**Mode S Transponder Level 2/3/4 Requirements**

This document clarifies the level of capability required for the Mode S transponder in the current and future airspace environment. Although there has been much discussion about the need for a Level 4 Mode S transponder, an investigation of current industry mandates show that only a Level 2 Mode S transponder is needed.

**Description of Transponder Levels**

The Mode S Transponder has the ability to utilize many different formats to communicate air-to-air and air-to-ground. These formats are separated into “short” messages (56 bits long) and “long” messages (112 bits long). A “UF” message is from the interrogator (can be a ground station or a TCAS) to the Mode S transponder. A “DF” message is from the Mode S transponder to the interrogator.

**Level 1**

This is the minimum Mode S Transponder. It has the ability to reply to Mode S interrogations, but it does not have any datalink capability. The message formats used by a Level 1 transponder are listed below. These are all short (56 bit) messages.

- **UF 0** Short Special Surveillance (UF messages are interrogations to the Transponder)
- **UF 4** Surveillance, Altitude Request
- **UF 5** Surveillance, Identity Request
- **UF 11** Mode S Only All Call
- **DF 0** Short Special Surveillance (DF messages are replies from the Transponder)
- **DF 4** Surveillance, Altitude Reply
- **DF 5** Surveillance, Identity Reply
- **DF 11** All Call Reply

**Level 2**

These Transponders support all the features of a Level 1 Transponder with the addition of standard length datalink capabilities. Standard length datalink communication, from the Transponder’s point of view, consists of receiving a single UF message and replying with a single DF message. The message formats used by a Level 2 transponder consist of the same messages used by the Level 1 transponder with the addition of several long (112 bit) messages listed below. The long messages are used in the standard length datalink.

- **UF 16** Long Special Surveillance (UF messages are interrogations to the Transponder)
- **UF 20** Comm-A, Altitude Request
- **UF 21** Comm-A, Identity Request
- **DF 16** Long Special Surveillance (DF messages are replies from the Transponder)
- **DF 20** Comm-B, Altitude Reply
- **DF 21** Comm-B, Identity Reply

The UF 16 and DF 16 are used for TCAS air-to-air communication. The UF/DF 20 and 21 are utilized for air-to-ground, ground-to-air communication and are used for the Enhanced Surveillance DAPS requirements.
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**Level 3**
These Transponders have the features of a Level 2 Transponder with the addition of the capability to receive Extended Length Messages (ELM). The ELM is a single message consisting of up to 16 segments, with each segment consisting of a single UF 24 Comm-C interrogation which is 112 bits long.

**Level 4**
Level 4 Transponders have the capabilities of a Level 3 Transponder with the addition of the capability to transmit Extended Length Messages (ELM). Each segment of the ELM consists of a single DF 24 Comm-D reply (112 bits long) and an ELM can have up to 16 segments.

**Brief History of Transponder Industry Mandates**
In 1987, it was believed that the Mode S communication would be the main datalink needed to support applications such as CNS/ATN and would require large block transfers of information. To support these future concepts, industry mandates of the time placed heavy requirements on the future capabilities of the Mode S Transponder. ICAO document 7030, Regional Supplementary Procedures, Fourth Edition, 1987 stated that:

> “by January 1, 1999, a Level 4 transponder will be mandatory for all IFR flights in the EUR region.”

ICAO document 7030 in 1987

As time progressed, it became apparent that a Level 4 datalink capability would not be needed to support flight operations in Europe and that other types of datalink, such as VDL Mode 4, might actually be more beneficial than Mode S. In addition, the infrastructure needed to support Mode S Level 4 would not be available for quite some time. Over the next few years, industry documents began to downgrade the need for Level 4. A 1996 EUROCONTROL working paper, CE 96/182/38, “Postponement of Mode S Implementation in Europe”, stated the following:

> “5.2 Based on the revised IIMSES strategy, airborne equipment requirements to satisfy the operational objective of Enhanced Surveillance are less stringent in terms of timescales and functionality than those which were originally agreed and published in Doc 7030. Thus at the outset a Level 2, standard message length, Mode S transponder with a DAP capability would suffice.”

1996 Eurocontrol Working Paper

The paper went on to recommend that for all aircraft weighing more than 5,700 kg., a Mode S Level 2 transponder should be required from January 1, 2000 and that a Mode S Level 2 transponder with DAP capability be required from January 1, 2003. The requirement for a Level 4 transponder for all aircraft weighing more than 5,700 kg. was postponed until January 1, 2005.
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In 1997, a proposal, EUR/NAT-S 97/12 EUR RAC/4, called for the deletion of the requirement for a Level 4 transponders from the ICAO 7030 document. The proposal stated:

“For IFR flights, as General Air Traffic (GAT), for new aircraft with effect from 1 January 2001, and, for all aircraft with effect from 1 January 2003; Level 2 transponder, as a minimum, with downlink aircraft parameter capability denoted as Basic Functionality and Enhanced Surveillance Functionality as detailed in paragraph 7.5.2 below.

Note: The employment of Level 4 transponders, as a minimum, with an Airborne Data Link Processor (ADLP), is envisaged as a possible future requirement in association with the extended use of Mode S datalink in an integrated air/ground communications network. The earliest target date is mid 2005 and this date will be consolidated once a strategy for surveillance and communications has been defined, with due regard to an agreed minimum 5 year notification period.”

accepted in March, 1999, in ICAO letter T 13/4.E-LD-L990350.ATM.

At present, the current draft Specimen AIC’s from EUROCONTROL for “Carriage and Operation of SSR Mode S Airborne Equipment”, revision 9, 22/06/00, does not even mention Level 4 transponders. The proposed AIC delays the mandate for a Level 2 transponder, for IFR flights, until March 31, 2003. In addition, it only lists a target date of March 31, 2005 for the requirement of Level 2 transponders with Enhanced Surveillance DAPs.

Reasons why Level 4 requirements have been dropped by Eurocontrol

There are several factors that contributed to the removal of the Level 4 transponder requirement from current industry mandates. These are:

1) Capability of Level 2 – the standard datalink capability of Level 2 has been shown to be all that’s needed in today’s airspace environment. Using Level 2, the transponder has the capability to transmit any of 256 BDS (B Definition Subfield) registers, each with 56 bits of information. The size of the registers permits the transfer of flight information such as aircraft intent, GPS position, TCAS advisories, and Flight ID. Since only a handful of BDS registers have actually been defined, there is still a lot of room for future expansion in the datalink ability of Level 2.

2) Ground Infrastructure – Level 4 capabilities would require significant upgrades to the ATC ground stations at a time when ATC is struggling just to upgrade ground stations just to Level 2 compatibility. Level 4 upgrades would require even more economic resources.

3) Transponder Airplane Interfaces – Level 4 allows the transponder to datalink large amounts of information, however, the question remains of how to transfer the large amounts of information into the transponder so that it can be datalinked.

   An Airborne Data Link Processor (ADLP) is required either external or internal to the transponder to concentrate the data from various sources on the airplane and relay it to the datalink function. An external ADLP presents various airplane issues because another LRU will need to be created and installed onto the airplane. An internal ADLP requires additional
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wiring changes to connect the transponder to various data sources. The current ARINC 718 interface specification does not provide the necessary inputs for the transponder to act as a data concentrator. An ED-86 specification is released, but has not been adopted by AEEC/ARINC and continues to be actively debated.

Compatibility of Honeywell’s Enhanced TRA-67A with Current Transponder and Datalink Mandates

When the Enhanced TRA-67A Mode S Transponder was being developed in 1998, an evaluation of industry regulations and mandates was done to ensure that the capabilities of the Enhanced TRA-67A would meet all requirements in the foreseeable future. The evaluation led to the following requirements for the Enhanced TRA-67A:

1) TCAS Change 7 Compatibility – The European AIC’s showed mandates for the equipage of TCAS Change 7 (ACAS II) in January 1, 2000.

2) Basic and Enhanced Surveillance DAPs (Downlink Aircraft Parameters) requires the following functionality:

   For Basic Surveillance:
   - Flight ID (BDS register 2,0)
   - Capability Report (BDS register 1,0 and 1,7)
   - Recognition of Surveillance Identifier (SI) codes
   
   For Enhanced Surveillance (as currently defined):
   - Aircraft Intention (BDS register 4,0)
   - Track and Turn Report (BDS register 5,0)
   - Heading and Speed Report (BDS register 6,0)

   As stated previously the actual industry mandate dates have been fluctuating, but the Enhanced TRA-67A has the capability to meet these requirements today.

3) ADS-B (Automatic Dependent Surveillance – Broadcast)

   The Enhanced TRA-67A has the ability to transmit the long DF 17 squitter for aircraft position, velocity, and flight ID. Although there are no European or US requirements for ADS-B, there are currently various evaluation flight trials occurring in the US that the transponder is able to support. The Enhanced TRA-67A was designed to be compliant with the RTCA 1090 MOPS currently undergoing the approval and release process.

4) Level 2 Datalink – as stated earlier, the industry mandates showed that a Level 2 capability is all that is required. Level 3 and Level 4 are not needed.

   With these capabilities, the Enhanced TRA-67A has the functionality needed to support all flight operations in both today’s and the foreseeable future’s air traffic environment.