## LEAFLET NO 13 Revision 1: Certification of Mode S Transponder Systems for Elementary Surveillance

### 1 PREAMBLE

This Interim Guidance material is issued in response to the revision of ICAO Regional Supplementary Procedures, Doc 7030 /4-EUR, Part 1, Rules of the Air, Air Traffic Services and Search and Rescue, concerning the use of Mode S Secondary Surveillance Radar. Operational use of Mode S with *basic functionality* is to be introduced for *elementary surveillance* in designated European airspace in accordance with a transition plan starting from 31 March 2003.

Revision 1 of this guidance material takes account of Amendment 77 to ICAO Annex 10 Volumes III and IV, July 2002.

### 2 PURPOSE

This guidance material has been prepared for the installation and certification of Mode S Secondary Surveillance Radar for elementary surveillance.

The guidance material does not constitute a regulation but does establish an acceptable means that can be used to obtain airworthiness approval of Mode S systems. An applicant may elect to use an alternative means of compliance. However, that means of compliance must meet the objectives of this guidance material and be acceptable to the responsible authority. Compliance with this guidance material is not mandatory hence use of the terms *shall* and *must* apply only to an applicant who elects to comply with this guidance material as the means to obtain airworthiness approval.

The units of measurement used in this document are in accordance with the International System of Units (SI) specified in Annex 5 to the Convention on International Civil Aviation. Non-SI units are shown in parentheses following the base units. Where two sets of units are quoted, it should not be assumed that the pairs of values are equal and interchangeable. It may be inferred, however, that an equivalent level of safety is achieved when either set of units is used exclusively.

Note: This interim guidance may be amended periodically and will be replaced by the appropriate JAR Requirements and Interpretative Material.

### 3 SCOPE

This guidance material addresses only the use of the Mode S transponder system for elementary surveillance in conjunction with interrogating ground stations. It does not deal with down-linking of aircraft derived data for enhanced surveillance, automatic dependent surveillance, the use of the transponder as a data link component of the Aeronautical Telecommunication Network (ATN), or security aspects relating to unlawful interference with aircraft operation.

### 4 REFERENCE MATERIAL

4.1 JAA

a) JTSO-2C112a**,** Minimum Operational Performance Specification for SSR Mode S Transponders. (Based on EUROCAE ED-73A).

Note: 1. This JTSO is being updated to version B based on EUROCAE document ED-73B.
2. The standard of transponder defined by FAA TSO C112, 1986, (Based on RTCA DO-

181) does not provide the full functionality required for the European Region.

b) JAR OPS 1 and 3: Change 1: 1.845, 1.860 and 1.865 and associated AMCs

c) JAA Temporary Guidance Leaflet No. 6 Revision 1, Guidance Material for RVSM Operations.
Note: This material is applicable to the accuracy of altimetry systems used for altitude reporting in RVSM airspace.

d) JAA Temporary Guidance Leaflet No. 8 Revision 2, Certification Considerations for the Airborne Collision Avoidance System: ACAS II.

4.2 EUROCONTROL

a) "The Concept of Operations - Mode S in Europe", document SUR.ET2.ST02.1000-CNP-01-00, Edition 2, Nov 1996.

b) "Operational Hazard Assessment of Elementary and Enhanced Surveillance", document Mode-S /OHA/00, Edition 1.0, October 2001.

4.3 ICAO

a) ICAO Annex 10, Amd. 77, Aeronautical Communications (Digital Data Communication Systems), Volume III, July 2002.

b) ICAO Annex 10, Amd. 77, Aeronautical Communications (Surveillance Radar and Collision Avoidance Systems), Volume IV, July 2002

c) Manual of the Secondary Surveillance Radar System (SSR), Doc 9684, First Edition 1997.

d) Deleted.

e) PANS Rules of the Air and Air Traffic Services, Doc 4444-RAC/501.

f) Designator for Aircraft Operating Agencies, Aeronautical Authorities and Services, Doc 8585.

g) Regional Supplementary Procedures, Doc 7030 /4-EUR, Part 1, Rules of the Air, Air Traffic Services and Search and Rescue

4.4 EUROCAE

a) Minimum Operational Performance Specification for Secondary Surveillance Radar Mode S Transponders, ED-73B, January 2003.
Note: Version ED-73B takes account of Amd 77 to ICAO Annex 10.

b) Deleted.

c) Minimum Performance Specification for Airborne Altitude Measurement and Coding Systems, ED-26, March 1979.

d) Minimum Aviation System Performance Specification for CNS/ATM Recording Systems, ED-93, November 1998.

e) Minimum Operational Performance Specification for Mode S Specific Service Applications, ED-101, August 2000.

4.5 RTCA

a) Minimum Operational Performance Specification for Air Traffic Control Radar Beacon System/ Mode Select (ATCRBS/Mode S) Airborne Equipment, RTCA DO-181C: June 2001.

## 5 ASSUMPTIONS

Applicants should note that this guidance material is based on the following assumptions concerning the proposed use of aircraft derived data by the air traffic services:

a) Means are implemented, where appropriate, by the air traffic services to verify the validity of received data (e.g. as currently performed by means of the ICAO required controller-pilot verification procedure for the altitude report ).

b) A safety review will performed by EUROCONTROL to verify the level of integrity required for aircraft derived data prior to such data being used within the air traffic management system.

On this basis, for the purposes of system certification, failure conditions involving lost or erroneous aircraft derived data can be classified as 'Minor'.

## 6 SYSTEM DESCRIPTION

6.1 The transponder Level is defined by ICAO and identifies the communication protocol capabilities of the transponder.

Level 1 This is the basic transponder permitting surveillance based on Modes A and C as well as Mode S. With a Mode S aircraft address, it has the minimum features for compatible operation with the Mode S system. It has no data communication capability, is not prescribed for international flights, and does not satisfy the European requirement.

Level 2 has the capabilities as Level 1 but permits standard length digital communication from ground to air and air to ground using Comm A and Comm B protocols. It includes automatic aircraft identification reporting.

Level 3 has the capabilities as level 2 but permits extended data communications from the ground to the aircraft using the Comm C protocol. The usefulness of this standard of transponder has been largely overtaken by technological advances.

Level 4 has the capabilities as level 3 but permits extended data communications from the aircraft to the ground using the Comm D protocol.

Level 5 extends these protocols to permit Comm B and extended length and simultaneous data communications with multiple interrogators. This level of transponder has a higher minimum data communication capability than transponders of lower levels.

In addition to the above designations, the letters "e" and "s" are added to indicate that the transponder includes extended squitter functionality and surveillance interrogator (SI) code capability.

Basic functionality with SI code capability is the minimum level permitted for operations in European airspace hence the transponder required is designated ICAO Level 2s. (Amd 77 to ICAO Annex 10, Vol IV, paragraph 2.1.5.1.7).

6.2 The transponder Mark is assigned by ARINC/ EUROCAE and defines required equipment characteristics for the interface between the transponder and other aircraft systems. Equipment characteristics have the objective of standardising those aspects of equipment design which affect interchangeability between different brands.

Mark 3 corresponds to ARINC Characteristic 718.

Mark 4 corresponds to the AEEC draft ARINC Characteristic 718A. This standard of equipment includes extended interface functions which provide for the access of aircraft derived data necessary to fulfil the functions of automatic dependent surveillance - broadcast (ADS-B), extended (112 bit) squitter functions for passive surveillance, the surveillance capabilities specified in the ICAO Manual on Mode S Specific Services, and dedicated communication functions.

Notes: 1. The Mark 4 transponder does not support altitude data in Gillham's code format and is not backward compatible with the Mark 3 equipment.
2. Compliance with an ARINC Characteristic is not required for certification.

6.3 A detailed technical definition of the aircraft derived data is given in Amd 77 to ICAO Annex 10, Vol III, Part 1, Appendix 1 to Chapter 5, 'Tables for Section 2'. The data to be transmitted for the purposes of elementary surveillance are shown in Table 1 of Annex 1 to this guidance material.

6.4 Use of the dataflash function is not required for elementary surveillance.

6.5 Recording, on the aircraft accident recorders, of data exchanged exclusively for the purposes of Mode S elementary surveillance is not required.

## 7 AIRWORTHINESS CERTIFICATION OBJECTIVES

7.1 For the purposes of elementary surveillance, the installed transponder systems in the aircraft must be designed to deliver aircraft derived data that satisfy the characteristics and integrity targets given in Tables 1 and 2 of Annex 1 and which take account of ICAO Annex 10, Amendment 77, Volume III, Part 1, Appendix 1 to Chapter 5, 'Tables for Section 2'. The criticality classifications take account of the assumptions of Section 5, and correspond with the definitions of JAR 25.1309 and associated advisory material.

Notes: 1. In anticipation of increasing reliance by the air traffic services on automatic processing of data for safety nets (i.e. SAPS), and of future applications using aircraft derived data, the aircraft system should be designed such as to provide, so far as is practicable, data of high accuracy, high availability and high integrity.

2. For aircraft that require ACAS II, the Resolution Advisory discrete will need to be transmitted by the transponder (ICAO Annex 10, Volume IV).

7.2 For aircraft approved for RVSM operations, the performance of the altitude sensors and encoders must meet the standards given in JAA TGL No. 6.

7.3 When the pressure datum is set to 1013.25 hPa, the performance of the altitude sensor(s) must be such that the reported altitude corresponds to within plus or minus 38.1m (125ft) on a 95% probability basis with the displayed pressure altitude used by the flight crew to adhere to the assigned flight profiles. (ICAO Annex 10, Vol IV, 3.1.1.7.12.2.4. See also EUROCAE ED-26).

## 8 FUNCTIONAL CRITERIA

8.1 An ICAO 24 bit aircraft address must be assigned by the responsible authority in the state of registration and must be implemented in the aircraft.

8.2 Mode S equipped aircraft with a maximum mass in excess of 5700 kg or a maximum cruising true airspeed capability in excess of 463 km/h (250kt) must operate with transponder antenna diversity.

Note: For the purposes of certification, the decision to provide antenna diversity may be based on a calculation of maximum cruising true airspeed capability using the maximum normal operating values of permissible altitude and airspeed (i.e. $V_{NO}$, or $V_{MO}/M_{MO}$ as applicable) quoted in the Limitations section of the Aircraft Flight Manual. For example, if the AFM states a maximum operating altitude of 25,000ft and $V_{NO}$ of 170 knots, then the aircraft has an equivalent TAS capability of 250 knots in the ICAO Standard atmosphere. The calculation may be made using a pilot's TAS computer.

8.3 The peak pulse power of the transponder shall comply with Amendment 77 to ICAO Annex 10, Volume IV, 3.1.2.10.2. In particular, transponders in aircraft with a maximum cruising true airspeed in excess of 324 km/h (175kt) must operate with a peak transmitter power of not less than 21.0 dBW and not exceeding 27.0 dBW.

8.4 Physical locations of the transponder antennas and the ACAS antennas will need to satisfy isolation and longitudinal separation limits as defined by the installation instructions.

8.5 Where a suitable source is available, pressure altitude information must be obtained from a monitored air data sensor supplying pressure altitude information in either databus or synchro format and which is the most accurate source available on the aircraft. Ideally, this source should supply information (with appropriate segregation) to the pilots' flight deck altitude display(s).

Notes: 1. Either a databus or synchro source is the preferred altitude data interface as it avoids the altitude jump risk inherent in Gillham's format encoders. It also allows an ACAS interrogator, where installed, to process altitude data with a resolution of 25ft so reducing nuisance traffic alerts.

2. The altitude information should be supplied to an ACAS before it is quantitised for transponder altitude reporting purposes.

3. To satisfy the requirements for RVSM operations, the secondary surveillance radar transponder with its altitude reporting system will need to be connected to the altitude measurement system in use for altitude keeping. (See JAA TGL No. 6).

8.6 For aircraft equipped with ACAS II where the available source of pressure altitude information supplies information only in Gillham's code format, detection of an altitude source or encoder failure must be provided. This need can be satisfied by means of dual independent altitude corrected sensors together with an altitude data comparator (which may be incorporated and enabled in the transponder). Similar provision is needed also for alternative altitude information sources that do not signal erroneous data. Failure of altitude reporting information should be indicated to the flight crew.

Notes: 1. A Gillham's format encoder provides a resolution of 100ft.

2. Further guidance on altitude measurement and coding systems may be found in EUROCAE Minimum Performance Specification document ED-26.

3. For aircraft without ACAS II, detection of Gillham encoder failure, as described in this paragraph, is recommended.

8.7 The transponder must indicate correctly the altitude resolution (quantitisation) used, i.e. 100ft (Gillham's coded source) or 25ft (from an appropriate source). The conversion of Gillham's coded data to another format before inputting to the transponder is not permitted unless failure detection can be provided as discussed in paragraph 8.6, and the resolution (quantitisation) is set in the transmitted data to indicate 100ft.

8.8 If more than one transponder is installed, simultaneous operation of both transponders must be prevented.

## 9 ACCEPTABLE MEANS OF AIRWORTHINESS COMPLIANCE

9.1 For the immediate future, a single Mode S Transponder installation will meet the minimum requirements for elementary surveillance.

9.2 Subject to compliance with this guidance material, an acceptable certification standard for the Mode S Transponder is JTSO-2C112a. This standard of transponder includes the Surveillance Identifier (SI) codes functionality required by ICAO Annex 10 Amendment 77 to permit a reduction in the ground infrastructure complexity. (See also 8.3).

Note: JTSO-2C112a is based on EUROCAE document ED-73A, Minimum Operational Performance Specification for SSR Mode S transponders. This document has been superseded by version ED-73B to take full account of Amd 77 to ICAO Annex 10. The JTSO will be updated in due course.

9.3 In demonstrating compliance with this guidance material, the following specific points should be noted:

a) The applicant will need to submit, to the responsible authority, a compliance statement that shows how the criteria of this guidance material have been satisfied, together with evidence resulting from the activities described in the following paragraphs.

b) Compliance with the airworthiness requirements for intended function and safety may be demonstrated by equipment qualification, safety analysis of the interface between the transponder and data sources, structural analyses of new antenna installations, equipment cooling verification, and ground tests. To support the approval application, design data will need to be submitted showing that the objectives and criteria of Sections 7 and 8 of this guidance material have been satisfied.

c) The safety analysis of the interface between the transponder and its data sources should show no unwanted interaction under normal or fault conditions

9.4 On the assumption that the transponder installation has been shown to meet the existing criteria for Mode A, C and ACAS II, then the additional functionality introduced for elementary surveillance may be demonstrated by ground testing, using ramp test equipment where appropriate, that verifies:

- system operation;
- the ICAO 24 bit aircraft address in the transmitted response;
- the data in the transmitted response; and
- the functioning of system fault detectors.

9.5 To minimise the certification effort for transponder follow-on installations, the applicant may claim credit, from the responsible authority, for applicable certification and flight test data obtained from equivalent aircraft installations.

## 10 FLIGHT MANUAL

The Flight Manual is not affected when Mode S transponder elementary surveillance capability is provided in the aircraft.

Note: It may be necessary to delete redundant restrictions for Mode S transponders installed prior to the availability of certification criteria.

## 11 MINIMUM EQUIPMENT LIST

The MEL will need to indicate the mandatory carriage of a serviceable system to meet applicable operational requirements for flight in designated airspace. Despatch with partial unserviceability of the system or non-availability of some required aircraft derived data may be permitted in accordance with applicable exemption criteria.

## 12 MAINTENANCE

12.1 Maintenance testing of altitude reporting transponders should be suitably screened to minimise the risk of nuisance traffic or collision resolution advisories in operating aircraft.

12.2 Maintenance tests should include a periodic verification check of aircraft derived data including the ICAO 24 bit aircraft address using suitable ramp test equipment. The check of the aircraft address should be made also in the event of a change of state of registration of the aircraft.

12.3 Where possible, maintenance tests should check the correct functioning of system fault detectors.

12.4 Maintenance tests for encoding altitude sensors with Gillham's code output should be based on the transition points defined in EUROCAE ED-26, Table 13. (Included as Annex 2 to this guidance material).

## 13 CREW OPERATING INSTRUCTIONS

Crew Operating Instructions for the Mode S transponder should emphasise the need to use the ICAO defined format for entry of the Aircraft Identification or Registration mark as applicable to the flight. The shortened format commonly used by airlines (a format used by International Airlines Transport Association -IATA) is not compatible with the ground systems of the air traffic services.

## 14 AVAILABILITY OF DOCUMENTS

Copies of EUROCAE documents may be purchased from EUROCAE, 17 rue Hamelin, 75783 PARIS Cedex 16, France; Fax: 33 1 45 05 72 30 or web site: www.eurocae.org .

Copies of EUROCONTROL documents may be requested from EUROCONTROL, Documentation Centre, GS4, Rue de la Fusee, 96, B-1130 Brussels, Belgium; Fax: 32 2 729 9109 or web site www.eurocontrol.int.

FAA documents may be obtained from Department of Transportation, Subsequent Distribution Office SVC-121.23, Ardmore East Business Centre, 3341 Q 75th Avenue, Landover, MD 20785, USA. Web site www.faa.gov/aviation.htm.

Copies of ARINC documents may be obtained from Aeronautical radio Inc., 2551 Riva Road, Annapolis, Maryland 24101-7465, USA; Web site www.arinc.com.

Copies of RTCA documents may be obtained from RTCA Inc., 1140 Connecticut Avenue, N.W., Suite 1020, Washington, DC 20036-4001, USA; Tel: 1 202 833 9339 or web site www.rtca.org.

Copies of JAA documents are available from Information Handling Services (IHS). Information on prices, where and how to order is available on the JAA web site (www.jaa.nl) as well as on the IHS web sites www.global.ihs.com and www.avdataworks.com.

Copies of ICAO documents may be purchased from Document Sales Unit, International Civil Aviation Organisation, 999 University Street, Montreal, Quebec, Canada H3C 5H7, Fax: 1 514 954 6769, or e-mail: sales_unit@icao.org or through national agencies.

**Annex 1**

## Table 1: Required Characteristics of Aircraft Derived Data for Basic functionality

| Item | Parameter | Range | Minimum Resolution | Accuracy Limits | Maximum Data Age at Transmission | Remarks |
|---|---|---|---|---|---|---|
| 1 | Aircraft Identification | See Note 2 | - | - | See Note 3 | ICAO Annex 10, Vol IV, 3.1.2.9 |
| 2 | Capability Report | - | - | - | See Note 1,2,4 | ICAO Annex 10, Vol III, Part 1, Appendix to Chapter 5, 2.5.4, and Vol IV, 3.1.2.6.10.2 |
| 3 | Pressure Altitude | -1000 ft to maximum certificated altitude of aircraft plus 5000 ft | 100 ft (Gillham's code) or 25 ft as provided by the source. | As the installed sensor. See Notes 6 and 7 | 1 second | ICAO Annex 10, Vol IV, 3.1.2.6.5.4. Referenced to 1013.25 hPa. |
| 4 | Flight Status | Discretes See Notes 10 & 11 | - | | 1 second | ICAO Annex 10, Vol IV, 3.1.2.6.5.1 |

**Notes:**

1 The minimum parameter characteristics shown above are applicable to the data source and need to be maintained through any intermediate data processing systems until delivered to the transponder.

2 The objective of Aircraft Identification is that a parameter should be transmitted as specified in item 7 of the ICAO flight plan. This parameter should conform to the definition given in ICAO Doc. 4444 section 6 subparagraph 4.5.3.4 and ICAO Doc. 8585. If no flight plan has been filed, the aircraft registration, which may be pre-set, should be used. Direct recognition by the air traffic controller of the Aircraft Identification in a radar label provides verification of radar identity. This parameter is required in addition to the ICAO 24-bit aircraft address.

3 If the Aircraft Identification is changed during flight, the data to the transponder should be updated within 5 seconds.

4 Formatted data is held in BDS Registers (Comm-B Data Stores) for extraction when the ground station interrogates the Mode S transponder. The BDS format is defined in Amd 77 to ICAO Annex 10, Vol III, Part 1, Appendix to Chapter 5, 'Tables for Section 2'.

5 Where reference is made to "the installed sensor", this should be interpreted to mean either the primary system used to fly the aircraft or an approved system of equivalent performance.

6 The performance of the altitude sensor(s) will need to ensure that, when the pressure datum is set to 1013.25 hPa, the reported altitude corresponds to within plus or minus 38.1m (125ft) with the displayed pressure altitude used by the flight crew to adhere to the assigned flight profiles. (ICAO Annex 10, Vol IV, 3.1.1.7.12.2.4. See also EUROCAE ED-26).

7 For aircraft approved for RVSM operations, the accuracy of the altitude sensors and encoders will need to meet the standards given in JAA TGL No. 6.

8 For aircraft that require ACAS II, the Resolution Advisory discrete will need to be transmitted by the transponder (ICAO Annex 10, Volume IV).

9 Information on interface characteristics may be found in ICAO Annex 10, Vol IV, 3.1.2.10.5.

10 Provision of Flight Status may not be practical for helicopters with skids, or for aircraft with fixed landing gear, and the operator may request alleviation from this requirement.

11 Attention is directed to Amendment 77 to ICAO Annex 10, Volume III, Part 1, 3.1.2.6.1.4.1, for antenna selection during flight/ground transition.

12 The updating of the BDS registers containing Capability Report information (BDS 1.0 and 1.7) is defined in Amd 77 to ICAO Annex 10, Vol III, Part 1, Appendix to Chapter 5, Section 2.1, including paragraph 2.1.4.

## Table 2: Failure Condition Categories of Aircraft Derived Data for Basic Functionality Annex 1

1. With exception of the capability report, the Failure Condition categories listed here assume that aircraft derived data are used only as air traffic controller accessed parameters (CAP) and are subject to a correspondence check by means of radio communication with the pilot, or verification by the end user by other equivalent means. Aircraft derived data used as system accessed parameters (SAPs) for air traffic safety nets involving automated processing may require higher levels of integrity yet to be established. In anticipation of increasing reliance by the air traffic services on automatic processing of data for safety nets, the aircraft system should be designed such as to provide, so far as is practicable, data of high accuracy, high availability and high integrity.

2. Use of aircraft derived data for other purposes such as Automatic Dependent Surveillance- Broadcast, is expected to require data meeting more demanding availability and integrity criteria. Designers of Mode S systems are strongly recommended to take account of such expectations.

| Parameter | Loss of Parameter | Erroneous Parameter | Remarks |
|---|---|---|---|
| Aircraft Identification | Minor | Minor | |
| Capability Report | Minor | Minor | |
| Pressure Altitude | Minor | Minor | See Section 8 of this guidance material. |
| Flight Status | Minor | Minor | |

## Extract from EUROCAE Document ED-26: Table 13: Altitude Encoding Transition Points — Annex 2

| Nominal Transition Altitude (feet) | Transition Pulse | Enabled Information Pulses. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $D_2$ | $D_4$ | $A_1$ | $A_2$ | $A_4$ | $B_1$ | $B_2$ | $B_4$ | $C_1$ | $C_2$ | $C_4$ |
| -950 | $C_1$ | | | | | | | | | | 1 | |
| | | | | | | | | | | 1 | 1 | |
| -850 | $C_2$ | | | | | | | | | 1 | 1 | |
| | | | | | | | | | | 1 | | |
| -750 | $B_4$ | | | | | | | | | 1 | | |
| | | | | | | | | | 1 | 1 | | |
| -450 | $C_4$ | | | | | | | | 1 | | 1 | |
| | | | | | | | | | 1 | | 1 | 1 |
| -250 | $B_2$ | | | | | | | | 1 | | | 1 |
| | | | | | | | | 1 | 1 | | | 1 |
| 750 | $B_1$ | | | | | | | 1 | | | | 1 |
| | | | | | | | 1 | 1 | | | | 1 |
| 2750 | $A_4$ | | | | | | 1 | | | | | 1 |
| | | | | | | 1 | 1 | | | | | 1 |
| 6750 | $A_2$ | | | | | 1 | | | | | | 1 |
| | | | | | 1 | 1 | | | | | | 1 |
| 14750 | $A_1$ | | | | 1 | | | | | | | 1 |
| | | | | 1 | 1 | | | | | | | 1 |
| 30750 | $D_4$ | | | 1 | | | | | | | | 1 |
| | | | 1 | 1 | | | | | | | | 1 |
| 62750 | $D_2$ | | 1 | | | | | | | | | 1 |
| | | 1 | 1 | | | | | | | | | 1 |