW platforms.
- 2.6.2 Military aircraft operating within the auspices of civil ATS may have a requirement to mask certain elements of downlink aircraft information such as maximum speed, place of origin, destination etc., for security reasons. The necessity for non-activation/deselection will depend on the actual level of functionality fitted to military platforms to meet civil Mode S airborne equipment requirements.

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## Annex E Bibliography

- Mode S Civil/Military Task Force - Concept of Operations Mode S in Europe (Mode S CONOPS), Version 1.0, EUROCONTROL Document, dated 15 February 1995.
- EATCHIP Strategy for the Initial Implementation of Mode S Enhanced Surveillance in the Core Area; EUROCONTROL Document SUR.ET2-ST01.1000-REP-01-00, Edition 1.1, dated 1 July 1995.
- EATCHIP Operational Concept Document for the EATCHIP Phase III System Generation; EUROCONTROL Document OPR.ET1.ST02.1000-OCD-01-00, Edition 1.1, dated 28 June 1995.
- EATCHIP Pre-Operational European Mode S Station Functional Specification; SUR.ET2-ST03.3110-SPC-01-00, Edition 1.9, dated 23 November 1995.
- EATCHIP Transition Guidelines for Initial Air/Ground Data Communications Services; OPR.ET1.ST05.1000-Gui-01-00, Edition 1.0, dated 13 July 1995.
- EUROCONTROL Aeronautical Information Circular - Harmonisation of Regulations Governing Airborne SSR Equipment; AIC/5, dated 15 November 1989.
- ICAO Secondary Surveillance Radar Mode S Advisory Circular; 174-AN/110, 1983
- ICAO Annex 10 to the Convention on Civil Aviation - Aeronautical Telecommunications (Volume 1).
- ICAO Doc 4444 - Rules of the Air and Air Traffic Services.
- ICAO Manual on Mode S Specific Services
- NATO Military Committee, IMSM-KEC-382.95, dated 16 October 1995, 'Official NATO Military Position on Mode S'.
- NATO Standardization Agreement (STANAG) 4193 - Technical Characteristics of IFF Mk XA and Mk XII Interrogators and Transponders, Part I, General Description of the System; Part III, IFF Installed System Characteristics.

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## Annex F Abbreviations

AAR	Air to Air Refuelling
ACAS	Airborne Collision Avoidance System
ACC	Area Control Centre
ACCS	(NATO) Air Command and Control System
AD	Air Defence
ADLP	Airborne Data Link Processor
ADS	Automatic Dependent Surveillance
AIC	Aeronautical Information Circular
AOR	Area of Responsibility
ARTAS	ATC Radar Tracker and Server
ASTERIX	All purpose Structured EUROCONTROL Radar Information Exchange
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATS	Air Traffic Services
AWACS	(NATO) Airborne Early Warning and Control system
CFMU	Central Flow Management Unit
CNS	Communications, Navigation and Surveillance
CONOPS	Concept of Operations
DAC	Deployable ACCS Component
DAP	Downlink Aircraft Parameter
DPSK	Differential Phase Shift Keying
EASIE	Enhanced ATM and Mode S Implementation in Europe
EATCHIP	European ATC Harmonisation and Integration Programme
EATMS	European Air Traffic Management System
ECAC	European Civil Aviation Conference
ECM	Electronic Countermeasures
ELM	Extended Length Message
FIC	Flight Information Centre
FPPS	Flight Plan Processing System
FRUIT	False Replies from Unsynchronised Interrogator Transmissions (NATO) Friendly Replies Unsynchronised in Time
GAT	General Air Traffic
GDLP	Ground Data Link Processor
GICB	Ground Initiated Comm B (Protocol)

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ICAO	International Civil Aviation Organisation
IFF	Identification Friend or Foe
IFR	Instrument Flight Rules
MATSE	Meeting (of ECAC Ministers) on the Air Traffic System in Europe
MHz	Megahertz
MNC	Major NATO Commander
MPA	Maritime Patrol Aircraft
MSAW	Minimum Safe Altitude Warning
NACMA	NATO ACCS Management Agency
NAEW	NATO Airborne Early Warning
NATO	North Atlantic Treaty Organisation
OAT	Operational Air Traffic
ODT	(EATCHIP) Operational Requirements and Data Processing Team
ODIAC	Operational Development of Initial Air/Ground Data Communications (Task Force)
OLDI	On-line Data Processing Interchange
ORCAM	Originating Region Code Assignment Method
PPM	Pulse Position Modulation
RADNET	Radar Data Network
RAP	Recognised Air Picture
RAPNET	Regional ATC Packet Switched Network
RDPS	Radar Data Processing System
RF	Radio Frequency
RPC	RAP Production Centre
RT	Radio Telephony
SARPS	(ICAO) Standards and Recommended Practices
SICASP	(ICAO) SSR Improvements and Collision Avoidance Systems Panel
SSR	Secondary Surveillance Radar
STANAG	(NATO) Standardisation Agreement
STCA	Short Term Conflict Alert
SURT	(EATCHIP) Surveillance Team
SYSCO	System Supported Coordination
TCAS	Traffic Alert and Collision Avoidance System
VFR	Visual Flight Rules
VHF	Very High Frequency