Traffic Information Service Broadcast: an Innovative Approach to ATM - TIS-B

Interface Design Document (IDD)

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1 Introduction

1.1 Context

Quadrant represents a family of products in the field of aircraft surveillance. The Quadrant ADS-B Sensor is the first member and cornerstone of this family. It receives and processes 1090 MHz messages which are sent to client systems for further processing.

A complementary function is the transmission of ADS B is the Traffic Information Services-Broadcast (TIS-B), a ground-based uplink report of proximate traffic that is under surveillance by ATC but is not ADS-B-equipped. This service would be available even with limited ADS-B implementation.

Within the Quadrant products, TIS B can be realised using components designed and developed for the Quadrant ADS-B Sensor.

The TIS B Transmitter is complemented by a TIS-B Server that receives data from a ground-based tracker and schedules the transmission requests for a number of TIS-B ground stations. The interfaces are of the TIS-B server are also included in this document.

1.2 Purpose

This document defines the System Interfaces for the TIS-B (Traffic Information Service – Broadcast) surveillance system. The TIS-B capability is incorporated into the already existing ADS-B Quadrant System.

1.3 Document Conventions

The TIS-B Server mentioned in this document is a synonym for the central controller software handling the TIS-B messages.

The document is self-contained and structured as follows. In chapter 2 the external interfaces are described. Chapter 3 describes the internal interfaces which has been identified.

1.4 Intended Audience

This document provides a guideline for system engineers working on either or both software and hardware components of the final product.

1.5 References

[RF 01] small application MIB TBD by Comsoft (see 2.3)

[RF 02] Quadrant FPGA-PXA270 Interface Design Document (QINETIQ/ D&TS/SS/IDD061222) (see 3.2)

[RF 03] System requirement document for DSP (see 3.3)

2 External Interfaces

2.1 External TIS-B Server to Quadrant Transceiver

The Quadrant TIS-B transceiver receives input data via a stream of UDP/IP packets from the TIS-B server. The interfaces and the format of packets are proprietary and evolved under the control of COMSOFT. The initial version of the specification is described in this document.

The transceiver will expect packets on a predefined, but configurable UDP port.

Each packet contains a header and an optional payload. A packet header consists of 4 bytes. The first 2 bytes contain the packet type, encoded as a 16 bit unsigned integer in network byte order. The next two bytes contain the total length of the packet, again as a 16bit unsigned integer in network byte order.

The only packet type defined so far are type 1 for transmitting Mode S message send requests, and type 2 (structurally identical) for transmitting Mode S test messages.

The total message length shall not exceed 2048 bytes (2 kB).

2.1.1 Payload Format of Message Send Request (Type 1)

The payload of a type 1 message is composed of a number of individual records, where each record contains a single ICAO DF18 message and a desired time of transmission for this message. Records are laid out sequentially and consecutively, with no padding between records.

A record consists of the following items, arranged consecutively, in the listed order, and without any padding inserted between them:

- 8 byte time stamp

The 8 byte time stamp is interpreted as an unsigned (long long) integer number in network byte order. It represents the scheduled time of transmission for this message in microseconds since the UNIX epoch (January first, 1970 UTC), where in accordance with UTC each day is assumed to have exactly 86400 seconds.

The time stamp with value 0 (all bits zero) shall be reserved to indicate immediate transmission, i.e. transmission as soon as possible.

Telegrams received with already expired time stamps will be discarded.

- one byte (8 bit) transmission power indicator. It is currently expected that at most 5 bits of this will be used.

- one byte antenna selector, which selects exactly one of the possible segments of the antenna. It is again assumed that only 3 bits of this will be used in current configurations.

- 112 bit (14 byte) Mode S telegram to transmit.

The 14 byte Mode S telegram is the raw telegram transmitted in natural byte order. This is an opaque sequence of bytes, no check or analysis is performed.

The following example contains two (unspecified) Mode S messages, the first scheduled for immediate sending on antenna segment 3 with power level 1, the second for sending on April 18th, 2007 at 12:49:08 sharp, on antenna segment 1 and with power level 6.

Note that each row contains the 2 bytes of one 16-bit word in hexadecimal notation.

```
           --- type -----
Header:    x00 0x01
           ---- payload length (header+2 records = 52 bytes) ---
Header:    x00 0x34
           ---- time stamp of message 1 (8 bytes) -------
Message 1: 0x00 0x00
Message 1: 0x00 0x00   Scheduled for immediate transmission
Message 1: 0x00 0x00
Message 1: 0x00 0x00
           ---- Power and antenna selection
Message 1: 0x01 0x03
           ----- actual Mode-S telegram (14 bytes) -------
```

```
Message 1: 0x.. 0x..

Message 1: 0x.. 0x..

Message 1: 0x.. 0x..

Message 1: 0x.. 0x..

Message 1: 0x.. 0x..

Message 1: 0x.. 0x..

Message 1: 0x.. 0x..

           ----- time stamp of message 2 (8 bytes) -------

Message 2: 0x00 0x04

Message 2: 0x2E 0x62   Scheduled for transmission at 2007-04-18:12-
49-8

Message 2: 0x83 0x19   (1176900548000000 usec after the epoch)

Message 2: 0x79 0x00

           ---- Power and antenna selection

Message 1: 0x06 0x01

           ----- actual Mode-S telegram (14 bytes) -------

Message 2: 0x.. 0x..

Message 2: 0x.. 0x..

Message 2: 0x.. 0x..

Message 2: 0x.. 0x..

Message 2: 0x.. 0x..

Message 2: 0x.. 0x..

Message 2: 0x.. 0x..

           ------
```

Table 1: Example type 1 message with two Mode S telegrams

2.1.2 Payload Format of Test Messages (Type 2)

The type 2 message payload has exactly the same structure as type 1. The messages are, however, interpreted as test messages to be injected at low power directly into a potentially co-located ADS-B antenna. If the configuration of the TIS-B station does not allow this, e.g. because there is no co-located ADS-B station, the message will be ignored.

2.2 Quadrant Transceiver to TIS-B Server ASTERIX back channel

The Quadrant TIS-B unit will use ASTERIX CAT023 over UDP to signal its status to the TIS-B server. ASTERIX is an international standard developed under the control of Eurocontrol.

Remark: CAT023 allows us to either specify the exact service (i.e. TIS-B Extended Squitter) and a very generic status indicator, or to give a report on the whole ground station, but with a much more comprehensive state description. Therefore, we will consider the TIS-B component as a "virtual" ground station and describe its state via Type 001 messages.

Messages will be send periodically. For the initial release, the Quadrant TIS-B station will send messages of **CAT023** with the following items:

000 Message type will be set to 001 to indicate a Ground Station Status message,

010 Data Source Identifier will be the assigned SAC/SIC,

070 Time of Day will use the UNIX system time,

100 Ground Station Configuration and Status

This will use the bits as follows:

- OP: Operational Release Status - this will be a user-configurable item.
- ODP: This will be set if either the number of scheduled messages is higher than a set limit (current suggestion: 10000 messages, to allow for 10 second pre-scheduling at 1000 messages/second) or if the CPU utilization of the system is higher than 75%.
- OXT: Scheduled messages are discarded before they can be transferred to the FPGA for sending, as their time stamps have expired.
- MSC: <TBD>, probably 0
- TSV: This will be set if the system is not in synchronized state.
- Spare: Set to 0
- FC: Set to 0

2.3 Quadrant Transceiver SNMP interface

The TIS-B transceiver gives access to some of its states via an SNMP MIB. The Simple Network Management Protocol (SNMP) is an internet standard developed and maintained by the Internet Engineering Task Force (IETF). Quadrant supports SNMP v2c (specified in RFCs 1901-1908) and SNMP v3 (RFCs 3411-3418).

The Quadrant Transceiver supports the relevant parts of the SNMP MIB-II (RFC1213) and a small application MIB TBD(see reference section).

2.4 TIS-B Sender to TIS-B Users

The external transmission interface from the TIS-B ground station to the TIS-B users consists of pulse-coded EM-transmissions on the 1090 MHz frequency. The exact properties (e.g. power, pulse shape, encoding), and the contents of the encoded packages, are described in Annex 10 to the Convention on International Civil Aviation (ICAO Annex 10). This is an international standard maintained and developed by the International Civil Aviation Authority. Various documents refining these standards have been issued by the Radio Technical Commission for Aeronautics (RTCA) and are developed and maintained by this organization.

2.5 TIS-B Server to Tracker Interface

The TIS-B Server receives tracked position-reports from a ground-based tracker and forwards corresponding send requests to the TIS-B groundstation.

The interface between the TIS-B Server and the Tracker is unidirectional (Tracker to Server) and shall be completely standard-based, i.e. follow the corresponding EUROCONTROL and general communication standards.

In detail the TIS-B Server to Tracker Interface shall be compliant to the ARTAS version V8 (WAM version). As such it shall adhere to (to be checked):

- EUROCONTROL Standard Document for Surveillance Data Exchange, ASTERIX, Part 9, Category 062, SDPS Track Messages, SUR.ET1.ST05.2000-STD-09-01, Ed. 1.7, November 2007

A standard UAP shall be used.

The transport-level communication between the Tracker and the TIS-B Sever shall be via a standard TCP/IP communication protocol.

On transport layer UDP (User Datagramm Protocol) shall be used. Both, TIS-B Server and Tracker shall be identified by a wellknown and firm IP-adress and UDP Port number.

The employed version of IP shall be IP Version 4.

On physical layer an Ethernet-based LAN shall be employed (it is assumed that the tracker and the TIS-B server are co-located at an Air Traffic Control Centre).

The Ethernet type shall be 100BaseT or 1000BaseT.

Over the ASTERIX Cat 62 connections the TIS-B Server expects data of the following characteristics:

- Aperiodical position updates (immediate service) of classical and non-classical aircraft from ARTAS tracker
- ARTAS broadcast service
- ARTAS Track volume including the complete Service Volume of the TIS-B server
- All ASTERIX items present that relate to ADS data
- Identification that track was updated by an ADS-report in the past (item I062/290) (to be checked)
- Age of last ADS-update for ADS-equipped aircraft (item I062/290) (to be checked)

The maximum update rate for conventional track input (i.e. track updates triggered by PSR, SSR, Mode S) is assumed to be that of the ARTAS tracker under the Maastricht load scenario

The maximum update rate for ADS-B-triggered track input is assumed to be limited by 500 reports/sec. (ref. TIS-B Server SRS, Req 6.2-3, 6.2-4, 6.2.5).

2.6 TIS-B Ground Station Coverage - Configuration Interface

The TIS-B groundstation and the TIS-B server need to have a common model of the coverage of the groundstation. This is configuration information that needs to be exchanged between the two systems in a standardized format. As exchange format XML was chosen.

2.6.1 Introduction

The Ground Station Coverage Description (GSCD) XML file describes the location of a TIS-B ground station and its area of coverage. For each ground station, one single XML file is needed.

A GSCD file can be split into three parts:

The first part is the location of the ground station, represented as altitude, longitude, and latitude.

The second part is the physical coverage of the ground station, which is the sum of the actual reachable area for every flight level.

The third part is the power coverage of the ground station, in which the sectors and power levels of the ground station and the maximal / minimal reachable range with each power level are defined.

2.6.2 Format

A GSCD file shall have the following format:

Header:

```
<?xml version="1.0" ?>
<GroundStation id="SICSAC">
```

The root of the GSCD XML file, with an attribute id identifies the ground station.

2.6.2.1 Location and IP Address

```
<Location>
	<Latitude>123.45</Latitude>
	<Longitude>23.45</Longitude>
	<Altitude>100</Altitude>
</Location>
```

The location of the ground station expressed in terms of the Altitude, Latitude, and Longitude. The altitude is given as altitude AMSL (above mean sea level). AMSL is defined as the height above the geoid as opposed to the height above the e.g. Bessel (used for WGS84) ellipsoid. The difference between the (theoretically described) ellipsoid and geoid is known and can be assumed a constant. The altitude unit is meter.

Latitude and longitude are given in WGS84 coordinates in decimal degrees. Latitude range is [-90.0; +90.0] and longitude range is [-180.0; +180.0].

<IP version=”4”>127.0.0.1</IP>

<Port>7158</Port>

The IP section defines the IP address of the ground station. A version attribute refers the version of IP address, has value “4” or “6”, “4” by default if is omitted. IPv4 address is given in the dotted-decimal notation, IPv6 in colon separated hexadecimal notation.

Port section defines the UDP port used by the ground station for receiving incoming TIS-B message, given in decimal. Default port suggestion: 7158, since its similar looking as “TISB”.

2.6.2.2 Physical Coverage

The physical coverage section defines the actual area that can be covered by the ground station. It shall have the following structure:

- Physical coverage
    - o Flight Level
        - Altitude at 100 (AMSL, Meter)
        - Default Inner Bound (Meter)
        - Section from 0 to e.g. 3 (degrees)
            - Maximal Reachable Range (Meter)
            - Minimal Reachable Range (Optional) (Meter)
        - Section from ... to ...
            - Maximal Reachable Range
            - Minimal Reachable Range (Optional)
        - Section from ... to ...
            - Maximal Reachable Range
            - Minimal Reachable Range (Optional)
        - …
    - o Flight Level
        - Altitude at ....
        - Default Inner Bound

        - Section from 0 to 5
            - Maximal Reachable Range
            - Minimal Reachable Range (Optional)
        - Section from ... to ...
            - Maximal Reachable Range
            - Minimal Reachable Range (Optional)
        - …
    - Flight Level …
        - …

The physical coverage is composed by several flight levels. For each flight level referred by an altitude, a default inner bound is specified, as normally the cone of silence has symmetrical boundaries at a certain altitude. Every flight level is in turn divided into many sections, for each section a maximal reachable distance of a message that is being sent out into this direction is defined, and an optional inner bound can, if necessary, be assigned. The unit of Flight Level and Min/Max Reachable Range is meter.

The angle range specified by the sections can be continuous or not continuous, but there should not be any overlapping or repetitive definition.

Example:


```
<PhysicalCoverage>
	<FlightLevel>
		<Altitude>100</Altitude>
		<DefaultInnerBound>20</DefaultInnerBound>
		<Section from="0" to="5">
			<MaximalReachable>110</MaximalReachable>
		</Section>
		<Section from="5" to="9">
			<MaximalReachable>100</MaximalReachable>
		</Section>
		<Section from="9" to="15">
			<MaximalReachable>115</MaximalReachable>
		</Section>
		<Section from="15" to="21">
			<MaximalReachable>90</MaximalReachable>
		</Section>
		<Section from="21" to="26">
			<MaximalReachable>95</MaximalReachable>
		</Section>
		<Section from="26" to="35">
			<InnerBound>15</InnerBound>
		<MaximalReachable>100</MaximalReachable>
		</Section>
		<Section from="35" to="55">
			<MaximalReachable>100</MaximalReachable>
		</Section>
```

```
        <Section from="55" to="57">
            <InnerBound>15</InnerBound>
        <MaximalReachable>100</MaximalReachable>
        </Section>
            <Section from="57" to="60">
        <MaximalReachable>100</MaximalReachable>
        </Section>
            <Section from="60" to="360">
        <MaximalReachable>100</MaximalReachable>
        </Section>
    </FlightLevel>
    ……
    <FlightLevel>
        <Altitude>200</Altitude>
        <DefaultInnerBound>40</DefaultInnerBound>
        <Section from="0" to="5">
            <MaximalReachable>110</MaximalReachable>
        </Section>
        <Section from="5" to="9">
            <MaximalReachable>100</MaximalReachable>
        </Section>
        ……
    </FlightLevel>
</PhysicalCoverage>
```


2.6.3 Power Coverage

The power coverage defines, for a certain sector of a ground station, the power levels to be used in order to reach a certain distance. It has the following structure:

- Power coverage
    - Sector with id 1, range from 0 to 60 (degree)
        - Power level 1 (minimum)
            - Minimal reachable distance (Meter)
            - Maximal reachable distance (Meter)
        - Power level 2
            - Minimal reachable distance
            - Maximal reachable distance
        - Power level 3 ...
            - …
        - …
        - Power level 8 (maximum)
            - Minimal reachable distance
            - Maximal reachable distance (i.e. the maximal possible range of the ground station.
    - Sector with id 2, range from 60 to 120
        - …
    - …
    - Sector with id 6, range from 300 to 360

- …

A ground station may have up to 6 sectors, each of them with up to 8 power levels. For each power level, a minimal reachable distance is specified, which will be used to decide whether an aircraft can be reached for sure, and a maximal reachable distance is also specified, which will be used for the interference detection between neighbor ground stations. The unit for Min/Max Reachable distance is meter.

Example:


```
<PowerCoverage>
	<Sector id="1" from="0" to="60">
	<PowerLevel value="1">
		<MinimalReachable>20</MinimalReachable>
		<MaximalReachable>40</MaximalReachable>
	</PowerLevel>
	<PowerLevel value="2">
		<MinimalReachable>40</MinimalReachable>
		<MaximalReachable>60</MaximalReachable>
	</PowerLevel>
	<PowerLevel value="3">
		<MinimalReachable>50</MinimalReachable>
		<MaximalReachable>70</MaximalReachable>
	</PowerLevel>
	<PowerLevel value="4">
		<MinimalReachable>60</MinimalReachable>
		<MaximalReachable>80</MaximalReachable>
	</PowerLevel>
	<PowerLevel value="5">
		<MinimalReachable>80</MinimalReachable>
		<MaximalReachable>85</MaximalReachable>
	</PowerLevel>
	<PowerLevel value="6">
		<MinimalReachable>90</MinimalReachable>
		<MaximalReachable>100</MaximalReachable>
	</PowerLevel>
	</Sector>

<Sector id="2" from="60" to="120">
	<PowerLevel value="1">
		<MinimalReachable>20</MinimalReachable>
		<MaximalReachable>40</MaximalReachable>
	</PowerLevel>
……
</Sector>

<Sector id="6" from="300" to="360">
…..
</Sector>
</PowerCoverage>
</GroundStation>
```


3 Internal Interfaces

3.1 DP to DSP

TIS-B transmissions will be initiated by the Digital Processor (DP) and executed by the Digital Signal Processing (DSP) component. The interface between DP and DSP is a proprietary interface and an extension the existing interface described in the Quadrant FPGA-PXA270 Interface Design Document (QINETIQ/D&TS/SS/IDD061222).

The TIS-B functionality will be enabled or disabled via bit 12 in control register 1 (address 0x00). The default will be "enabled", and will be indicated by a value of 1. The DSP will ensure that enabling either DAC (control register bits 10 and 11) will disable TIS-B functionality, and that enabling TIS-B functionality will disable both DACs.

Remark: This last requirement is only to avoid hardware conflicts with older boards. In the future, DAC logic can be removed completely from the FPGA, as the DACs will be removed physically as well.

TIS-B send requests will be handed to the DSP via the existing memory interface. For this purpose, the memory map will be extended by a 12 register/24 byte input register set as follows:

1) 7 16-bit words will be reserved for the 112 bit extended squitter message to be send (address 0xD0 to 0xDC).

2) 2 16-bit words will be reserved for the scheduled time of transmission, expressed as a value of the 100 MHz FPGA counter (address 0xDE to.0xE0).

3) 1 16-bit word will be used as the control word (address 0xE2).

This will contain:

Bit 1: use time stamp (0: ignore time stamp, send as soon as possible; 1: use time stamp)

Bit 3 to 7: signal strength

Bit 8: keep receiver protection (0: disable protection after sending; 1: keep protection after sending)

Bit 0 and 2: validation bits (1: TIS-B register contains valid transmission data; 0: otherwise)

4) 1 16-bit word will be used as the receiver protection delay word (address 0xE4).

This will contain:

Bit 0 to 7: receiver protection activation delay before transmission

Bit 8 to 15: receiver protection deactivation delay after transmission

In order to commence transmission an arbitrary value needs to be written to the TIS-B Control Access Register (address 0x71).

```
0x71   "1110001" => -- TISB Control Access register
…
 0xd0   "11010000" => -- TISB Message bits 111 to 96
 0xd2   "11010010" => -- TISB Message bits 95 to 80
 0xd4   "11010100" => -- TISB Message bits 79 to 64
 0xd6   "11010110" => -- TISB Message bits 63 to 48
 0xd8   "11011000" => -- TISB Message bits 47 to 32
 0xda   "11011010" => -- TISB Message bits 31 to 16
 0xdc   "11011100" => -- TISB Message bits 15 to 0
 0xde   "11011110" => -- TISB timestamp bits 31 to 16
 0xe0   "11100000" => -- TISB timestamp bits 15 to 0
 0xe2   "11100010" => -- TISB Control register
 0xe4   "11100100" => -- TISB Receiver Protection Delay register
```

The FPGA will maintain a SHADOW and a SEND register of 24 bytes each. Whenever the Control Access register is written and both validation bits are set, it will atomically copy the current input register set into the SHADOW register (potentially overwriting a previous job).

When the scheduled time is reached or if the ignore time stamp is set and the SEND register is available, the FPGA will atomically move the data from the SHADOW register to the SEND register and immediately send the message from the SEND register. At the same time, it will inform the processor via an interrupt line (see below) that sending has commenced and the SHADOW register is available again. Sending will be completed within 125 µs if receiver protection and power amplifier are already enabled, and within 221 µs otherwise.

According to the "keep receiver protection" bit the receiver protection will be disabled after transmission or will stay enabled. It is the responsibility of the FPGA to schedule messages depending on the receiver protection enable delay, if receiver protection is disabled and otherwise depending on the transmit suppression delay (5 µs).

During sending, the SEND register is not available. If a message in the SHADOW register becomes ready for sending during this time, it is discarded and the "SHADOW register ready" interrupt is raised. It is the responsibility of the DP to schedule messages with sufficient time to avoid message loss in the DSP.

3.2 DSP to DP

The interface from the DSP to the DP requires only minor changes compared to the pure ADS-B interface described in the Quadrant FPGA-PXA270 Interface Design Document (QINETIQ/D&TS/SS/IDD061222).

These changes are the following:

1) The use of a current spare DP/DSP connection as an extra interrupt line to signal the commencement of a send request (see above). For this purpose, the FPGA pin AG18 (SPARE1/NET "MCU_Spare(0)) shall be connected to the PXA270 GPIO81 pin. Electrical properties/timings shall be as for the current FIFO interrupt.

3.3 DSP to 1090MHz Synthesizer/ TIS-B Sender

The interface from the DSP to the 1090 synthesizer is a proprietary interface designed and evolved under control of COMSOFT and in cooperation with QinetiQ.

The TIS-B subsystem will be connected to the basic Quadrant board via a suitable hardware connector (TBD).

It will be driven via a video signal corresponding to the desired message. This video signal will be expected on FPGA pin D30.

The DSP will provide the receiver protection signal as specified in the system requirement document (SRD) on a dedicated output pin.

The DSP will provide the transmission suppression signal as specified in the SRD on a dedicated output pin.

Remark: Details TBC by COMSOFT HW team and QinetiQ. This is affected by and affects handling of CR011, regarding the removal of the DACs and the reuse of FPGA pins. Also see above for the logic separating TIS-B and DAC control.

Appendix A: Glossary

ASTERIX	All Purpose Structured EUROCONTROL Surveillance Information Exchange (previously All Purpose Structured EUROCONTROL Radar Information Exchange). Standard format for surveillance-data exchange.
CRC	Cyclic Redundancy Check
DAC	Digital analogue converter
DF	Downlink Format
DP	Data processing
DSP	Digital signal processing is the study of signals in a digital representation and the processing methods of these signals
Eurocontrol	European Organisation for the Safety of Air Navigation
FIFO	First in, first out means the way data stored in a queue is processed
FPGA	Field-programmable gate array is a semiconductor device containing programmable logic components
ICAO	International Civil Aviation Organisation
IETF	Internet Engineering Task Force develops and promotes Internet standards
MIB	Management information base is a type of database used to manage the devices in a communications network
PPS	Pulse per second is an electrical signal that very precisely indicates the start of a second
QinetiQ	British defence technology company
RFC	Request for Comments documents are a series of memoranda encompassing new research, innovations, and methodologies applicable to Internet technologies
RTCA	Radio Technical Commission for Aeronautics develops standards related to the Federal Aviation Authority

SNMP	Simple Network Management Protocol forms part of the internet protocol suite
UDP	User Datagram Protocol is one of the core protocols of the Internet protocol suite

Appendix B: Issues List

Final Page!