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# Manual on the
# Universal Access Transceiver (UAT)
# Revision 0.4

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# 1 Introduction

## 1.1 Outline of the Manual

This manual contains guidance material relating to the implementation of the Standards and Recommended Practices (SARPs) for the Universal Access Transceiver (UAT). This manual will be updated to reflect any necessary changes as experience with implementation of UAT is gained. This manual includes material related to system description and operation, detailed description of message formats, and also includes material on overall system performance based on extensive testing and simulation performed during development of the UAT system.

Section 1 of this document presents the objectives and scope of the manual and provides definition of key terms used in the manual

Section 2 describes the applications supported by UAT and fundamentals of system operation

Section 3 provides details on UAT message payloads and formats.

Section 4 describes procedures for avionics and ground transmitters including requirements for processing timing information

Section 5 describes interface requirements for airborne equipment.

Section 6 describes potential future services that could be supported by UAT.

Appendix A provides guidance on the implementation of UAT Ground Infrastructure. Assumptions consistent with this guidance have been used to estimate UAT performance when supporting air-ground applications of ADS-B.

Appendix B contains a specific example of a UAT ADS-B Message with an exemplary payload, formatted in a manner consistent with Section 3 of this Manual.

Appendix C describes the Standard Interference Environments that have been used to estimate UAT System performance. These environments are based upon internationally-developed traffic scenarios for future high and low density airspace and near-worst-case estimates of interference caused by other systems transmitting on or near the UAT intended operational frequency of 978 MHz.

Appendix D details the UAT System Performance Simulation Results, which summarizes results of UAT System performance evaluations in the Standard Interference Environments of Appendix C. Air-to-air and air-ground system performance is assessed. All performance estimates reflect broadcast of all State Vector (SV), Mode Status (MS), and Intent information (including Trajectory Change Reports).

Appendix E discusses UAT Timing Performance, an aspect of the UAT System that underpins, for example, potential use of UAT for independent validation of position information of received UAT ADS-B Messages.

Appendix F describes measurement data that were collected on UAT equipment to characterize the performance in various interference environments, including JTIDS/MIDS, DME/TACAN and self-interference, as described in Appendix C.

Appendix G describes test results that substantiate compatibility of the UAT System with Distance Measuring Equipments (DMEs).

Appendix H describes the UAT Error Detection and Correction Performance.

Appendix I provides a set of Acronyms and Definitions of Terms.

Appendix J describes a potential installation of UAT sharing the airborne antenna subsystem of an SSR transponder.

## 1.2 Objective and Scope

The objective of this manual (in conjunction with the SARPs) is to define a set of internationally agreed characteristics of the UAT system that accomplish the following:

- Establish a basis for RF compatibility to other systems from UAT and vice versa.
- Establish a common basis for UAT intersystem interoperability across implementations manufactured and certified in different regions of the world.
- Provide implementation guidance on UAT ground network configuration and operation

This manual alone is not considered adequate for manufacture or certification of UAT equipment and is not a replacement for local certification guidance.

## 1.3 Definitions

**UAT**: Universal Access Transceiver (UAT) is a broadcast data link intended to operate globally on a single channel, with a channel signaling rate of 1.041667 Mbps.

**UAT ADS-B message:** UAT ADS-B messages are broadcast by each aircraft once per second to convey state vector and other information. UAT ADS-B messages can be in one of two forms depending on the amount of information to be transmitted in a given second: the *Basic UAT ADS-B message* or the *Long UAT ADS-B message* (see Section 12.4.4.1 for definition of each).

***Note:*** *The format of UAT ADS-B messages are specific to each individual ADS-B data link system*

**UAT Ground Uplink message:** The UAT Ground Uplink message is used by ground stations to uplink flight information such as text and graphical weather data, advisories, and other aeronautical information, to any aircraft that may be in the service volume of the ground uplink station message (see Section 12.4.4.2 for further details).

**Basic Receiver:** A general purpose receiver with less rejection of interference from adjacent channel DMEs than the High Performance receiver.

**High Performance Receiver:** A UAT receiver with additional filter selectivity to aid in the rejection of adjacent channel DME interference.

**Optimum Sampling Point**: The optimum sampling point of a received UAT bit stream is at the nominal center of each bit period, when the frequency offset is either plus or minus 312.5 kHz.

Additional Acronyms and Definitions of terms are provided in Appendix I. [*Need to insure that all of the listed Acronyms and Definitions are in fact used in the technical manual, and that all Acronyms and Definitions are consistent with ICAO practice.]*

# 2 Operating Concepts

## 2.1 Applications Supported

### 2.1.1 Automatic Dependent Surveillance –Broadcast (ADS-B)

Automatic Dependent Surveillance – Broadcast (ADS-B) is a surveillance technique in which aircraft automatically provide, via a broadcast-mode data link, data derived from on-board navigation and position fixing systems, including aircraft identification, four-dimensional position, and additional data as appropriate.

[*This definition may be updated after the 11th Air Navigation Conference.]*

With such information made available by ADS-B from other proximate aircraft, it is possible to establish the relative position and movement of those aircraft with reference to one's own aircraft. It is also possible for ground-based facilities to monitor ADS-B broadcasts to enable basic surveillance capabilities, or to supplement existing surveillance systems. Other data that are shared using ADS-B include information related to the aircraft's intended flight path ("intent" data), aircraft type, and other information.

ADS-B is automatic in the sense that no pilot or controller action is required for the information to be broadcast. It is dependent surveillance in the sense that the aircraft surveillance-type information is derived from on-board navigation equipment.

ADS-B is considered to be a key enabling technology to enhance safety and efficiency in airspace operations. These include basic applications, such as the use of ADS-B to enhance the pilot's visual acquisition of other nearby aircraft[1], as well as more advanced applications, such as enabling enhanced closely spaced parallel approach operations. Other applications involving airport surface operations, improved surveillance in non-radar airspace, and advanced conflict management are also described. Fleet management and search and rescue are also applications for ADS-B.

### 2.1.2 Ground Uplink Services

In the context of this manual, Traffic Information Service - Broadcast (TIS-B) is a ground-based service to UAT-equipped aircraft to provide surveillance data on non-UAT-equipped aircraft. The service is intended to provide UAT-equipped aircraft with a more-complete traffic picture in situations where not all aircraft are equipped with UAT.

When providing surveillance data for non-ADS-B equipped aircraft, TIS-B involves three major functions. First, another source of surveillance information on non-ADS-B aircraft (such as Secondary Surveillance Radar [SSR]) must be available. Second, this surveillance information must be converted and processed so as to be usable by UAT-equipped aircraft. And third, UAT is used to convey this information to UAT-equipped aircraft.

[1] This Manual deals with aircraft's use of UAT. Ground vehicles in the movement area, obstacles, etc., may also transmit UAT ADS-B Messages when appropriate. In appropriate contexts, the term "aircraft" may include such other transmitters.

When serving as a "gateway," the TIS-B service takes as input ADS-B reports from aircraft broadcasting on an ADS-B data link other than UAT and converts those reports to a format appropriate to UAT, and broadcasts appropriate messages to UAT equipped aircraft.

UAT preferably supports TIS-B by having UAT ground uplink stations transmit TIS-B information as UAT ADS-B Messages in the ADS-B segment of the UAT frame. Alternatively, if necessary, TIS-B information could be broadcast in the ground segment of the UAT frame.

FIS-B is the ground-to-air broadcast of non-control, advisory information needed by pilots to operate more safely and efficiently. For example, FIS-B may provide weather graphics and text (e.g., METAR and TAF), Special Use Airspace information, Notices to Airmen, and other information. UAT has been designed to support the broadcast of FIS-B information in the ground segment of the UAT frame using the ground uplink message.

### 2.1.3 UAT Broadcast Connectivity

Figure 2-1 below shows the connectivity supported by UAT for ADS-B air-air, ADS-B air-ground, and the uplink services of TIS-B and FIS-B.

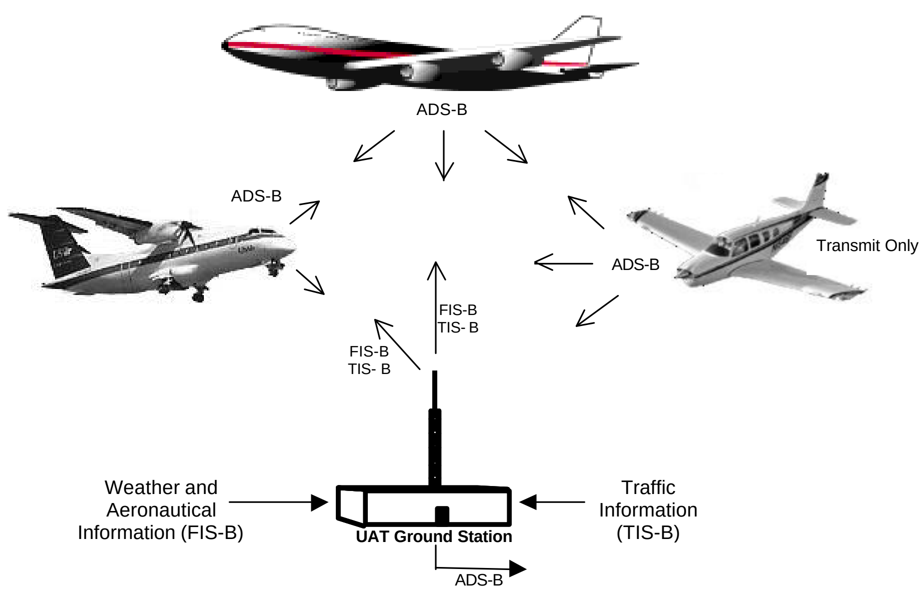



**Figure 2-1:** **UAT Connectivity**

Aircraft UAT equipment may support transmit-only or transmit and receive capability. When aircraft are in coverage of a ground station, uplink services may be provided and the ground station can serve as a surveillance sensor for ground based ADS-B applications. Regardless of whether airborne users are in coverage of a ground station or not, air-air ADS-B connectivity is available. While networking of ground stations can offer certain advantages, each can also operate independently of others if desired. The only requirements for coordination among ground stations is that they all operate on a common time standard and that the ground uplink slots on which they transmit are assigned through appropriate spectrum management procedures. [*Material should be added providing guidance on the spectrum management of ground stations.*]

## 2.2 Channel and Waveform Description

The UAT employs a single common global channel to support ADS-B and appropriate ground uplink services. The UAT channel is at [978] MHz and has a signaling rate of just over 1 Mbps. A single channel architecture ensures seamless air-air connectivity and obviates the need for multi-channel receivers or tuning procedures. The UAT channel has been sized to ensure ADS-B performance is maintained in future high traffic density environments. Additionally, the UAT waveform has been designed specifically to provide tolerance to self-interference and other pulsed interference encountered in the frequency band of UAT operation. The UAT waveform is defined in the UAT RF SARPs.

Detailed information on UAT ADS-B performance assessment in low density and in projected future high-density traffic environments is provided in Appendix D. This assessment also accounts for all expected sources of interference from other systems as described in Appendix C. Appendix F describes the bench test measurements used to develop receiver performance models that provide the underpinning of the simulations in Appendix D.

There are two types of broadcast transmissions - or messages - on the UAT channel: the UAT ADS-B Message, and the UAT Ground Uplink Message. Regardless of type, each message has two fundamental components: the message payload that contains user information, and message overhead, principally consisting of Forward Error Correction (FEC) code parity, that supports the error-free transfer of the data. The FEC was selected to ensure that UAT Messages would have a transmission integrity at the UAT link layer of at most one in $10^{-8}$ probability of an undetected error per message. Details on the format of these message types are provided in §3.1.1 and §3.1.2. Details on the contents and format of the message payloads are provided in §3.2.1 and §3.2.2.

## 2.3 Timing Structure and Medium Access

UAT support for multiple services is accomplished using a hybrid medium access approach that incorporates both time-slotted and pseudorandom access. By virtue of its waveform, signaling rate, precise time reference, and message-starting discipline, UAT may potentially be used for independent validation of position information of received UAT ADS-B Messages (see Appendix E).

Figure 2-2 illustrates the basic UAT Message timing structure called a UAT frame. A frame is one second long and begins at the start of each Universal Coordinated Time (UTC) second. Each frame is divided into two segments: the Ground Segment in which UAT Ground Uplink Messages are broadcast in one or more time slots, and the ADS-B Segment in which UAT ADS-B Messages are broadcast. Guard times are incorporated between the segments to allow for signal propagation and timing drift. The UAT frame contains 3952 Message Start Opportunities (MSOs) that are spaced at 250μs intervals. This spacing represents the smallest time increment used by UAT for scheduling message transmissions, and all such transmissions must start only at a valid MSO.

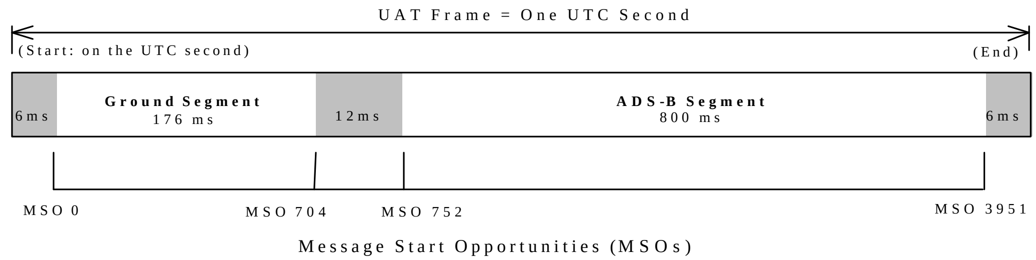



**Figure 2-2: UAT Frame**

***Notes:***

1. *Shaded segments represent guard times for signal propagation and timing drift (not to scale).*

2. *ADS-B transmissions will partially occur within the final guard interval when the last MSO is selected.*

As shown in Figure 2-2, 176 milliseconds in each 1-second UAT frame are devoted to UAT Ground Uplink Message transmissions, and 800ms are devoted to UAT ADS-B Message transmissions. MSOs start at the end of the initial 6ms guard time, are spaced at 250µs intervals, and are numbered sequentially from 0 through 3951.

### 2.3.1 UAT ADS-B Message Transmission

As shown in Figure 2-2, the ADS-B Segment of each UAT frame is 800 milliseconds long, and spans 3200 MSOs (i.e., from MSO 752 to MSO 3951). All UAT ADS-B Messages are transmitted in this segment of the frame. Each UAT-equipped aircraft or ground vehicle makes exactly one UAT ADS-B Message transmission per frame, and makes a pseudo-random selection from among any of the 3200 MSOs in the segment to start transmission of the message. Approximately 6 milliseconds of guard time are appended after the ADS-B Segment to fill out the UAT frame to the end of the UTC second.

The pseudo-random selection of an MSO within each UAT frame for the start of an aircraft's UAT ADS-B Message is intended to prevent two aircraft from systematically interfering with each other's UAT ADS-B Message transmissions. Adherence to the MSO-based timing scheme enables the receiving UAT equipment to determine range to the UAT equipment that transmitted the message. This information could be used in validity checks of the position data conveyed in the UAT ADS-B Message itself. More information on UAT support for an independent ADS-B validation application is presented in Appendix E.

### 2.3.2 Ground Uplink Services

From the perspective of a receiving aircraft, TIS-B transmissions will appear to be nearly identical to UAT ADS-B Messages both in terms of message format and media access. One approach for ground station transmission of TIS-B messages is provided in §4.1.3.

UAT Ground Uplink Messages are used to support FIS-B. UAT Ground Uplink Messages will occur within one or more of the 32 time slots defined within the ground segment of the UAT frame. Detailed procedures for UAT Ground Uplink Message transmission are provided in §4.1.3.

UAT preferably supports TIS-B through transmission of individual messages in the ADS-B format in the ADS-B segment of the frame. Each such TIS-B transmission must start only at a valid MSO as is the case with transmission of ADS-B messages from aircraft. However, UAT can also support TIS-B through transmissions in the Ground Uplink segment. This approach for transmission of TIS-B information is beyond the scope of this Manual.

## 2.4 Basic Avionics Operation and Equipage Levels

### 2.4.1 Avionics Operating Concept

Implementations will consist of transmit and receive subsystems. Most implementations will include both subsystems; however, transmit-only configurations are also possible. Figure 2-3 shows the high level functions of an avionics implementation that supports both transmission and reception.

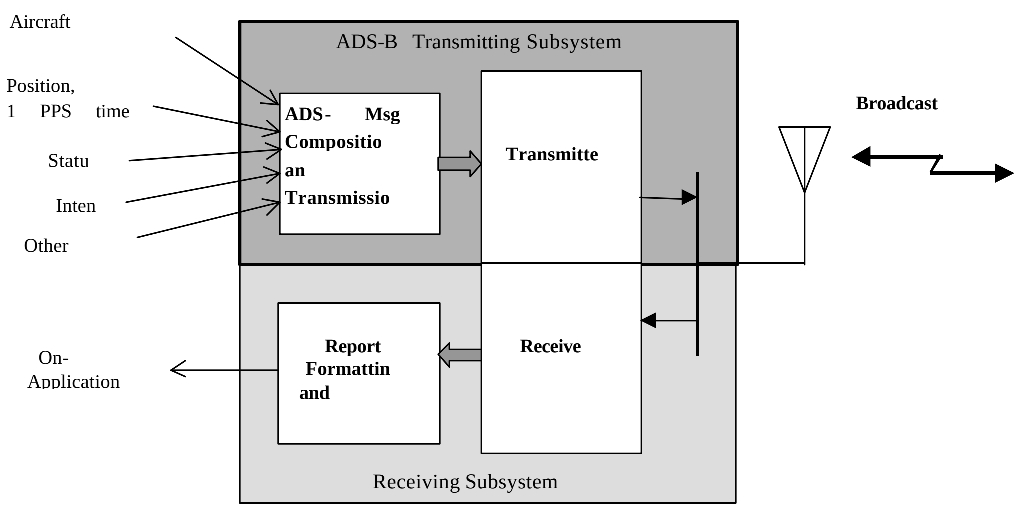



**Figure 2-3: High Level Function of UAT Avionics**

The UAT ADS-B Transmitting Subsystem performs the following basic functions:

- Determine the proper message format based on the predetermined (fixed) message transmit schedule.
- Receive various ADS-B input data and format into the UAT ADS-B Message structure.
- Determine time for transmission (once per second) based on pseudorandom seed.
- Select the antenna for transmission (for installations requiring transmit diversity)
- Transmit the message over the UAT channel.

These functions result in one message transmitted each second. Additionally, the UAT ADS-B Transmitting Subsystem may make a determination of whether its “Vertical Status” is ON GROUND or AIRBORNE. For some installations, the UAT ADS-B Message format may change slightly depending on the Vertical Status Reports. Otherwise, the UAT ADS-B Transmitting Subsystem operates in a consistent manner throughout the flight making one UAT ADS-B Message transmission each second with consecutive messages conforming to a predefined pattern (in terms of message types and transmit antenna) and format.

The UAT ADS-B Receiving Subsystem performs the following basic functions:

- Select antenna for reception (in installations that employ antenna switching, but do not employ receiver diversity).
- Detection and decoding of UAT Messages on the UAT channel.
- Apply "Successful Message Reception" criteria to each detected message to ensure integrity.
- For each Successful Message Reception, format resulting message payload into report format and output report to on-board applications.

Reports are generated in response to UAT Messages received (ADS-B or Ground Uplink). The conditions and procedures for generation of reports are straightforward. Each message successfully received will trigger the generation of a report. Each report includes the unaltered payload of the message just received. The integrity of each report is ensured by robust forward error correction coding that is included within each message. No tracking of an ADS-B participant need be employed in UAT avionics in order to generate ADS-B reports.

### 2.4.2 Avionics Equipage Classes

RTCA has categorized ADS-B equipment into aircraft system equipage classes as defined in RTCA/DO-242A (ADS-B MASPS). This categorization is based on potential ADS-B applications and the needs of particular airspace users. This Manual provides, for exemplary purposes, the configuration of the UAT system consistent with the RTCA equipage categories[1]. Appendix D to this Manual provides projections of UAT performance for each of these equipage classes using both high and low density traffic scenarios. For UAT ADS-B equipment, the installed performance of these equipment classes is defined by Table 2-1. *We will add a discussion of how long it takes for a recipient to determine the equipage class of a transmitting subsystem. Larry will have an analysis for the June 2003 meeting, which will be reflective of acquiring the Mode Status message.*

Aircraft systems supporting both transmission and reception of UAT Messages, termed Class A UAT Systems, are defined by equipage classification according to the provided user capability. The following types of Class A systems are defined:

- Class A0: Supports minimum transmission and reception capability for UAT ADS-B participants to a range of at least 10 NM between participants for air-to-air applications. Broadcast UAT ADS-B messages are based upon own-platform source data. UAT ADS-B messages received from other aircraft support generation of UAT ADS-B reports that are used by on-board applications.

[1] The RTCA definition for equipment classes has been used for UAT, as ICAO requirements for ADS-B are not yet developed.

- Class A1: supports all class A0 functionality and supports ADS-B air-to-air applications to a range of at least 20 NM between participants. For UAT, the A1 equipage class has been divided into two classes. For A1 aircraft that always operate below 18,000 feet MSL, the “A1 Low” class is created, and abbreviated throughout this document as “A1L.” For A1 aircraft that have no altitude operating restrictions, the “A1 High” class is created, and abbreviated throughout this document as “A1H.” The major equipment performance difference between classes A1L and A1H is the Transmitter RF output power.
- Class A2: Supports all Class A1 functionality and additionally provides extended range for ADS-B air-to-air applications of at least 40 NM and information processing to support longer range applications. This service requires the broadcast and receipt of intent information contained in Target State and Trajectory Change reports.
- Class A3: Supports all Class A2 functionality and has additional range capability for UAT ADS-B air-to-air applications between A3 equipped users of at least 120 NM. Class A3 has the ability to broadcast and receive multiple Trajectory Change reports (analysis indicates that the exchange of a second Trajectory Change report at distances of 120 NM is accomplished at approximately one-half of the update rate of the first Trajectory Change report).

The UAT SARPs refer to “Basic” and “High Performance” receivers. This classification maps the A-class equipment as follows: A3 employs the High Performance receiver and the remaining classes employ the Basic receiver.

The “high performance” Receiver is a narrower bandwidth to allow it to better reject DME emissions at 979 MHz. The narrow bandwidth introduces some distortion of the desired signal that degrades the co-channel performance. However the benefit of rejecting the DME energy more than offsets this effect in terms of overall performance. The full effect of the narrow bandwidth filter was accounted for in the performance assessments.

Some UAT ADS-B system participants may not need to be provided information from other participants but do need to broadcast their state vector and associated data. Class B UAT ADS-B systems meet the needs of these participants. Class B UAT systems are defined as follows:

- Class B0: Aircraft broadcast-only system. Class B0 systems require an interface with own-platform navigation systems. Class B0 systems require transmit powers and information capabilities equivalent to those of Class A0. For UAT, Class B0 installations are on aircraft that always operate below 18,000 feet MSL.
- Class B1: Aircraft broadcast-only system. Class B1 UAT systems require an interface with own-platform navigation systems. Class B1 UAT systems require transmit powers and information capabilities equivalent to those of Class A1H.
- Class B2: Ground vehicle broadcast-only UAT ADS-B system. Class B2 UAT systems require a high-accuracy source of navigation data and a nominal 5 NM effective broadcast range. Surface vehicles qualifying for UAT ADS-B equipage may be limited to those that operate within the surface movement area.
- Class B3: Fixed obstacle broadcast-only UAT ADS-B system. Obstacle coordinates may be obtained from available survey data. Collocation of the transmitting antenna with the obstacle is not required as long as broadcast coverage requirements are met. Fixed obstacle qualifying for UAT ADS-B are structures and obstructions identified by ATS authorities as a safety hazard.

Class C UAT ADS-B systems are used at UAT ground stations (see §2.5).

The complete set of ADS-B information transmitted will vary somewhat for each equipment class as determined by the schedule of ADS-B message payloads to be transmitted by each equipment class (see Section 4.3 of this Manual). Certain air-air applications may require the receiving application to determine the equipment class of ADS-B targets being surveilled. Since the equipment class is not explicitly encoded in the ADS-B message payload, receiving applications must infer the equipment class by observing the set of ADS-B message payloads being received from each participant.

Important characteristics of the UAT ADS-B Class A and Class B equipage classes are summarized in Table 2-1.

**<u>Table 2-1:</u> Exemplary UAT Installed Equipment Classes**

| **Equipage Class** | **Air-to-Air Application Ranges Supported** | **Transmit RF Power Delivered to Antenna System** | **Intended Antenna Diversity** | |
|---|---|---|---|---|
| | | | **Transmit** | **Receive** |
| A0 | 10 NM | Low Power *(Altitude always below 18,000 feet)* | Single Antenna (see Note 4) | Single Antenna (see Note 4) |
| A1L | 20 NM | | Alternate | Alternate |
| A1H | | Medium Power | Alternate | Alternate |
| A2 | 40 NM | Medium Power | Alternate | Dual Receiver |
| A3 | 120 NM | High Power | Alternate | Dual Receiver |
| B0 | 10 NM | Low Power *(Altitude always below 18,000 feet)* | Single Antenna (see Note 4) | n/a |
| B1 | 20 NM | Medium Power | Alternate | n/a |
| B2 | 5 NM | +28 to +32 dBm | Single Antenna | n/a |
| B3 | 5 NM | +30 dBm (minimum) | Single Antenna | n/a |

***<u>Notes:</u>***

1. *See §2.4.2.1 for definition of Transmitter RF power levels.*

2. *Transmitter RF power requirement depends on the aircraft maximum altitude capability. Low-altitude aircraft (<18,000 feet max altitude) need not support the higher-power transmitter requirements due to line-of-site limitations.*

3. *Top antenna is not required if use of a single antenna does not degrade signal propagation. This allows for single antenna installation on radio-transparent airframes.*

4. *For a single-antenna installation, antenna gain pattern performance should be shown at least equivalent to that of a quarter-wave resonant antenna mounted on the fuselage bottom surface.*

5. *For further information on Antenna diversity see RTCA DO-282, §2.2.8.1 and §2.2.6.1.3 or equivalent certification guidance.*

A receiving application infers the equipage class of a transmitting participant through observation of the pattern of transmitted UAT ADS-B Messages (see Table 4-1) and review of capability information within Mode Status messages. Identification of equipage class of a transmitting participant can generally be accomplished within TBD seconds.

### 2.4.2.1 Transmitting Subsystem

A UAT ADS-B Transmitting Subsystem is classified according to the unit's range capability and the set of parameters it is capable of transmitting. Table 2-2 defines the transmitter power levels. Power levels are measured in terms of power presented to the transmitting antenna.

**Table 2-2: Transmitter Power Levels**

| Power Classification | Minimum Power at Antenna | Maximum Power at Antenna |
|---|---|---|
| Low | 7.0 watts (+38.5 dBm) | 18 watts (+42.5 dBm) |
| Medium | 16 watts (+42 dBm) | 40 watts (+46 dBm) |
| High | 100 watts (+50 dBm) | 250 watts (+54 dBm) |

**Note:** *These transmitter power levels are referenced to the power delivered to the antenna. Performance assessments assume transmit antenna gain of 0 dB in the horizontal direction, with a maximum gain of 4 dB at 25 degrees from the horizontal. Alternate means that demonstrates equivalent performance can be approved. Refer to Appendix E in this Manual for guidance.*

### 2.4.2.2 Receiving Subsystem

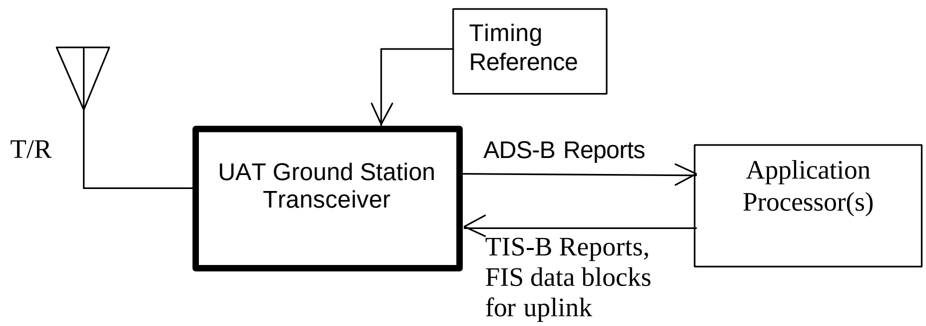
All Class A receivers have the same sensitivity requirements. The receiver sensitivity at the receiver antenna end of the cable connecting the antenna to the equipment (after antenna gain and before cable loss), for 90% Message Success Rate, is –93 dBm for Long UAT ADS-B Messages, and –91 dBm for Ground Uplink (ground-to-air) messages.

**Note:** *The above requirement also ensures appropriate message success rate for Basic UAT ADS-B Messages.*

## 2.5 Ground Station Operation

The UAT ground station will operate as a UAT ADS-B sensor similar to that of airborne units. The UAT System has been designed to support line-of-sight air-to-ground ADS-B coverage from a single ground station, even in future high density airspaces. The ground subsystem will also be capable of transmitting UAT Ground Uplink Messages in one or more of the 32 assigned Ground Segment time slots. TIS-B uplink from a UAT ground station preferably will utilize the UAT ADS-B Message format and the ADS-B segment of the UAT frame; in this event, the avionics receiving subsystem makes no distinction in its processing of UAT ADS-B and TIS-B data (although the airborne application can distinguish these via the Address Qualifier field). Alternatively, in particular traffic environments, a UAT ground station may transmit TIS-B information in one or more of the 32 assigned Ground Segment time slots.

The typical UAT ground station antenna is a 6-8 dBi omni DME-style. High density traffic environments may require use of separate transmit and receive antenna, and/or sectorized receive antenna (see Appendix A of this Manual). Figure 2-4 gives an overview of the ground station.




**<u>Figure 2-4:</u> UAT Ground Station Simplified Block Diagram**

A single ground station antenna/transceiver is capable of supporting the following functions:

- UAT ADS-B sensor.
- Providing time-of-arrival measurement of UAT ADS-B transmission for independent range to target measurement based on a single sensor independently of the ADS-B reported position.
- Ground broadcast service uplink (e.g., TIS-B).
- Providing timing beacon to airborne users that can serve as backup timing (see §6.1).

Networked ground stations with overlapping coverage can support surveillance based on the "multi-lateration" technique even if the aircraft that is under surveillance is unable to report its position within its UAT ADS-B Message.

Additional guidance on operation of ground infrastructure including network aspects and interference considerations is provided in Appendix A of this Manual.

# 3 UAT Messages

## 3.1 UAT Message Formats

### 3.1.1 UAT ADS-B Message Formats

The UAT ADS-B Message format is shown in Figure 3-1. Each message element is described in detail in §3.1.1 through §3.1.1.3.

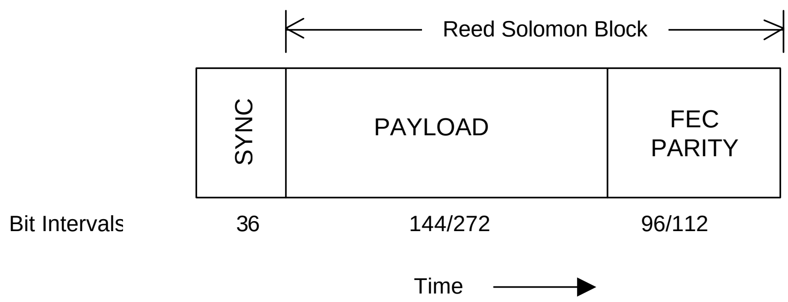



**Figure 3-1: UAT ADS-B Message Format**

***Notes:***

1. *All bit intervals depicted in Figure 3-1 comprise the ACTIVE state of the transmitter as defined in §3.1.1.1.*

2. *Traffic Information Services-Broadcast (TIS-B) transmissions preferably use the UAT ADS-B Message format — including use of the same synchronization pattern. Other approaches are possible, but beyond the scope of this Manual.*

#### 3.1.1.1 Transmitter Power Output Format

The Time/Amplitude profile of a UAT ADS-B Message Transmission **shall** fall within the following limits relative to a *reference time* defined as the beginning of the first bit of the synchronization sequence (§3.1.1.2) appearing at the output port of the equipment.

***Notes:***

1. *All power requirements for subparagraphs "**a**" through "**f**" below apply to the selected antenna port for installations that support transmitter diversity. The RF power output on the non-selected antenna port **shall** be at least 20 dB below the level on the selected port.*

2. *All power requirements for subparagraphs "**a**" and "**f**" assume a 300 kHz measurement bandwidth. All power requirements for subparagraphs "**b**," "**c**," "**d**" and "**e**" assume a 2 MHz measurement bandwidth.*

a. Prior to 8 bit periods before the reference time, the average RF output power **shall not** exceed –80 dBm.

   ***Note:*** *This unwanted power requirement is necessary to ensure that the UAT ADS-B Transmitting Subsystem does not prevent closely located UAT receiving equipment from meeting its requirements. It assumes that the isolation between transmitter and receiver equipment exceeds 20 dB.*

b. Between 8 and 4 bit periods prior to the reference time, the RF output power **shall** remain at least 20 dB below the minimum power requirement for the appropriate equipment class per Table 2-1.

c. During the Active state, defined as beginning at the reference time and continuing for the duration of the message (276 bit periods for the Basic Message and 420 bit periods for the Long Message), the RF output power **shall** comply with Table 2-2.

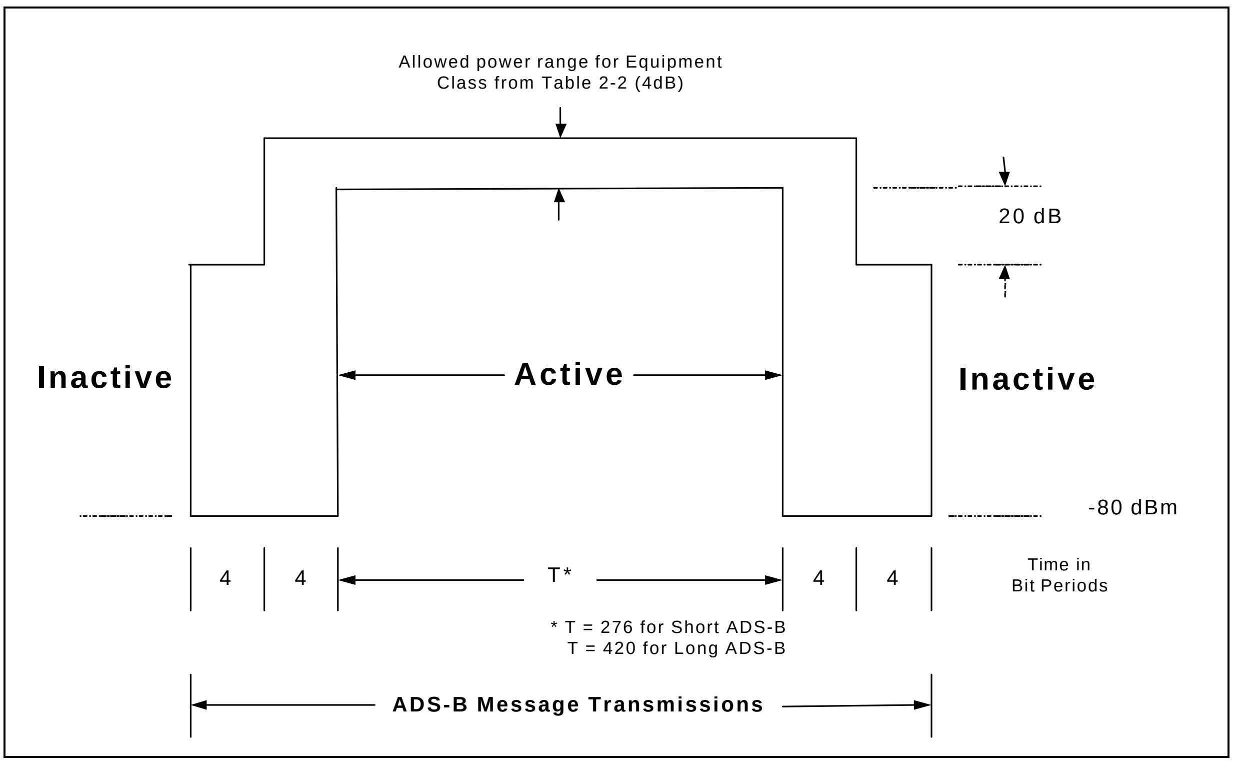
d. The RF output power **shall not** exceed the maximum limits of Table 2-2 at any time during the ADS-B Message Transmission, as shown in Figure 3-2.

e. Within 4 bit periods after the end of the Active state, the RF output power **shall** be at a level at least 20 dB below the minimum power requirement for the appropriate equipment class per Table 2-1.

f. Within 8 bit periods after the end of the Active state, the average RF output power **shall** fall to a level not to exceed –80 dBm.

**<u>Note:</u>** *This unwanted power requirement is necessary to ensure that the ADS-B Transmitting Subsystem does not prevent closely located UAT receiving equipment from meeting its requirements. It assumes that the isolation between transmitter and receiver equipment exceeds 20 dB.*

These requirements are depicted graphically in Figure 3-2.




**<u>Figure 3-2:</u> Time/Amplitude Profile of ADS-B Message Transmission**

### 3.1.1.2 Synchronization

Following ramp up, the message **shall** include a 36-bit synchronization sequence. For the UAT ADS-B Messages the sequence **shall** be:

111010101100110111011010010011100010

with the left-most bit transmitted first.

### 3.1.1.3 Payload

The format, encoding and transmission order of the payload message element is defined in §3.2.

### 3.1.1.4 FEC Parity

### 3.1.1.4.1 Code Type

The FEC Parity generation **shall** be based on a systematic Reed-Solomon (RS) 256-ary code with 8-bit code word symbols. FEC Parity generation **shall** be per the following code:

a. Basic UAT ADS-B Message: Parity **shall** be per a RS (30, 18) code.

***Note:*** *This results in 12 bytes (code symbols) of parity capable of correcting up to 6 symbol errors per block.*

b. Long UAT ADS-B Message: Parity **shall** be per a RS (48, 34) code.

***Note:*** *This results in 14 bytes (code symbols) of parity capable of correcting up to 7 symbol errors per block.*

For either message length the primitive polynomial of the code **shall** be as follows:

$$p(x) = x^8 + x^7 + x^2 + x + 1\,.$$

The generator polynomial **shall** be as follows:

$$\prod_{i=120}^{P} (x - a^i)\,.$$

P = 131 for RS (30,18) code and P = 133 for RS (48,34) code

$a$ is a primitive element of a Galois field of size 256 (i.e., GF(256)).

***Note:*** *See Appendix B for more information on the implementation of the Reed Solomon code.*

### 3.1.1.4.2 Generation and Transmission Order of FEC Parity

FEC Parity bytes **shall** be ordered most significant to least significant in terms of the polynomial coefficients they represent. The ordering of bits within each byte **shall** be most significant to least significant. FEC Parity bytes **shall** follow the message payload.

***Note:*** *See Appendix B for a message generation and encoding example.*

### 3.1.2 UAT Ground Uplink Message Formats

The UAT Ground Uplink Message format is shown in Figure 3-3. Each message element is described in detail in §3.1.2.1 through §3.2.

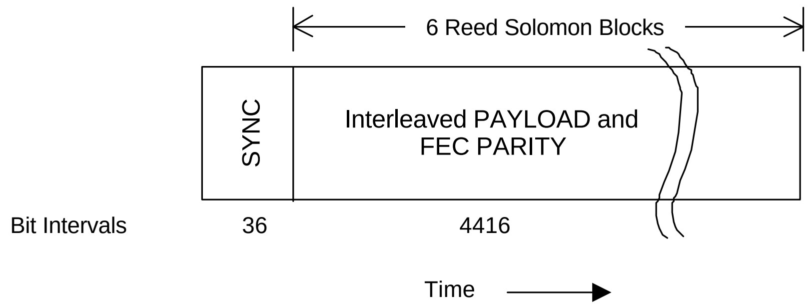



**Figure 3-3: UAT Ground Uplink Message Format**

### 3.1.2.1 Synchronization

The polarity of the bits of the synchronization sequence used for UAT Ground Uplink Messages is inverted from that used for the UAT ADS-B Message, that is, the ONEs and ZEROs are interchanged. This synchronization sequence is:

000101010011001000100101101100011101

with the left-most bit transmitted first.

***Note:*** *Because of the close relationship between the synchronization sequences used for the ADS-B and UAT Ground Uplink Messages, the same correlator can search for both simultaneously.*

### 3.1.2.2 FEC Parity (Before Interleaving and After De-interleaving)

### 3.1.2.2.1 Code Type

The FEC Parity generation is based on a systematic RS 256-ary code with 8 bit code word symbols. FEC Parity generation for each of the six blocks is per RS (92,72) code.

***Note:*** *This results in 20 bytes (symbols) of parity capable of correcting up to 10 symbol errors per block. The additional use of interleaving for the UAT Ground Uplink Message allows additional robustness against concentrated burst errors.*

The primitive polynomial of the code is as follows:

$$p(x) = x^8 + x^7 + x^2 + x + 1.$$

The generator polynomial is as follows:

$$\prod_{i=120}^{P}(x-a^{i}).$$

Where P = 139

$a$ is a primitive element of a Galois field of size 256 (i.e., GF(256)).

***Note**: See Appendix B for more information on Reed Solomon encoding.*

### 3.1.2.2.2 Generation and Transmission Order of FEC Parity

FEC Parity bytes are ordered most significant to least significant in terms of the polynomial coefficients they represent. The ordering of bits within each byte will be most significant to least significant. FEC Parity bytes will follow the message payload.

***Note**: See Appendix B for a message generation and encoding example. Even though the example is for an UAT ADS-B Message, the procedure applies to any Reed Solomon block being encoded/decoded.*

### 3.1.2.3 Interleaved Payload and FEC Parity

UAT Ground Uplink Messages are interleaved and transmitted by the Ground Station, as listed below:

a. Interleaving Procedure: The part of the burst labeled "Interleaved Payload and FEC Parity" in Figure 3-3 consists of 6 interleaved Reed-Solomon blocks. The interleaver is represented by a 6 by 92 matrix, where each entry is a RS 8-bit symbol. Each row comprises a single RS (92,72) block as shown in Table 3-1. In Table 3-1, Block numbers prior to interleaving are represented as "A" through "F." The information is ordered for transmission column by column, starting at the upper left corner of the matrix.

**Table 3-1: Ground Uplink Interleaver Matrix**

| RS Block | Payload Byte # (From §2.2.3.2) | | | | | | FEC Parity (Block /Byte #) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 1 | 2 | 3 | … | 71 | 72 | A/1 | … | A/19 | A/20 |
| B | 73 | 74 | 75 | … | 143 | 144 | B/1 | … | B/19 | B/20 |
| C | 145 | 146 | 147 | … | 215 | 216 | C/1 | … | C/19 | C/20 |
| D | 217 | 218 | 219 | … | 287 | 288 | D/1 | … | D/19 | D/20 |
| E | 289 | 290 | 291 | … | 359 | 360 | E/1 | … | E/19 | E/20 |
| F | 361 | 362 | 363 | … | 431 | 432 | F/1 | … | F/19 | F/20 |

***Note:** In Table 3-1, Payload Byte #1 through #72 are the 72 bytes (8 bits each) of payload information carried in the first RS (92,72) block. FEC Parity A/1 through A/20 are the 20 bytes of FEC parity associated with that block (A).*

*b*. Transmission Order: The bytes are then transmitted in the following order:

1,73,145,217,289,361,2,74,146,218,290,362,3,. . .,C/20,D/20,E/20,F/20.

***Note:*** *On reception these bytes must be de-interleaved so that the RS blocks can be reassembled prior to error correction decoding.*

## 3.2 UAT Message Payload

### 3.2.1 UAT ADS-B Message Payload

#### 3.2.1.1 Payload Type

Each transmitted UAT ADS-B Message contains a payload that the receiver first identifies by the "PAYLOAD TYPE CODE" encoded in the first 5 bits of the payload. The Payload Type Code allows the receiver to interpret the contents of the UAT ADS-B Message payload per the definition contained in §3.2.1.2 through §3.2.1.5.2.8.

#### 3.2.1.2 Payload Elements

For convenience, the UAT ADS-B Message payload is organized into *payload elements*. These elements contain the individual message *fields* (e.g., LATITUDE, ALTITUDE, etc) that correspond to the various report elements issued by an UAT ADS-B Receiving Subsystem to an ADS-B application. Payload elements and their lengths are shown in Table 3-2.

**Table 3-2: ADS-B Payload Elements**

| Payload Element | Payload Bytes | Applicable ADS-B Reports (§5.2.1) | Subparagraph References |
|---|---|---|---|
| HEADER (HDR) | 4 | All | §3.2.1.5.1 |
| STATE VECTOR (SV) | 13 | State Vector | §3.2.1.5.2<br>§3.2.1.5.3 |
| MODE STATUS (MS) | 12 | Mode Status | §3.2.1.5.4 |
| AUX. STATE VECTOR (AUX SV) | 5 | State Vector, Air Reference Velocity | §3.2.1.5.5 |
| TARGET STATE (TS) | 5 | Target State | §3.2.1.5.6<br>§3.2.1.5.7 |
| TRAJECTORY CHANGE + 0 (TC+0) | 12 | Trajectory Change | §3.2.1.5.8 |
| TRAJECTORY CHANGE + 1 (TC+1) | 12 | Trajectory Change | §3.2.1.5.8 |

#### 3.2.1.3 ADS-B Payload Composition by Payload Type Code

Table 3-3 provides the assignment of payload elements of Table 3-2 to each Payload Type Code.

**Table 3-3: Composition of UAT ADS-B Message Payload**

| Payload Type Code | UAT ADS-B Message Payload Byte Number | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 ---- 4 | 5 ---- 17 | 18 --------- 24 | 25 ---- 28 | 29 | 30 --- 33 | 34 |
| 0 *(Note 1)* | HDR | SV | *Res* | *Byte 19-34 Not present in Type 0* | | | |
| 1 | HDR | SV | MS | | | AUX SV | |
| 2 | HDR | SV | *Reserved (Note 2)* | | | AUX SV | |
| 3 | HDR | SV | MS | | | TS | *Res* |
| 4 | HDR | SV | *Reserved for TC+0 (Note 2)* | | | TS | *Res* |
| 5 | HDR | SV | *Reserved for TC+1 (Note 2)* | | | AUX SV | |
| 6 | HDR | SV | *Res. (Note 2)* | TS | *Res* | AUX SV | |
| 7 | HDR | SV | *Reserved (Note 3)* | | | | |
| 8 | HDR | SV | | | | | |
| 9 | HDR | SV | | | | | |
| 10 | HDR | SV | | | | | |
| 11 through 29 | HDR | *Reserved (Note 2)* | | | | | |
| 30, 31 | HDR | Reserved for Developmental Use (*Note 4)* | | | | | |

***Notes***:

1. *Payload Type 0 is conveyed in the* Basic *UAT ADS-B Message; byte 18 is reserved for future definition.*

2. *Not defined in this Manual. Reserved for definition in future versions.*

3. *Payload Types 7 – 10 will allow a degree of backward compatibility with future message definition for receivers operating according to this Manual.*

4. *Payload Types 30 and 31 are intended for developmental use, such as to support on-air flight testing of new payload types, prior to their adoption in future Manual versions. These payload types should be ignored by operational equipment.*

### 3.2.1.4 Payload Transmission Order

The UAT ADS-B Message payload **shall** be transmitted in byte order with byte #1 first. Within each byte, bits **shall** be transmitted in order with bit #1 transmitted first. Bit-level definition of the payload is provided in §3.2.1.5 through §3.2.1.5.8.

### 3.2.1.5 Payload Contents

### 3.2.1.5.1 HEADER Element

Format for the HEADER element is defined in Table 3-4. This encoding **shall** apply to UAT ADS-B Messages with PAYLOAD TYPE CODES of "0" through "31." Each of the fields shown is defined in §3.2.1.5.1.1 through §3.2.1.5.1.3.6.

**Table 3-4: Encoding of HEADER Element into UAT ADS-B Message Payload**

| Payload Byte # | Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 |
|---|---|---|---|---|---|---|---|---|
| 1 | (MSB) | PAYLOAD TYPE CODE | | | (LSB) | ADDRESS QUALIFIER | | |
| 2 | (MSB)A1 | A2 | A3 | . . . | | | | |
| 3 | | | | ADDRESS | | | | |
| 4 | | | | | . . . | A22 | A23 | A24(LSB) |

.

.

### 3.2.1.5.1.1 "PAYLOAD TYPE CODE" Field Encoding

The "PAYLOAD TYPE CODE" field is a 5-bit (bit 1 of byte 1 through bit 5 of byte 1) field used to identify the payload for decoding by the receiver. Definition of the "PAYLOAD TYPE CODE" field encoding that **shall** be used for all UAT ADS-B Messages is provided in Table 3-3.

### 3.2.1.5.1.2 "ADDRESS QUALIFIER" Field Encoding

The "ADDRESS QUALIFIER" field is a 3-bit (bit 6 of byte 1 through bit 8 of byte 1) field used to indicate what the 24-bit "ADDRESS" field represents. Definition of the "ADDRESS QUALIFIER" field encoding that **shall** be used for all UAT ADS-B Messages is provided in Table 3-5.

**Table 3-5: "ADDRESS QUALIFIER" Encoding**

| **Address Qualifier** (binary) Bit 6 | Bit 7 | Bit 8 | **Address Qualifier** (decimal) | **Address Type** | **Reference subparagraph** |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | ADS-B target with ICAO 24-bit address | §3.2.1.5.1.3.1 |
| 0 | 0 | 1 | 1 | Reserved for National use | §3.2.1.5.1.3.2 |
| 0 | 1 | 0 | 2 | TIS-B target with ICAO 24-bit address | §3.2.1.5.1.3.3 |
| 0 | 1 | 1 | 3 | TIS-B target with track file identifier | §3.2.1.5.1.3.4 |
| 1 | 0 | 0 | 4 | Surface Vehicle | §3.2.1.5.1.3.5 |
| 1 | 0 | 1 | 5 | Fixed ADS-B Beacon | §3.2.1.5.1.3.6 |
| 1 | 1 | 0 | 6 | (Reserved) | |
| 1 | 1 | 1 | 7 | (Reserved) | |

### 3.2.1.5.1.3 "ADDRESS" Field Encoding

The "ADDRESS" field is a 24-bit (bit 1 of byte 2 through bit 8 of byte 4) field used in conjunction with the "ADDRESS QUALIFIER" field to identify the participant. The meaning of the "ADDRESS" field depends on the "ADDRESS QUALIFIER" field as described in §3.2.1.5.1.3.1 through §3.2.1.5.1.3.6.

### 3.2.1.5.1.3.1 ICAO 24-Bit Aircraft Address of Transmitting Aircraft

An "ADDRESS QUALIFIER" value of ZERO (binary 000) **shall** indicate that the message is an UAT ADS-B Message from an aircraft, and that the "ADDRESS" field holds the ICAO 24-bit address that has been assigned to that particular aircraft. The ICAO Aircraft Address **shall** be stored (or "latched") in the UAT Transmitting System upon Power Up.

The UAT ADS-B Transmitting Subsystem **shall** declare a device failure in the event that its own ICAO 24-bit Address (i.e., the Mode-S Address) is invalid, unavailable, or set to all "ZEROs" or all "ONEs."

***Note:*** *The world-wide method for allocating and assigning the 24-bit ICAO aircraft addresses is described in Annex 10 to the Convention on International Civil Aviation, Volume III, Chapter 9. [ICAO Annex 10, Vol. III, Ch. 9].*

### 3.2.1.5.1.3.2 Reserved for National Use

An "ADDRESS QUALIFIER" value of ONE (binary 001) **shall** be reserved for National use. In one State the use of such a value will indicate that the message is an UAT ADS-B Message from an aircraft, and that the "ADDRESS" field holds the transmitting aircraft's self-assigned ownship temporary address.

### 3.2.1.5.1.3.3 ICAO 24-Bit Aircraft Address of TIS-B Target Aircraft

An "ADDRESS QUALIFIER" value of TWO (binary 010) is used by a UAT Ground Station providing TIS-B uplinks in the UAT ADS-B Message Format to indicate that the message is for a TIS-B target and the "ADDRESS" field holds the ICAO 24-bit address that has been assigned to the target aircraft being described in the message.

***Note:*** *The world-wide scheme for allocating and assigning the 24-bit ICAO aircraft addresses is described in Annex 10 to the Convention on International Civil Aviation, Volume III, Chapter 9. [ICAO Annex 10, Vol. III, Ch. 9].*

### 3.2.1.5.1.3.4 TIS-B Track File Identifier

An "ADDRESS QUALIFIER" value THREE (binary 011) is used by a UAT Ground Station providing TIS-B uplinks in the UAT ADS-B Message Format to indicate that the message is for a TIS-B target and that the "ADDRESS" field holds a TIS-B track file identifier by which the TIS-B data source identifies the target aircraft being described in the message.

***Note:*** *It is beyond the scope of this Manual to specify the method by which a TIS-B service provider would assign track file identifiers for those TIS-B targets for which the ICAO 24-bit address is unknown.*

### 3.2.1.5.1.3.5 Surface Vehicle Address

An "ADDRESS QUALIFIER" value of FOUR (binary 100) is used by the UAT Transmitting Subsystem of a surface vehicle to indicate that the "ADDRESS" field holds the address of a surface vehicle authorized to transmit UAT ADS-B Messages.

***Note:*** *It is beyond the scope of this Manual to specify the method by which UAT ADS-B surface vehicle addresses are assigned.*

### 3.2.1.5.1.3.6 Fixed ADS-B Beacon Address

An "ADDRESS QUALIFIER" value of FIVE (binary 101) is used to indicate that the "ADDRESS" field holds the address assigned to a fixed UAT ADS-B beacon or "parrot."

***Note:*** *It is beyond the scope of this Manual to specify the method by which UAT ADS-B beacon addresses are assigned.*

### 3.2.1.5.2 STATE VECTOR Element

Format for the STATE VECTOR element is defined in Table 3-6. This encoding **shall** apply to UAT ADS-B Messages with PAYLOAD TYPE CODES of "0" through "10," when the ADDRESS QUALIFIER value is "0," "4" or "5." Each of the fields shown is defined in §3.2.1.5.2.1 through §3.2.1.5.2.10.

**Table 3-6: Format of STATE VECTOR Element**

| Payload Byte # | Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 |
|---|---|---|---|---|---|---|---|---|
| 5 | (MSB) | | | | | | | |
| 6 | | | | LATITUDE (WGS-84) | | | | |
| 7 | | | | | | | (LSB) | (MSB) |
| 8 | | | | | | | | |
| 9 | | | | LONGITUDE (WGS-84) | | | | |
| 10 | | | | | | | (LSB) | Alt Type |
| 11 | (MSB) | | | ALTITUDE | | | | |
| 12 | | | | (LSB) | (MSB) | NIC | | (LSB) |
| 13 | (MSB) A/G STATE | | Reserved | | | | | |
| 14 | | | | HORIZONTAL VELOCITY | | | | |
| 15 | | | | | | | | |
| 16 | | VERTICAL VELOCITY or A/V LENGTH/WIDTH CODE | | | | | | |
| 17 | | | | | UTC | Reserved | | |

### 3.2.1.5.2.1 "LATITUDE" and "LONGITUDE" Field Encoding

a. The "LATITUDE" field is a 23-bit (bit 1 of byte 5 through bit 7 of byte 7) field used to encode the latitude provided to the UAT ADS-B Transmitting Subsystem in WGS-84. The encoding of this field **shall** be as indicated in Table 3-7. Also see Figure 3-4.

b. The "LONGITUDE" field is a 24-bit (bit 8 of byte 7 through bit 7 of byte 10) field used to encode the longitude provided to the UAT ADS-B Transmitting Subsystem in WGS-84. The encoding of this field **shall** be as indicated in Table 3-7. Also see Figure 3-4.

c. The encoding of ALL ZEROs in the "LATITUDE" <u>and</u> "LONGITUDE" <u>and</u> "NIC" (§3.2.1.5.2.4) fields **shall** indicate that Latitude/Longitude information is "unavailable."

***Note**: Since the encoding of ALL ZEROs is a valid location on the earth, UAT ADS-B Receiving Subsystems will interpret this as Latitude/Longitude information "unavailable" only if the NIC field is also set to ZERO.*

If either the Latitude Input or the Longitude Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the LATITUDE, LONGITUDE and NIC fields **shall** default to a value of ALL ZEROs.

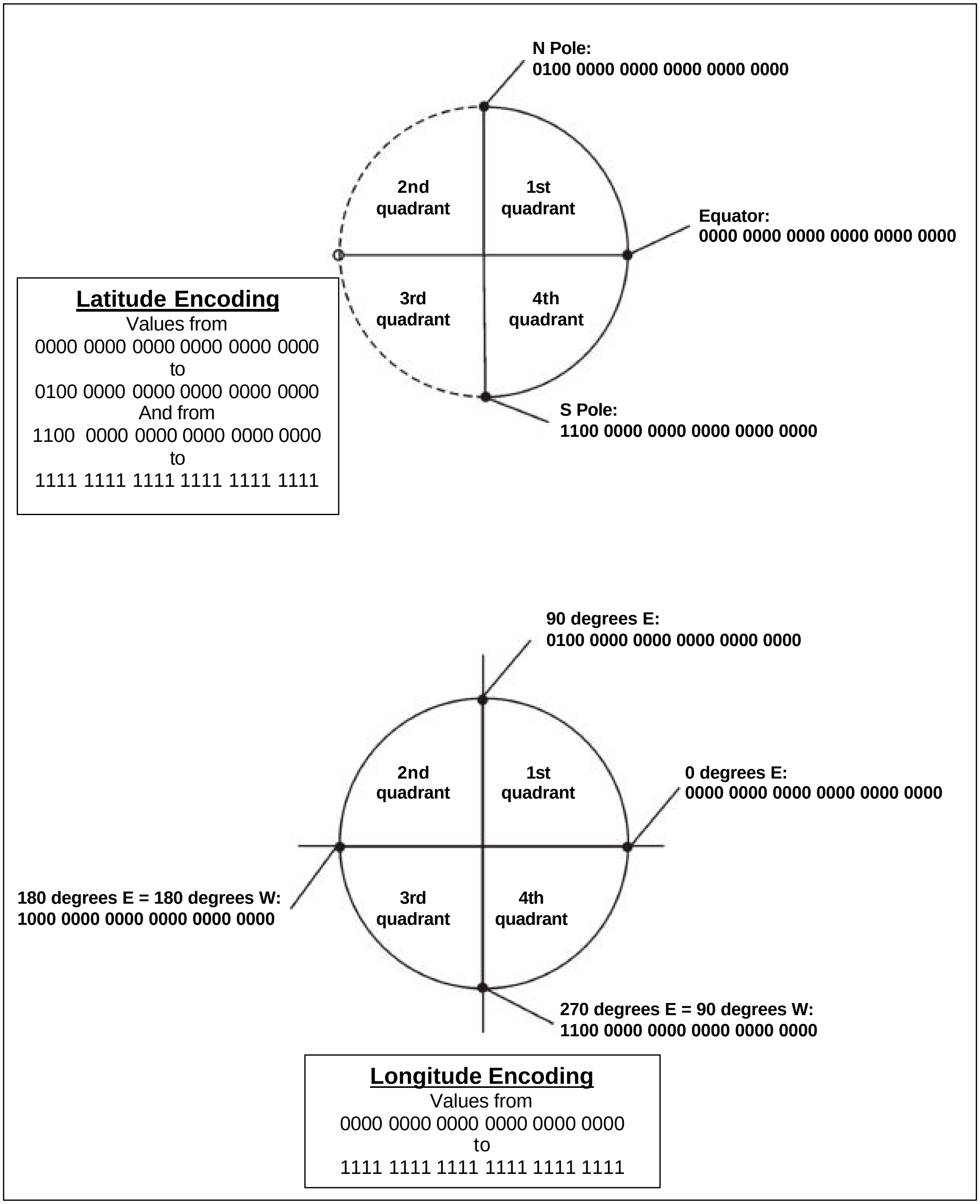
**Table 3-7: Angular Weighted Binary Encoding of Latitude and Longitude**

| Quadrant | "LATITUDE" or "LONGITUDE" bits | | Meaning $LSB = \frac{360}{2^{24}} = 2.145767 \; x10^{-5\circ}$ | |
|---|---|---|---|---|
| | MSB | LSB | **Latitude** | **Longitude** |
| | 0000 0000 0000 0000 0000 0000 | | ZERO degrees (Equator) | ZERO degrees (Prime Meridian) |
| 1st | 0000 0000 0000 0000 0000 0001 | | *LSB* degrees North | *LSB* degrees East |
| quadrant | ... | | ... | ... |
| | 0011 1111 1111 1111 1111 1111 | | (90-*LSB*) degrees North | (90-*LSB*) degrees East |
| | 0100 0000 0000 0000 0000 0000 | | 90 degrees (North Pole) | 90 degrees East |
| $2^{nd}$ | 0100 0000 0000 0000 0000 0001 | | <Illegal Values> | (90+*LSB*) degrees East |
| quadrant | ... | | <Illegal Values> | ... |
| | 0111 1111 1111 1111 1111 1111 | | <Illegal Value> | (180-*LSB*) degrees East |
| | 1000 0000 0000 0000 0000 0000 | | <Illegal Value> | 180 degrees East or West |
| $3^{rd}$ | 1000 0000 0000 0000 0000 0001 | | <Illegal Value> | (180-*LSB*) degrees West |
| quadrant | ... | | <Illegal Values> | ... |
| | 1011 1111 1111 1111 1111 1111 | | <Illegal Values> | (90-LSB) degrees West |
| | 1100 0000 0000 0000 0000 0000 | | -90 degrees (South Pole) | 90 degrees West |
| $4^{th}$ | 1100 0000 0000 0000 0000 0001 | | (90-*LSB*) degrees South | (90-*LSB*) degrees West |
| quadrant | ... | | ... | ... |
| | 1111 1111 1111 1111 1111 1111 | | *LSB* degrees South | *LSB* degrees West |

***Notes:***

1. *The most significant bit (MSB) of the angular weighted binary "LATITUDE" is omitted from the transmitted message. This is because all valid Latitudes, other than the Latitude of the North pole (exactly 90 degrees North), have the same value in their 2 most significant bits. The application using the ADS-B reports has the responsibility to differentiate the North and South Poles.*

2. *Raw data used to establish the Latitude or Longitude fields will normally have more resolution (i.e., more bits) than that required by the Latitude or Longitude fields. When converting such data to the Latitude or Longitude subfields, the accuracy of the data **shall** be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the Latitude or Longitude field.*




**<u>Figure 3-4:</u> Angular Weighted Binary Encoding of Latitude and Longitude**

### 3.2.1.5.2.2 "ALTITUDE TYPE" Field Encoding

The "ALTITUDE TYPE" field is a 1-bit (bit 8 of byte 10) field used to identify the source of information in the "ALTITUDE" field. The encoding of this field is reflected in Table 3-8.

If the Altitude Type Selection Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the "ALTITUDE TYPE" **shall** default to a value of ZERO if Pressure Altitude is available.

**<u>Table 3-8:</u> "ALTITUDE TYPE" Encoding**

| **Altitude Type** | **"ALTITUDE" Field** (§3.2.1.5.2.3) | **"SECONDARY ALTITUDE" Field** (§3.2.1.5.5.1) |
|---|---|---|
| 0 | Pressure Altitude | Geometric Altitude |
| 1 | Geometric Altitude | Pressure Altitude |

***<u>Note</u>:*** *"Pressure Altitude" refers to "Barometric Pressure Altitude" relative to a standard atmosphere at a standard pressure of 1013.2 millibars (29.92 in Hg) and specifically **DOES NOT** refer to "Barometric Corrected Altitude."*

A means **shall** be provided to operationally inhibit the broadcast of Pressure Altitude information, making it unavailable for transmission. A means **shall** be provided to operationally select the preferred ALTITUDE TYPE that is reported if more than one ALTITUDE TYPE is available. If only one ALTITUDE TYPE is available, then that Altitude **shall** be indicated in the "ALTITUDE TYPE" field.

**<u>Note:</u>** *The means to operationally inhibit the broadcast of pressure altitude information can be used at the request of ATC, or when altitude is determined to be invalid by the pilot.*

If the Altitude Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then that Altitude **shall** be deemed unavailable for the purposes of encoding the "ALTITUDE TYPE" field.

### 3.2.1.5.2.3 "ALTITUDE" Field Encoding

The "ALTITUDE" field is a 12-bit (bit 1 of byte 11 through bit 4 of byte 12) field used to encode the altitude of the ADS-B Transmitting Subsystem. The encoding of this field **shall** be as indicated in Table 3-9.

**Table 3-9: "ALTITUDE" Encoding**

| Coding (binary) MSB LSB | Coding (decimal) | Meaning |
|---|---|---|
| 0000 0000 0000 | 0 | Altitude information unavailable |
| 0000 0000 0001 | 1 | Altitude = -1000 feet |
| 0000 0000 0010 | 2 | Altitude = -975 feet |
| … | … | … |
| 0000 0010 1000 | 40 | Altitude = -25 feet |
| 0000 0010 1001 | 41 | Altitude = ZERO feet |
| 0000 0010 1010 | 42 | Altitude = 25 feet |
| … | … | … |
| 1111 1111 1110 | 4094 | Altitude = 101,325 feet |
| 1111 1111 1111 | 4095 | Altitude > 101,337.5 feet |

**Note:** *Raw data used to establish the "ALTITUDE" field will normally have more resolution (i.e., more bits) than that required by the "ALTITUDE" field. When converting such data to the "ALTITUDE" field, the accuracy of the data* ***shall*** *be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the "ALTITUDE" field.*

### 3.2.1.5.2.4 "NIC" Field Encoding

The Navigation Integrity Category ("NIC") field is a 4-bit (bits 5 through 8 of byte 12) field used to allow surveillance applications to determine whether the reported position has an acceptable level of integrity for the intended use. The value of the NIC parameter specifies an integrity containment radius, $R_C$. The encoding of this field **shall** be as indicated in Table 3-10.

If the NIC Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the "NIC" **shall** default to a value of ALL ZEROs.

**Table 3-10: "NIC" Encoding**

| NIC (binary) MSB … LSB | NIC (decimal) | Horizontal and Vertical Containment Bounds | Comment |
|---|---|---|---|
| 0000 | 0 | $R_C \geq 37.04$ km (20 NM) | Unknown Integrity |
| 0001 | 1 | $R_C < 37.04$ km (20 NM) | RNP-10 containment radius |
| 0010 | 2 | $R_C < 14.816$ km (8 NM) | RNP-4 containment radius |
| 0011 | 3 | $R_C < 7.408$ km (4 NM) | RNP-2 containment radius |
| 0100 | 4 | $R_C < 3.704$ km (2 NM) | RNP-1 containment radius |
| 0101 | 5 | $R_C < 1852$ m (1 NM) | RNP-0.5 containment radius |
| 0110 | 6 | $R_C < 1111.2$ m (0.6 NM) | RNP-0.3 containment radius |
| 0111 | 7 | $R_C < 370.4$ m (0.2 NM) | RNP-0.1 containment radius |
| 1000 | 8 | $R_C < 185.2$ m (0.1 NM) | RNP-0.05 containment radius |
| 1001 | 9 | $R_C < 75$ m and VPL < 112 m | e.g., SBAS, HPL, VPL |
| 1010 | 10 | $R_C < 25$ m and VPL < 37.5 m | e.g., SBAS, HPL, VPL |
| 1011 | 11 | $R_C < 7.5$ m and VPL < 11 m | e.g., GBAS, HPL, VPL |
| 1100 | 12 | (Reserved) | (Reserved) |
| 1101 | 13 | (Reserved) | (Reserved) |
| 1110 | 14 | (Reserved) | (Reserved) |
| 1111 | 15 | (Reserved) | (Reserved) |

***Notes**:*

1. *The "NIC" field is closely associated with the "SIL" field (defined in §3.2.1.5.4.8). The value of the "SIL" field is the probability of the true position lying outside the containment radius, $R_C$, without alerting, including the effects of airborne equipment condition, which airborne equipment is in use, and which external signals are used.*

2. *VPL refers to the Vertical Protection Limit, which is an indication of the vertical interval within which the actual position of the transmitting participant lies, to a probability of 1 minus $10^{-7}$. HPL refers to the Horizontal Protection Limit.*

### 3.2.1.5.2.5 "A/G STATE" Field Encoding

The Air/Ground State ("A/G STATE") field is a 2-bit (bits 1 and 2 of byte 13) field that indicates the format used for representing horizontal velocity. The value of this field determines the encoding of the "HORIZONTAL VELOCITY" field. The "A/G STATE" field is composed of two (2) 1-bit fields used as follows:

1. The Vertical Status bit (bit 1 of byte 13) is used to reflect the AIRBORNE or ON-GROUND condition as determined in §3.2.1.5.2.5.1.

2. The Subsonic/Supersonic bit (bit 2 of byte 13) is used to indicate the scale factor for the velocity information. The Subsonic/Supersonic bit (bit 2 of byte 13) **shall** be set to ONE (1) if either the East – West velocity OR the North – South velocity, exceeds 1022 knots. The Subsonic/Supersonic bit (bit 2 of byte 13) **shall** be reset to ZERO (0) if the East - West and the North - South velocities, drop below 1000 knots.

The encoding of "A/G STATE" field **shall** be as indicated in Table 3-11.

**Table 3-11: "A/G STATE" Field Encoding**

| Ownship Conditions | "A/G STATE" Field Encoding | | | Resulting "HORIZONTAL VELOCITY" Subfield Formats | |
|---|---|---|---|---|---|
| | MSB | LSB | | | |
| | Vertical Status (bit 1 of byte 13) | Subsonic/Supersonic (bit 2 of byte 13) | (decimal) | "North Velocity **or** Ground Speed" Subfield Meaning | "East Velocity **or** Track Angle/Heading" Subfield Meaning |
| AIRBORNE condition. Subsonic condition. | 0 | 0 | 0 | North Velocity (LSB = 1 kt) | East Velocity (LSB = 1 kt) |
| AIRBORNE condition. Supersonic condition. | 0 | 1 | 1 | North Velocity (LSB = 4 kts) | East Velocity (LSB = 4 kts) |
| ON GROUND condition. | 1 | 0 | 2 | Ground Speed (LSB = 1 kt) | Track/Heading |
| <Reserved> | 1 | 1 | 3 | | |

### 3.2.1.5.2.5.1 Determination of Vertical Status

The UAT ADS-B Transmitting Subsystem **shall** determine its Vertical Status (i.e., AIRBORNE or ON-GROUND condition) using the procedure below.

a. If there is a means to automatically determine the Vertical Status of the ADS-B emitter target category, then such information **shall** be used to determine the Vertical Status.

***Note:*** *An "automatic" means of determining vertical status could come from a weight-on-wheels or strut switch, etc. Landing gear deployment is not considered a suitable automatic means.*

b. If there is no means to automatically determine the Vertical Status of the UAT ADS-B Transmitting Subsystem, or the automatic means becomes unavailable after the data timeout value listed in Table 5-1, then the UAT ADS-B Transmitting Subsystem **shall** assume the AIRBORNE condition except under the conditions given for each of the UAT ADS-B Emitter Category types given in Table 3-12. If the conditions given in Table 3-12 are met for the given UAT ADS-B Emitter Category, then the UAT ADS-B Transmitting Subsystem **shall** be in the ON-GROUND condition.

**<u>Table 3-12:</u> Determination of ON-GROUND Condition when there is no means to automatically determine Vertical Status**

| Emitter Category | Ground Speed | | Airspeed (if available) | | Radio Altitude (if available) |
|---|---|---|---|---|---|
| No aircraft type information | Always declare AIRBORNE condition | | | | |
| Light (ICAO) < 15,500 lbs | Always declare AIRBORNE condition | | | | |
| Small – 15,500 to 75,000 lbs | < 100 knots | ***or*** | < 100 knots | ***or*** | < 50 feet |
| Large – 75,000 to 300,000 lbs | < 100 knots | ***or*** | < 100 knots | ***or*** | < 50 feet |
| High Vortex Large (e.g., B757) | < 100 knots | ***or*** | < 100 knots | ***or*** | < 50 feet |
| Heavy (ICAO) - > 300,000 lbs | < 100 knots | ***or*** | < 100 knots | ***or*** | < 50 feet |
| Highly Maneuverable > 5G acceleration and high speed | < 100 knots | ***or*** | < 100 knots | ***or*** | < 50 feet |
| Rotocraft | Always declare AIRBORNE condition (See Note 1) | | | | |
| Glider/sailplane | Always declare AIRBORNE condition | | | | |
| Lighter than air | Always declare AIRBORNE condition (See Note 2) | | | | |
| Parachutist/sky diver | Always declare AIRBORNE condition | | | | |
| Ultra light/hang glider/paraglider | Always declare AIRBORNE condition | | | | |
| Unmanned aerial vehicle | Always declare AIRBORNE condition | | | | |
| Space/trans-atmospheric vehicle | < 100 knots | ***or*** | < 100 knots | ***or*** | < 50 feet |
| Surface vehicle—emergency vehicle | Always declare ON-GROUND condition | | | | |
| Surface vehicle—service vehicle | Always declare ON-GROUND condition | | | | |
| Point Obstacle (includes tethered balloons) | (See Note 3) | | | | |
| Cluster Obstacle | | | | | |
| Line Obstacle | | | | | |

***<u>Notes:</u>***

1. *Because of the unique operating capabilities of rotorcraft, i.e., hover, etc., an operational rotorcraft will always report the AIRBORNE condition unless the ON-GROUND condition is specifically declared in compliance with subparagraph "a." above.*

2. *Because of the unique operating capabilities of "Lighter-than-Air" vehicles, e.g., balloons, an operational "Lighter-than-Air" vehicle will always report the AIRBORNE condition unless the ON-GROUND condition is specifically declared in compliance with subparagraph "a." above.*

3. *The Vertical Status reported will be appropriate to the situation. In any case the altitude is always present in the transmitted message.*

If any of the inputs used to derive the ON-GROUND condition as specified in Table 3-12 are "unavailable" for the "Data Lifetime" timeout duration listed in Table 5-1, then the input **shall** no longer be used for the purposes of determining the ON-GROUND condition.

### 3.2.1.5.2.5.2 Validation of Vertical Status

When an automatic means of determining Vertical Status indicates ON-GROUND, the Vertical Status **shall** be changed to AIRBORNE under the conditions listed in Table 3-13.

If any of the inputs used to derive the override of the ON-GROUND condition as specified in Table 3-13 are “unavailable” for the “Data Lifetime” timeout duration listed in Table 5-1, then the input **shall** no longer be used for the purposes of overriding the ON-GROUND condition.

***Note:*** *The Vertical Status can be used by UAT ADS-B Transmitting Subsystems to select only the TOP antenna when in the ON-GROUND condition. A false indication of the automatic means could therefore impact signal availability. To minimize this possibility, this validation procedure has been established.*

**Table 3-13: Criteria for Overriding an ON-GROUND Condition Determined by Automatic Means**

| **Emitter Category** | **Ground Speed** | | **Airspeed** (if available) | | **Radio Altitude** (if available) |
|---|---|---|---|---|---|
| No aircraft type information | No Change to condition | | | | |
| Light (ICAO) < 15,500 lbs | No Change to condition | | | | |
| Small – 15,500 to 75,000 lbs | > 100 knots | ***or*** | > 100 knots | ***or*** | > 50 feet |
| Large – 75,000 to 300,000 lbs | > 100 knots | ***or*** | > 100 knots | ***or*** | > 50 feet |
| High Vortex Large (e.g., B-757) | > 100 knots | ***or*** | > 100 knots | ***or*** | > 50 feet |
| Heavy (ICAO) - > 300,000 lbs | > 100 knots | ***or*** | > 100 knots | ***or*** | > 50 feet |
| Highly Maneuverable > 5G acceleration and high speed | > 100 knots | ***or*** | > 100 knots | ***or*** | > 50 feet |
| Rotocraft | No Change to condition | | | | |

### 3.2.1.5.2.6 “HORIZONTAL VELOCITY” Subfields

The “HORIZONTAL VELOCITY” Field is composed of two components:

a. The “North Velocity or Ground Speed” component is represented by an 11-bit subfield from bit 4 of byte 13 through bit 6 of byte 14.

b. The “East Velocity or Track/Heading” component is an 11-bit subfield from bit 7 of byte 14 through bit 1 of byte 16.

Each component can assume multiple formats depending on the “A/G STATE” field. Subparagraphs §3.2.1.5.2.6.1 through §3.2.1.5.2.6.4 describe the encoding for each form of each component.

### 3.2.1.5.2.6.1 Encoding as “North Velocity” Form

When the “A/G STATE” field is set to “0,” or “1,” the “North Velocity or Ground Speed” component **shall** assume the “North Velocity” format indicated in Table 3-14.

**Table 3-14: “North Velocity” Format**

| Byte 13 | | | | | Byte 14 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 | Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 |
| **N/S Sign** | (MSB) **--North Velocity Magnitude--** (LSB) | | | | | | | | | |

a. The “N/S Sign” subfield (bit 4 of byte 13) **shall** be used to indicate the direction of the North/South velocity vector as shown in Table 3-15.

**<u>Table 3-15:</u> “North/South Sign” Encoding**

| Coding | Meaning |
|---|---|
| 0 | NORTH |
| 1 | SOUTH |

b. The “North Velocity Magnitude” subfield is a 10-bit (bit 5 of byte 13 through bit 6 of byte 14) subfield that **shall** be used to report the magnitude of the North/South velocity of the UAT ADS-B Transmitting Subsystem. The Range, Resolution and No Data encoding of the “North Velocity Magnitude” subfield **shall** be as shown in Table 3-16.

**<u>Table 3-16:</u> “North Velocity Magnitude” Encoding**

| **Coding** MSB(binary)LSB | **Coding** (decimal) | **Meaning (Subsonic Scale)** (A/G STATE = 0) | **Meaning (Supersonic Scale)** (A/G STATE = 1) |
|---|---|---|---|
| 00 0000 0000 | 0 | N/S Velocity not available | N/S Velocity not available |
| 00 0000 0001 | 1 | N/S Velocity is ZERO | N/S Velocity is ZERO |
| 00 0000 0010 | 2 | N/S Velocity = 1 knots | N/S Velocity = 4 knots |
| 00 0000 0011 | 3 | N/S Velocity = 2 knots | N/S Velocity = 8 knots |
| … | … | … | … |
| 11 1111 1110 | 1022 | N/S Velocity = 1021 knots | N/S Velocity = 4,084 knots |
| 11 1111 1111 | 1023 | N/S Velocity > 1021.5 knots | N/S Velocity > 4,086 knots |

***<u>Notes:</u>***

1. *The encoding represents Positive Magnitude data only. Direction is given completely by the N/S Sign Bit.*

2. *Raw data used to establish the “North Velocity Magnitude” subfield will normally have more resolution (i.e., more bits) than that required by the “North Velocity Magnitude” subfield. When converting such data to the “North Velocity Magnitude subfield,” the accuracy of the data **shall** be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the “North Velocity Magnitude” subfield.*

If the North Velocity Magnitude Input is “unavailable” for the “Data Lifetime” value listed for this input in Table 5-1, then the “North Velocity Magnitude” subfield **shall** default to a value of ALL ZEROs.

### 3.2.1.5.2.6.2 Encoding as “Ground Speed” Form

When the “A/G STATE” field is set to “2,” the “North Velocity or Ground Speed” component **shall** assume the “Ground Speed” format indicated in Table 3-17.

**<u>Table 3-17:</u> “Ground Speed” Format**

| Byte 13 | | | | | Byte 14 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 | Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 |
| **Reserved** | (MSB) | | | | **--Ground Speed--** | | | | | (LSB) |

a. The 1-bit subfield (bit 4 of byte 13) **shall** be "Reserved" and set to ZERO (0).

b. The "Ground Speed" subfield is a 10-bit (bit 5 of byte 13 through bit 6 of byte 14) subfield that **shall** be used to report the Ground Speed of the UAT ADS-B Transmitting Subsystem (in knots). The Range, Resolution and No Data encoding of the "Ground Speed" subfield **shall** be as shown in Table 3-18.

**<u>Table 3-18:</u> "Ground Speed" Encoding**

| **Coding** MSB(binary)LSB | **Coding** (decimal) | **Meaning (A/G STATE = 2)** |
|---|---|---|
| 00 0000 0000 | 0 | Ground Speed information not available |
| 00 0000 0001 | 1 | Ground Speed is ZERO |
| 00 0000 0010 | 2 | Ground Speed = 1 knots |
| 00 0000 0011 | 3 | Ground Speed = 2 knots |
| … | … | … |
| 11 1111 1110 | 1022 | Ground Speed = 1021 knots |
| 11 1111 1111 | 1023 | Ground Speed > 1021.5 knots |

***<u>Note:</u>*** *Raw data used to establish the "Ground Speed" subfield will normally have more resolution (i.e., more bits) than that required by the "Ground Speed" subfield. When converting such data to the "Ground Speed" subfield, the accuracy of the data **shall** be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the "Ground Speed" subfield.*

If the Ground Speed Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the "Ground Speed" subfield **shall** default to a value of ALL ZEROs.

### 3.2.1.5.2.6.3 Encoding as "East Velocity" Form

When the "A/G STATE" field is set to "0" or "1," the "East Velocity or Track Angle/Heading" component **shall** assume the "East Velocity" format indicated in Table 3-19.

**<u>Table 3-19:</u> "East Velocity" Format**

| Byte 14 | | Byte 15 | | | | | | | | Byte 16 |
|---|---|---|---|---|---|---|---|---|---|---|
| Bit 7 | Bit 8 | Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 | Bit 1 |
| **E/W Sign** | (MSB) | | | | **--East Velocity Magnitude--** | | | | | (LSB) |

a. The "E/W Sign" subfield (bit 7 of byte 14) **shall** be used to indicate the direction of the East/West velocity vector as shown in Table 3-20.

**<u>Table 3-20:</u> "East/West Sign" Encoding**

| **Coding** | **Meaning** |
|---|---|
| 0 | EAST |
| 1 | WEST |

b. The “East Velocity Magnitude” subfield is a 10-bit (bit 8 of byte 14 through bit 1 of byte 16) subfield that **shall** be used to report the East/West velocity of the UAT ADS-B Transmitting Subsystem (in knots). The Range, Resolution and No Data encoding of the “East Velocity Magnitude” subfield **shall** be as shown in Table 3-21.

**<u>Table 3-21:</u> “East Velocity Magnitude” Encoding**

| **Coding** MSB(binary)LSB | **Coding** (decimal) | **Meaning (Subsonic Scale) (A/G STATE = 0)** | **Meaning (Supersonic Scale) (A/G STATE = 1)** |
|---|---|---|---|
| 00 0000 0000 | 0 | E/W Velocity not available | E/W Velocity not available |
| 00 0000 0001 | 1 | E/W Velocity is ZERO | E/W Velocity is ZERO |
| 00 0000 0010 | 2 | E/W Velocity = 1 knots | E/W Velocity = 4 knots |
| 00 0000 0011 | 3 | E/W Velocity = 2 knots | E/W Velocity = 8 knots |
| **…** | **…** | **…** | **…** |
| 11 1111 1110 | 1022 | E/W Velocity = 1021 knots | E/W Velocity = 4,084 knots |
| 11 1111 1111 | 1023 | E/W Velocity > 1021.5 knots | E/W Velocity > 4,086 knots |

***<u>Notes:</u>***

1. *The encoding represents Positive Magnitude data only. Direction is given completely by the E/W Sign Bit.*

2. *Raw data used to establish the “East Velocity Magnitude” subfield will normally have more resolution (i.e., more bits) than that required by the “East Velocity Magnitude” subfield. When converting such data to the “East Velocity Magnitude” subfield, the accuracy of the data **shall** be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the “East Velocity Magnitude” subfield.*

If the East Velocity Magnitude Input is “unavailable” for the “Data Lifetime” value listed for this input in Table 5-1, then the “East Velocity Magnitude” subfield **shall** default to a value of ALL ZEROs.

### 3.2.1.5.2.6.4 Encoding as “Track Angle/Heading” Form

When the “A/G STATE” field is set to “2” the “East Velocity or Track Angle/Heading” component **shall** assume the “Track Angle/Heading” format indicated in Table 3-22. Heading **shall** be encoded if available; if not available Track Angle **shall** be encoded.

**<u>Table 3-22:</u> “Track Angle/Heading” Format**

| Byte 14 | | Byte 15 | | | | | | | | Byte 16 |
|---|---|---|---|---|---|---|---|---|---|---|
| Bit 7 | Bit 8 | Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 | Bit 1 |
| **TA/H Type** | | (MSB) **--Track Angle/Heading--** (LSB) | | | | | | | | |

a. The Track Angle/Heading Type (“TA/H Type”) is a 2-bit subfield (bit 7 and 8 of byte 14) that **shall** be used to distinguish Track Angle from Heading as shown in Table 3-23.

**Table 3-23: “Track Angle/Heading Type” Encoding**

| Coding | Meaning |
|---|---|
| 00 | Data Not Available |
| 01 | True Track Angle |
| 10 | Magnetic Heading |
| 11 | True Heading |

b. The “Track Angle/Heading” subfield is a 9-bit (bit 1 of byte 15 through bit 1 of byte 16) subfield that **shall** be used to report the Track Angle or Heading of the ADS-B Transmitting Subsystem as shown in Table 3-24.

**Table 3-24: “Track Angle/Heading” Encoding**

| Coding MSB(binary)LSB | Coding (decimal) | Meaning |
|---|---|---|
| 0 0000 0000 | 0 | Track Angle/Heading is ZERO |
| 0 0000 0001 | 1 | Track Angle/Heading = 0.703125 degrees |
| 0 0000 0010 | 2 | Track Angle/Heading = 1.406250 degrees |
| 0 0000 0011 | 3 | Track Angle/Heading = 2.109375 degrees |
| … | … | … |
| 1 1111 1110 | 510 | Track Angle/Heading = 358.593750 degrees |
| 1 1111 1111 | 511 | Track Angle/Heading = 359.296875 degrees |

***Note:*** *Raw data used to establish the “Track Angle/Heading” subfield will normally have more resolution (i.e., more bits) than that required by the “Track Angle/Heading” subfield. When converting such data to the “Track Angle/Heading” subfield, the accuracy of the data* ***shall*** *be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the ”Track Angle/Heading” subfield.*

If either the Track Angle/Heading Type or the Track Angle/Heading Inputs are “unavailable” for the “Data Lifetime” value listed for these inputs in Table 5-1, then the “Track Angle/Heading Type” and the “Track Angle/Heading” subfields **shall** default to values of ALL ZEROs.

### 3.2.1.5.2.7 “VERTICAL VELOCITY or A/V LENGTH/WIDTH CODE” Field

### 3.2.1.5.2.7.1 Encoding as “Vertical Velocity” Form

When the ADS-B Transmitting Subsystem is in the AIRBORNE condition, the format for the “VERTICAL VELOCITY or Aircraft/Vehicle (A/V) SIZE” field **shall** assume the “Vertical Velocity” form as shown in Table 3-25.

**Table 3-25: "Vertical Velocity" Format**

| Byte 16 | | | | | | | Byte 17 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 | Bit 1 | Bit 2 | Bit 3 | Bit 4 |
| **VV Src** | **VV Sign** | (MSB) **--Vertical Rate--** (LSB) | | | | | | | | |

### 3.2.1.5.2.7.1.1 "Vertical Velocity Source" Subfield Encoding

The Vertical Velocity Source ("VV Src") subfield is a 1-bit (bit 2 of byte 16) field that **shall** be used to indicate the source of Vertical Rate information as defined in Table 3-26.

**Table 3-26: "Vertical Velocity Source" Encoding**

| Coding | Meaning |
|---|---|
| 0 | Vertical Rate information from Geometric Source (GNSS or INS) |
| 1 | Vertical Rate information from Barometric Source |

Vertical rate information **shall** come from a Geometric source when the *Precision* condition is met, specifically when:

a. The "$NAC_P$" (§3.2.1.5.4.11) value is "10" or "11," or

b. The "NIC" value is "9," "10" or "11"

Otherwise, the *Non-Precision* condition is in effect and Vertical Rate information **shall** come from a barometric source, if available.

### 3.2.1.5.2.7.1.2 "VV Sign" Subfield Encoding

The Sign Bit for Vertical Rate ("VV Sign") subfield is a 1-bit (bit 3 of byte 16) field used to indicate the direction of the "Vertical Rate" subfield. Encoding of this subfield **shall** be as indicated in Table 3-27.

**Table 3-27: "Sign Bit for Vertical Rate" Encoding**

| Coding | Meaning |
|---|---|
| 0 | UP |
| 1 | DOWN |

### 3.2.1.5.2.7.1.3 "Vertical Rate" Subfield Encoding

The "Vertical Rate" subfield is a 9-bit (bit 4 of byte 16 through bit 4 of byte 17) field is used to report the Vertical Rate (in feet/minute) of the UAT ADS-B transmission device.

Range, Resolution, and No Data encoding of the "Vertical Rate" subfield **shall** be as shown in Table 3-28.

**Table 3-28: "Vertical Rate" Encoding**

| **Coding** MSB(binary)LSB | **Coding** (decimal) | **Meaning** |
|---|---|---|
| 0 0000 0000 | 0 | No Vertical Rate information available |
| 0 0000 0001 | 1 | Vertical Rate is ZERO |
| 0 0000 0010 | 2 | Vertical Rate = 64 feet / minute |
| 0 0000 0011 | 3 | Vertical Rate = 128 feet / minute |
| … | … | … |
| 1 1111 1110 | 510 | Vertical Rate = 32,576 feet / minute |
| 1 1111 1111 | 511 | Vertical Rate > 32,608 feet / minute |

***Notes:***

1. *The encoding shown represents Positive Magnitude data only. Direction is given completely by the VV Sign Subfield.*

2. *Raw data used to establish the "Vertical Rate" subfield will normally have more resolution (i.e., more bits) than that required by the "Vertical Rate" subfield. When converting such data to the "Vertical Rate" subfield, the accuracy of the data **shall** be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the "Vertical Rate" subfield.*

3. *For codes "0" and "1," the VV Sign Subfield is encoded as ZERO.*

If the Vertical Rate Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the "Vertical Rate" subfield **shall** default to a value of ALL ZEROs.

### 3.2.1.5.2.7.2 Encoding as "A/V Length and Width Code" Form

When the UAT ADS-B Transmitting Subsystem is in the ON-GROUND condition, the "VERTICAL VELOCITY or A/V Length and Width Code" field **shall** assume the "A/V Length and Width Code" form as shown in Table 3-29. The encoding of the "A/V Length and Width Code" **shall** be as shown in Table 3-30, using the rule that the smallest code for which the A/V satisfies both the Length Category inequality and the Width Category inequality will be used. The encoding of the "Position Offset Applied" (POA) flag shown in Table 3-31 indicates whether the reported position reflects application of a position offset to normalize the ownship navigation sensor position to the ADS-B reference point.

**Table 3-29: "A/V Length and Width" Format**

| Byte 16 | | | | | | | Byte 17 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 | Bit 1 | Bit 2 | Bit 3 | Bit 4 |
| **A/V Length and Width** | | | | **POA** | **Reserved** | | | | | |

**Table 3-30: "Aircraft/Vehicle Length and Width" Encoding**

| A/V - L/W Code (decimal) | Length Code | | | Width Code | Length Category (meters) | Width Category (meters) |
|---|---|---|---|---|---|---|
| | Bit 2 | Bit 3 | Bit 4 | Bit 5 | | |
| 0 | 0 | 0 | 0 | 0 | L < 15 | W < 11.5 |
| 1 | | | | 1 | | W < 23 |
| 2 | 0 | 0 | 1 | 0 | L < 25 | W < 28.5 |
| 3 | | | | 1 | | W < 34 |
| 4 | 0 | 1 | 0 | 0 | L < 35 | W < 33 |
| 5 | | | | 1 | | W < 38 |
| 6 | 0 | 1 | 1 | 0 | L < 45 | W < 39.5 |
| 7 | | | | 1 | | W < 45 |
| 8 | 1 | 0 | 0 | 0 | L < 55 | W < 45 |
| 9 | | | | 1 | | W < 52 |
| 10 | 1 | 0 | 1 | 0 | L < 65 | W < 59.5 |
| 11 | | | | 1 | | W < 67 |
| 12 | 1 | 1 | 0 | 0 | L < 75 | W < 72.5 |
| 13 | | | | 1 | | W < 80 |
| 14 | 1 | 1 | 1 | 0 | L < 200 | W < 80 |
| 15 | | | | 1 | | W ≥ 80 |

**Table 3-31: "Position Offset Applied" Encoding**

| Coding | Meaning |
|---|---|
| 0 | Position Offset Not Applied |
| 1 | Position Offset Applied (POA) |

### 3.2.1.5.2.8 "UTC" Field Encoding

The "UTC" field is a 1-bit field (bit 5 of byte 17) that indicates whether the ADS-B Transmitting Subsystem is in the "UTC Coupled" condition or the "Non-UTC Coupled" condition (§4). The encoding of this field **shall** be as indicated in Table 3-32.

If the UTC 1-PPS Timing Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the "UTC" field **shall** default to a value of ZERO.

**Table 3-32: "UTC" Encoding**

| Coding | Meaning |
|---|---|
| 0 | Non UTC Coupled Condition |
| 1 | UTC Coupled Condition |

### 3.2.1.5.2.9 Reserved Bits

Bits 6 through 8 of byte 17 are reserved for future use and **shall** be set to ZERO when the "ADDRESS QUALIFIER" field is set to "0," "1," "4," or "5."

### 3.2.1.5.2.10 Reserved Byte 18 of Payload Type Zero

Byte 18 of the UAT ADS-B Message Payload definition in Table 3-3, when the Payload Type is ZERO (0) is reserved for future use, and **shall** be set to ALL ZEROs.

### 3.2.1.5.3 STATE VECTOR Element (For TIS-B)

Format for the STATE VECTOR element used for a TIS-B is defined in Table 3-33. This encoding applies to UAT ADS-B Messages with PAYLOAD TYPE CODES of "0" through "10" <u>only</u> when a TIS-B target is being reported (ADDRESS QUALIFIER value is "2" or "3"). Each of the fields shown is defined in §3.2.1.5.3.1 and §3.2.1.5.3.2.

**<u>Table 3-33:</u> Format of STATE VECTOR Element (For TIS-B)**

| Payload Byte # | Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 |
|---|---|---|---|---|---|---|---|---|
| | | | | . | | | | |
| | | | | . | | | | |
| 5 | | | | | | | | |
| 6 | | | | LATITUDE (WGS-84) | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | LONGITUDE (WGS-84) | | | | |
| 10 | | | | | | | | Alt Type |
| 11 | | | | ALTITUDE | | | | |
| 12 | | | | | | NIC | | |
| 13 | A/G STATE | | Reserved | | | | | |
| 14 | | | | HORIZONTAL VELOCITY | | | | |
| 15 | | | | | | | | |
| 16 | | | | VERTICAL VELOCITY or A/V LENGTH/WIDTH CODE | | | | |
| 17 | | | | | | **TIS-B SITE ID** | | |
| | | | | . | | | | |
| | | | | . | | | | |

***<u>Note:</u>*** *Design of the TIS-B Ground Subsystem is in a preliminary phase. The message structure in Table 3-33 may be changed as this design matures.*

### 3.2.1.5.3.1 "TIS-B SITE ID" Field Encoding

The "TIS-B SITE ID" field shall be a 4-bit (bits 5 through 8 of byte 17) field with the MSB as bit 5 and the LSB as bit 8. See Table 3-59 for the encoding of this field.

***<u>Notes:</u>***

1. *The "UTC" field shown in Table 3-6 for the State Vector Element is not provided for TIS-B transmissions. The "UTC Coupled" status of the ground station transmitting TIS-B information is available in the UAT Ground Uplink Message (§3.2.2.1.4).*

2. *The application that uses TIS-B reports is assumed to make appropriate checks for a TIS-B Site ID of value ZERO. If the Address Qualifier indicates that this is a TIS-B Message, and the TIS-B Site ID indicates a value of ZERO, an error condition is indicated.*

### 3.2.1.5.3.2 Encoding for All Other Fields

The encoding of all other fields in the STATE VECTOR Element for TIS-B shown in Table 3-33 shall be consistent with that of §3.2.1.5.2.1 through §3.2.1.5.2.7.2.

### 3.2.1.5.4 MODE STATUS Element

Format for the MODE STATUS element is defined in Table 3-34. This encoding **shall** apply to UAT ADS-B Messages with PAYLOAD TYPE CODES of "1" and "3." Each of the fields shown is defined in the following subparagraphs.

**<u>Table 3-34:</u> Format of MODE STATUS Element**

| Payload Byte # | Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 |
|---|---|---|---|---|---|---|---|---|
| . . . | | | | | | | | |
| 18–19 | (MSB) EMITTER CATEGORY AND CALL SIGN CHARACTERS #1 AND #2 (Compressed Encoding) (LSB) | | | | | | | |
| 20–21 | (MSB) CALL SIGN CHARACTERS #3, #4, AND #5 (Compressed Encoding) (LSB) | | | | | | | |
| 22–23 | (MSB) CALL SIGN CHARACTERS #6, #7, AND #8 (Compressed Encoding) (LSB) | | | | | | | |
| 24 | EMERGENCY/PRIORITY STATUS | | | UAT MOPS VERSION | | | SIL | |
| 25 | (MSB) TRANSMIT MSO (LSB) | | | | | | Reserved | |
| 26 | $NAC_P$ | | | | $NAC_V$ | | | $NIC_{BARO}$ |
| 27 | CAPABILITY CODES | | OPERATIONAL MODES | | | TRUE/MAG | CSID | Reserved |
| 28–29 | Reserved | | | | | | | |
| . . . | | | | | | | | |

***<u>Note:</u>*** *In the above table, where MSB and LSB are not specifically noted, the MSB is the leftmost bit and the LSB is the rightmost bit.*

**3.2.1.5.4.1 "EMITTER CATEGORY AND CALL SIGN CHARACTERS #1 AND #2" Field**

The "EMITTER CATEGORY AND CALL SIGN CHARACTERS #1 AND #2" field is a 16-bit (bit 1 of byte 18 to bit 8 of byte 19) field encoded as the binary numeral generated as:

$$40^2 B_2 + 40 B_1 + B_0$$

Where the values $B_2$, $B_1$ and $B_0$ are:

$B_2$ - EMITTER CATEGORY (encoded as in §3.2.1.5.4.4)

$B_1$ - Character #1 of CALL SIGN (encoded as in §3.2.1.5.4.5)

$B_0$ - Character #2 of CALL SIGN (encoded as in §3.2.1.5.4.5)

**3.2.1.5.4.2 "CALL SIGN CHARACTERS #3, #4 AND #5" Field**

The "CALL SIGN CHARACTERS #3, #4 AND #5" field a 16-bit (bit 1 of byte 20 to bit 8 of byte 21) field encoded as the binary numeral generated as:

$$40^2 B_2 + 40 B_1 + B_0$$

Where the values $B_2$, $B_1$ and $B_0$ are.

$B_2$ - Character #3 of CALL SIGN (encoded as in §3.2.1.5.4.5)

$B_1$ - Character #4 of CALL SIGN (encoded as in §3.2.1.5.4.5)

$B_0$ - Character #5 of CALL SIGN (encoded as in §3.2.1.5.4.5)

**3.2.1.5.4.3 "CALL SIGN CHARACTERS #6, #7 AND #8" Field**

The "CALL SIGN CHARACTERS #6, #7 AND #8" field a 16-bit (bit 1 of byte 22 to bit 8 of byte 23) field encoded as the binary numeral generated as:

$$40^2 B_2 + 40 B_1 + B_0$$

Where the values $B_2$, $B_1$ and $B_0$ are.

$B_2$ - Character #3 of CALL SIGN (encoded as in §3.2.1.5.4.5)

$B_1$ - Character #4 of CALL SIGN (encoded as in §3.2.1.5.4.5)

$B_0$ - Character #5 of CALL SIGN (encoded as in §3.2.1.5.4.5)

### 3.2.1.5.4.4 EMITTER CATEGORY

The EMITTER CATEGORY **shall** be encoded as shown in Table 3-35.

**Table 3-35: EMITTER CATEGORY Encoding**

| (decimal) | Meaning | (decimal) | Meaning |
|---|---|---|---|
| 0 | No aircraft type information | 20 | Cluster Obstacle |
| 1 | Light (ICAO) < 15 500 lbs | 21 | Line Obstacle |
| 2 | Small - 15 500 to 75 000 lbs | 22 | (reserved) |
| 3 | Large - 75 000 to 300 000 lbs | 23 | (reserved) |
| 4 | High Vortex Large (e.g., aircraft such as B757) | 24 | (reserved) |
| 5 | Heavy (ICAO) - > 300 000 lbs | 25 | (reserved) |
| 6 | Highly Maneuverable > 5G acceleration and high speed | 26 | (reserved) |
| 7 | Rotocraft | 27 | (reserved) |
| 8 | (Unassigned) | 28 | (reserved) |
| 9 | Glider/sailplane | 29 | (reserved) |
| 10 | Lighter than air | 30 | (reserved) |
| 11 | Parachutist/sky diver | 31 | (reserved) |
| 12 | Ultra light/hang glider/paraglider | 32 | (reserved) |
| 13 | (Unassigned) | 33 | (reserved) |
| 14 | Unmanned aerial vehicle | 34 | (reserved) |
| 15 | Space/transatmospheric vehicle | 35 | (reserved) |
| 16 | (Unassigned) | 36 | (reserved) |
| 17 | Surface vehicle — emergency vehicle | 37 | (reserved) |
| 18 | Surface vehicle — service vehicle | 38 | (reserved) |
| 19 | Point Obstacle (includes tethered balloons) | 39 | (reserved) |

### 3.2.1.5.4.5 CALL SIGN

The CALL SIGN **shall** consist of eight characters, which must contain only decimal digits 0-9, the capital letters A-Z, and – as trailing pad characters only – the "space" character. Each character of the CALL SIGN **shall** be encoded as shown in Table 3-36. The left-most character of the Call Sign corresponds to Character #1; the right-most corresponds to Character #8.

If the Call Sign is not available, then all eight characters of the CALL SIGN Field **shall** be set to the Base-40 digit code 37.

The 8 characters of the CALL SIGN field **shall** be encoded with an identifier appropriate for the Emitter Category, operating rules, and procedures under which the A/V is operating. For aircraft, the Call Sign could be an abbreviation of the authorized radiotelephone Call Sign for that aircraft as assigned by ATS, the aircraft registration marking, or other authorized identifier for special operations.

***Note:*** *A Call Sign of less than 8 characters should be padded with spaces in the right-most (trailing) positions. The first character should not be a space.*

**Table 3-36: "Call Sign" Character Encoding**

| (decimal) | Character | (decimal) | Character |
|---|---|---|---|
| 0 | 0 | 20 | K |
| 1 | 1 | 21 | L |
| 2 | 2 | 22 | M |
| 3 | 3 | 23 | N |
| 4 | 4 | 24 | O |
| 5 | 5 | 25 | P |
| 6 | 6 | 26 | Q |
| 7 | 7 | 27 | R |
| 8 | 8 | 28 | S |
| 9 | 9 | 29 | T |
| 10 | A | 30 | U |
| 11 | B | 31 | V |
| 12 | C | 32 | W |
| 13 | D | 33 | X |
| 14 | E | 34 | Y |
| 15 | F | 35 | Z |
| 16 | G | 36 | SPACE |
| 17 | H | 37 | Not Available |
| 18 | I | 38 | (reserved) |
| 19 | J | 39 | (reserved) |

### 3.2.1.5.4.6 "EMERGENCY/PRIORITY STATUS" Field Encoding

The "EMERGENCY/PRIORITY STATUS" field is a 3-bit (bits 1 through 3 of byte 24) field. The encoding of this field **shall** be as indicated in Table 3-37.

If the Emergency/Priority Status Selection Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the "EMERGENCY/PRIORITY STATUS" field **shall** default to a value of ALL ZEROs.

**Table 3-37: "EMERGENCY/PRIORITY STATUS" Encoding**

| Status Code bits MSB(Binary)LSB | Status Code bits (Decimal) | Meaning |
|---|---|---|
| 000 | 0 | No emergency/Not reported |
| 001 | 1 | General emergency |
| 010 | 2 | Lifeguard/medical emergency |
| 011 | 3 | Minimum fuel |
| 100 | 4 | No communications |
| 101 | 5 | Unlawful interference |
| 110 | 6 | Downed Aircraft |
| 111 | 7 | (Reserved) |

*[Verify encodings above with SCRSP ]*

### 3.2.1.5.4.7 "UAT MANUAL VERSION" Field Encoding

The "UAT MANUAL VERSION" field is a 3-bit (bits 4 through 6 of byte 24) field. The encoding of this field **shall** be internally hard coded to ONE (binary 001) by all ADS-B Transmitting Subsystems for equipment complying with this Manual.

**Table 3-38: UAT MANUAL Version Number**

| **UAT MANUAL Version #** $_{MSB}$(Binary)$_{LSB}$ | **UAT MANUAL Version #** (Decimal) | **Meaning** |
|---|---|---|
| 000 | 0 | Reserved |
| 001 | 1 | Conformant to the first edition of the UAT MANUAL |
| 010 | 2 | Reserved |
| 011 | 3 | Reserved |
| 100 | 4 | Reserved |
| 101 | 5 | Reserved |
| 110 | 6 | Reserved |
| 111 | 7 | Reserved |

### 3.2.1.5.4.8 "SIL" Field Encoding

The Surveillance Integrity Level ("SIL") field is a 2-bit (bits 7 and 8 of byte 24) field used to define the probability of the integrity containment radius, used in the "NIC" field, being exceeded, without alerting. This includes the effects of airborne equipment condition, which airborne equipment is in use, and which external signals are being used by the navigation source. The encoding of the "SIL" field **shall** be as indicated in Table 3-39.

If the "SIL" field is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the "SIL" field **shall** default to a value of ALL ZEROs.

**Table 3-39: "SIL" Encoding.**

| **SIL** (binary) | **SIL** (decimal) | **Probability of Exceeding the $R_C$ Integrity Containment Radius Without Detection** | **Exemplary Navigation Source** |
|---|---|---|---|
| 00 | 0 | Unknown | |
| 01 | 1 | $1 \times 10^{-3}$ per flight hour or per operation | |
| 10 | 2 | $1 \times 10^{-5}$ per flight hour or per operation | e.g., RNP Level reporting Flight Management System |
| 11 | 3 | $1 \times 10^{-7}$ per flight hour or per operation | e.g., GNSS Receiver |

***Note:*** *It is assumed that SIL is a static (unchanging) value that depends on the position sensor being used. Thus, for example, if an UAT ADS-B participant reports a NIC code of 0 because four or fewer satellites are available for a GPS fix, there would be no need to change the SIL code until a different navigation source were selected for the positions being reported in the SV report.*

### 3.2.1.5.4.9 "TRANSMIT MSO" Field Encoding

The "TRANSMIT MSO" field is a 6-bit (bits 1 through 6 of byte 25) field that **shall** be used to encode the 6 LSBs of the Message Start Opportunity (§4.1.2.1) determined for this message transmission.

### 3.2.1.5.4.10 Reserved Bits

Bits 7 and 8 of byte 25 are reserved for future use and **shall** be set to ALL ZEROs for equipment conforming to this Manual.

***Note:*** *This field is reserved for future reporting of Barometric Altitude Quality (BAQ).*

### 3.2.1.5.4.11 "$NAC_P$" Field Encoding

The Navigation Accuracy Category for Position ("$NAC_P$") field is a 4-bit (bits 1 through 4 of byte 26) field used for applications to determine if the reported State Vector has sufficient position accuracy for the intended use. The encoding of the "$NAC_P$" field **shall** be as indicated in Table 3-40.

If the "$NAC_P$" field is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the "$NAC_P$" field **shall** default to a value of ALL ZEROs.

**Table 3-40: "$NAC_P$" Encoding**

| **$NAC_P$** (binary) MSB LSB | **$NAC_P$** (decimal) | **95% Horizontal and Vertical Accuracy Bounds (EPU and VEPU)** | **Comment** | **Notes** |
|---|---|---|---|---|

| $NAC_P$ (binary) MSB LSB | $NAC_P$ (decimal) | 95% Horizontal and Vertical Accuracy Bounds (EPU and VEPU) | Comment | Notes |
|---|---|---|---|---|
| 0000 | 0 | EPU ≥ 18.52 km (10 NM) | Unknown accuracy | |
| 0001 | 1 | EPU < 18.52 km (10 NM) | RNP-10 accuracy | 1 |
| 0010 | 2 | EPU < 7.408 km (4 NM) | RNP-4 accuracy | 1 |
| 0011 | 3 | EPU < 3.704 km (2 NM) | RNP-2 accuracy | 1 |
| 0100 | 4 | EPU < 1852 m (1NM) | RNP-1 accuracy | 1 |
| 0101 | 5 | EPU < 926 m (0.5 NM) | RNP-0.5 accuracy | 1 |
| 0110 | 6 | EPU < 555.6 m (0.3 NM) | RNP-0.3 accuracy | 1 |
| 0111 | 7 | EPU < 185.2 m (0.1 NM) | RNP-0.1 accuracy | 1 |
| 1000 | 8 | EPU < 92.6 m (0.05 NM) | e.g., GNSS (e.g. GPS with SA) | |
| 1001 | 9 | EPU < 30 m and VEPU < 45 m | e.g., GNSS high accuracy (e.g GPS with SA off) | 2 |
| 1010 | 10 | EPU < 10 m and VEPU < 15 m | e.g., SBAS | 2 |
| 1011 | 11 | EPU < 3 m and VEPU < 4 m | e.g., GBAS | 2 |
| 1100 | 12 | (Reserved) | | |
| 1101 | 13 | (Reserved) | | |
| 1110 | 14 | (Reserved) | | |
| 1111 | 15 | (Reserved) | | |

***Notes***:

1. *RNP accuracy includes error sources other than sensor error, whereas horizontal error for $NAC_P$ only refers to horizontal position error uncertainty.*

2. *If geometric altitude is not being reported then the VEPU tests are not assessed.*

3. *The Estimated Position Uncertainty (EPU) used in is a 95% accuracy bound on horizontal position. EPU is defined as the radius of a circle, centered on the reported position, such that the probability of the actual position being outside the circle is 0.05. When reported by a GNSS system, EPU is commonly called HFOM (Horizontal Figure of Merit).*

4. *Likewise, Vertical Estimated Position Uncertainty (VEPU) is a 95% accuracy limit on the vertical position. VEPU is defined as a vertical position limit, such that the probability of the actual vertical position differing from the reported vertical position by more than that limit is 0.05. When reported by a GNSS system, VEPU is commonly called VFOM (Vertical Figure of Merit).*

[*Verify accuracy of terminology above with GNSSP and SCRSP*.]

### 3.2.1.5.4.12 "$NAC_V$" Field Encoding

The Navigation Accuracy Category for Velocity ("$NAC_V$") field is a 3-bit (bits 5 through 7 of byte 26) field used for applications to determine if the reported State Vector has sufficient velocity accuracy for the intended use. The "$NAC_V$" field reflects the least accurate velocity component being transmitted. The "$NAC_V$" field **shall** be encoded as indicated in Table 3-41.

If the "$NAC_V$" field is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the "$NAC_V$" field **shall** default to a value of ALL ZEROs.

**<u>Table 3-41:</u> "$NAC_V$" Encoding**

| $NAC_V$ (binary) MSB LSB | $NAC_V$ (decimal) | Horizontal Velocity Error (95%) | Vertical Geometric Velocity Error (95%) |
|---|---|---|---|
| 000 | 0 | Unknown or ≥ 10 m/s | Unknown or ≥ 50 feet (15.24 m) per second |
| 001 | 1 | < 10 m/s | < 50 feet (15.24 m) per second |
| 010 | 2 | < 3 m/s | < 15 feet (4.57 m) per second |
| 011 | 3 | < 1 m/s | < 5 feet (1.52 m) per second |
| 100 | 4 | < 0.3 m/s | < 1.5 feet (0.46 m) per second |
| 101 | 5 | (Reserved) | (Reserved) |
| 110 | 6 | (Reserved) | (Reserved) |
| 111 | 7 | (Reserved) | (Reserved) |

### 3.2.1.5.4.13 "$NIC_{BARO}$" Field Encoding

The Barometric Altitude Integrity Code ("$NIC_{BARO}$") field is a 1-bit (bit 8 of byte 26) field that indicates whether or not the barometric pressure altitude provided in the State Vector element of the payload has been cross checked against another source of pressure altitude. The "$NIC_{BARO}$" field **shall** be encoded as indicated in Table 3-42.

If the "$NIC_{BARO}$" field is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the "$NIC_{BARO}$" field **shall** default to a value of ZERO.

**<u>Table 3-42:</u> "$NIC_{BARO}$" Encoding**

| Coding | Meaning |
|---|---|
| 0 | Barometric Pressure Altitude has NOT been cross checked |
| 1 | Barometric Pressure Altitude has been cross checked |

### 3.2.1.5.4.14 "CAPABILITY CODES" Field Encoding

The "CAPABILITY CODES" field is a 2-bit (bits 1 and 2 of byte 27) field used to indicate the capability of a participant to support engagement in various operations. The "CAPABILITY CODES" field **shall** be encoded as indicated in Table 3-43.

***<u>Note:</u>*** *The Target State Report Capability flag, the Trajectory Change Report capability level and the ARV Report Capability flag can be derived from the UAT transmissions of A1, A2 and A3 system participants. Reference RTCA DO-242A, Table 3.4(d) and 3.4(e).*

**Table 3-43: "CAPABILITY CODES" Encoding**

| Byte # | Bit # | Encoding |
|---|---|---|
| Byte 27 | Bit 1 | CDTI Traffic Display Capability.<br>0 = NO<br>1 = YES |
| | Bit 2 | TCAS/ACAS Installed and Operational.<br>0 = NO<br>1 = YES |

### 3.2.1.5.4.14.1 "CDTI Traffic Display Capability" Subfield

The Capability Code for "Cockpit Display of Traffic Information (CDTI) traffic display capability" **shall** be set to ONE if the transmitting aircraft has the capability of displaying nearby traffic on a CDTI. Otherwise, this code **shall** be ZERO.

If the "CDTI Traffic Display Capability" field is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the "CDTI Traffic Display Capability" field **shall** default to a value of ZERO.

### 3.2.1.5.4.14.2 "TCAS/ACAS Installed and Operational" Subfield

The Capability Code for "TCAS/ACAS installed and operational" **shall** be set to ONE if the transmitting aircraft is fitted with a TCAS (ACAS) computer and that computer is turned on and operating in a mode that can generate Resolution Advisory (RA) alerts. Likewise, this Capability Code **shall** be set to one if the transmitting ADS-B equipment cannot ascertain whether or not a TCAS II or ACAS computer is installed, or cannot ascertain whether that computer, if installed, is operating in a mode that can generate RA alerts. Otherwise, this Capability Code **shall** be ZERO.

If the "TCAS/ACAS installed and operational" field is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the "TCAS/ACAS installed and operational" field **shall** default to a value of ONE.

***Note:*** *A value of ONE is intended to signal a receiving ADS-B application that if it is necessary to avoid the transmitting aircraft, this should be done by horizontal rather than vertical maneuvers, because a Resolution Advisory from TCAS II or ACAS will advise the pilot to maneuver vertically. If it is unknown whether or not the transmitting aircraft has TCAS, it should set this Capability Code to ONE so that receiving aircraft will be more likely to use horizontal than vertical maneuvers if necessary to avoid the transmitting aircraft.*

[*Verify with RTCA SC-186 that the names of this field accurately reflects its meaning?*]

### 3.2.1.5.4.15 "OPERATIONAL MODES" Field Encoding

The "OPERATIONAL MODES" field is a 3-bit (bits 3 through 5 of byte 27) field used to indicate the capability of a participant to support engagement in various operations. The "OPERATIONAL MODES" field **shall** be encoded as indicated in Table 3-44.

**Table 3-44: "OPERATIONAL MODES" Encoding**

| Byte # | Bit # | Encoding |
|---|---|---|
| Byte 27 | Bit 3 | TCAS/ACAS Resolution Advisory Active Flag.<br>0 = NO<br>1 = YES |
| | Bit 4 | IDENT Switch Active Flag.<br>0 = NOT Active (> 20 seconds since activated by pilot)<br>1 = Active (<= 20 seconds since activated by pilot) |
| | Bit 5 | "Receiving ATC Services" Flag<br>0 = NOT Receiving ATC Services<br>1 = Receiving ATC Services |

### 3.2.1.5.4.15.1 "TCAS/ACAS Resolution Advisory Active" Flag

If the "TCAS/ACAS Installed and Operational" subfield is set to ZERO, then a transmitting ADS-B participant **shall** set the "TCAS/ACAS Resolution Advisory Active" Flag to ZERO. Otherwise:

1. If a Resolution Advisory is known to be in effect, a transmitting ADS-B participant **shall** set the "TCAS/CAS Resolution Advisory Active" Flag to ONE in the messages that it transmits to support the MS report so long as a TCAS/ACAS resolution advisory is in effect.

2. Likewise this Flag **shall** be set to ONE if the transmitting ADS-B equipment cannot ascertain whether the TCAS II or ACAS computer is currently issuing a Resolution Advisory.

3. If the "TCAS/ACAS Resolution Advisory Active" Flag is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the "TCAS/ACAS Resolution Advisory Active" Flag **shall** default to a value of ONE.

4. At all other times, the transmitting ADS-B participant **shall** set the "TCAS/ACAS Resolution Advisory Active" Flag to ZERO.

[*Verify with RTCA SC-186 that the names of this field accurately reflects its meaning*?]

### 3.2.1.5.4.15.2 "IDENT Switch Active" Flag

The "IDENT Switch Active" Flag is activated by an IDENT switch. Upon activation of the IDENT switch, this flag **shall** be set to ONE in all scheduled UAT ADS-B Messages containing the MODE STATUS element for an interval of 20 seconds +/-4 seconds. After the time interval expires, the flag **shall** be set to ZERO.

***Note:*** *This allows an ATC ground station 4-5 reception opportunities to receive the IDENT indication.*

If the “IDENT Switch Active” Flag is “unavailable” for the “Data Lifetime” value listed for this input in Table 5-1, then the “IDENT Switch Active” Flag **shall** default to a value of ZERO.

#### 3.2.1.5.4.15.3 “Receiving ATC Services” Flag

The “Receiving ATC Services” flag is based on a pilot setting. This flag **shall** be set to ONE to indicate that the transmitting ADS-B participant is receiving ATC services; when not receiving ATC services, a transmitting ADS-B participant should set this flag to ZERO.

If the “Receiving ATC Services” field is “unavailable” for the “Data Lifetime” value listed for this input in Table 5-1, then the “Receiving ATC Services” field **shall** default to a value of ZERO.

***Note:*** *This provides for a ground ATC system to identify an aircraft that is receiving ATC services, similar to an SSR transponder providing a squawk code of other than “1200.”*

#### 3.2.1.5.4.16 “True/Magnetic Heading” Flag

The “True/Magnetic Heading” Flag in the Mode-Status Element is a one-bit field (bit 6 of byte 27) which **shall** be set to ZERO to indicate that heading is reported referenced to true north, or set to ONE to indicate that heading is reported referenced to magnetic north. This “True/Magnetic Heading” Flag supports the “Heading/Track Indicator” Flag in the TARGET STATE Element defined in §3.2.1.5.6.1.1.

If the “True/Magnetic Heading” Flag field is “unavailable” for the “Data Lifetime” value listed for this input in Table 5-1, then the “True/Magnetic Heading” Flag field **shall** default to a value of ZERO.

#### 3.2.1.5.4.17 Call Sign Identification (CSID)

The Call Sign Identification (CSID) Flag in the Mode Status Element is a one-bit field (bit 7 of byte 27) which **shall** be set to ONE (1) in this version of this Manual.

#### 3.2.1.5.4.18 Reserved Bits

This Reserved Bits field is a 17-bit (bit 8 of byte 27 through bit 8 of byte 29) field used that may be used in the future to indicate the capability of a participant to support engagement in various operations. This Reserved Bits field is reserved for future use and **shall** be set to ALL ZEROs.

### 3.2.1.5.5 AUXILIARY STATE VECTOR Element

Format for the AUXILIARY STATE VECTOR element is defined in Table 3-45. This encoding **shall** apply to UAT ADS-B Messages with “PAYLOAD TYPE CODES” of “1,” “2,” “5,” and “6.” Each of the fields shown is defined in the following subparagraphs.

**Table 3-45: Format of AUXILIARY STATE VECTOR Element**

| Payload Byte # | Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 |
|---|---|---|---|---|---|---|---|---|
| . . . | | | | | | | | |
| 30 | (MSB) | | | SECONDARY ALTITUDE | | | | |
| 31 | | | | (LSB) | Reserved | | | |
| 32 | Reserved | | | | | | | |
| 33 | Reserved | | | | | | | |
| 34 | Reserved | | | | | | | |
| . . . | | | | | | | | |

### 3.2.1.5.5.1 “SECONDARY ALTITUDE” Field Encoding

The “SECONDARY ALTITUDE” field is a 12-bit (bit 1 of byte 30 through bit 4 of byte 31) field used to encode either the geometric altitude or barometric pressure altitude depending on the setting of the “ALTITUDE TYPE” field (§3.2.1.5.2.2). The altitude encoded in the “SECONDARY ALTITUDE” field is the opposite type to that specified by the “ALTITUDE TYPE” field. The encoding **shall** be consistent with that used for “ALTITUDE” described in Table 3-9.

### 3.2.1.5.5.2 Reserved Bits

Bit 5 of byte 31 through bit 8 of byte 34 are reserved for future use, and **shall** be set to ALL ZEROs.

***Note:*** *This field is reserved for future definition to contain either Air-Referenced Velocity or perhaps wind vector and temperature.*

### 3.2.1.5.6 TARGET STATE Element (Payload Type Codes "3" and "4")

Format for the TARGET STATE element is defined in Table 3-46. This encoding **shall** apply to UAT ADS-B Messages with "PAYLOAD TYPE CODES" of "3" and "4."

**<u>Table 3-46:</u> Format of TARGET STATE Element (Payload Type Codes "3" and "4")**

| Payload Byte # | Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 |
|---|---|---|---|---|---|---|---|---|
| . | | | | | | | | |
| . | | | | | | | | |
| 30 | **TARGET HEADING or TRACK ANGLE INFORMATION** | | | | | | | |
| 31 | | | | | | | | |
| 32 | | | | | | | | |
| 33 | **TARGET ALTITUDE INFORMATION** | | | | | | | |
| . | | | | | | | | |
| . | | | | | | | | |

### 3.2.1.5.6.1 "TARGET HEADING or TRACK ANGLE INFORMATION" Field Encoding

The "TARGET HEADING or TRACK ANGLE INFORMATION" field is composed of subfields as indicated in Table 3-47.

**<u>Table 3-47:</u> "TARGET HEADING or TRACK ANGLE INFORMATION" Format**

| Byte 30 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 |
| **Hdg/Trk** | **Target Source Indicator (H)** | | **Mode Indicator (H)** | | **Reserved** | (MSB) | |
| Byte 31 | | | | | | | |
| Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | |
| **-- Track Heading or Track Angle --** | | | | | | (LSB) | |

### 3.2.1.5.6.1.1 "Heading/Track Indicator" Flag Encoding

The "Heading/Track Indicator" flag (bit 1 of byte 30) **shall** be set to ZERO to indicate that the "Target Heading or Track Angle" subfield conveys target heading, or ONE to indicate that it conveys target track angle. The reference direction (true north or magnetic north) is conveyed in the "True/Magnetic Heading Flag" of the Mode Status Element referenced in §3.2.1.5.4.16.

If this indication is present in the UAT Transmitting System, and if the "Heading/Track Indicator" field is "unavailable" for the "Data Lifetime" timeout listed for this field in Table 5-1, then the "Heading/Track Indicator" field **shall** default to a value of ZERO.

### 3.2.1.5.6.1.2 "Target Source Indicator (Horizontal)" Subfield Encoding

The "Target Source Indicator (Horizontal)" subfield is a 2-bit (bits 2 and 3 of byte 30) field that indicates the source of Target Heading/Track Angle information. The encoding of this field **shall** be as indicated in Table 3-48.

**Table 3-48: "Target Source Indicator (Horizontal) Encoding**

| Bit 2, Byte 30 | Bit 3, Byte 30 | **Encoding** (decimal) | **Meaning** |
|---|---|---|---|
| 0 | 0 | 0 | No Valid Horizontal Target State data is available |
| 0 | 1 | 1 | Autopilot control panel selected value, such as Mode Control Panel (MCP) or Flight Control Unit (FCU) |
| 1 | 0 | 2 | Maintaining current heading or track angle (e.g., autopilot mode select) |
| 1 | 1 | 3 | FMS/RNAV system (indicates track angle specified by leg type) |

If the Target Source Indicator (Horizontal) Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the "Target Source Indicator (Horizontal)" subfield **shall** default to a value of ALL ZEROs.

### 3.2.1.5.6.1.3 "Mode Indicator (Horizontal)" Subfield Encoding

The "Mode Indicator (Horizontal)" 2-bit (bits 4 and 5 of byte 30) subfield that reflects the aircraft's state relative to the target heading or track angle. The "Mode Indicator (Horizontal)" subfield **shall** be encoded as indicated in Table 3-49. If this indication is present in the UAT Transmitting System, and if the "Mode Indicator (Horizontal)" subfield is "unavailable" for the "Data Lifetime" timeout listed for this subfield in Table 5-1, then the "Mode Indicator (Horizontal)" subfield **shall** default to a value of ZERO.

**Table 3-49: "Mode Indicator (Horizontal)" Subfield Encoding**

| **Coding** (binary) | **Coding** (decimal) | **Meaning** |
|---|---|---|
| 00 | 0 | Mode Indicator Not Available |
| 01 | 1 | Target Heading or Track Angle being Acquired |
| 10 | 2 | Target Heading or Track Angle is Captured or is being Maintained |
| 11 | 3 | Reserved |

[Check in June meeting as to whether a note should be added here as per action taken by SCRSP/SC-186.]

### 3.2.1.5.6.1.4 Reserved Bits

Bit 6 of byte 30 is reserved for future use and **shall** always be set to ZERO.

### 3.2.1.5.6.1.5 "Target Heading or Track Angle" Subfield Encoding

The "Track Angle/Heading" subfield is a 9-bit (bit 7 of byte 30 through bit 7 of byte 31) subfield that **shall** be used to report the Track Angle or Heading of the ADS-B Transmitting Subsystem as shown in Table 3-50.

If a source for this subfield is present in the UAT Transmitting System, and if the "Track Angle/Heading" field is "unavailable" for the "Data Lifetime" timeout listed for this field in Table 5-1, then both the "Track Angle/Heading" field and the Target Source Indicator (Horizontal) **shall** default to a value of ALL ZEROs.

**Table 3-50: "Target Heading or Track Angle" Encoding**

| **Coding** MSB(binary)LSB | **Coding** (decimal) | **Meaning** |
|---|---|---|
| 0 0000 0000 | 0 | Track Angle/Heading is ZERO degrees |
| 0 0000 0001 | 1 | Track Angle/Heading = 0.703125 degrees |
| 0 0000 0010 | 2 | Track Angle/Heading = 1.406250 degrees |
| … | … | … |
| 1 1111 1110 | 510 | Track Angle/Heading = 358.593750 degrees |
| 1 1111 1111 | 511 | Track Angle/Heading = 359.296875 degrees |

***Note:*** *Raw data used to establish the "Target Heading or Track Angle" subfield will normally have more resolution (i.e., more bits) than that required by the "Target Heading or Track Angle" subfield. When converting such data to the "Target Heading or Track Angle" subfield, the accuracy of the data **shall** be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the "Target Heading or Track Angle" subfield.*

### 3.2.1.5.6.2 "TARGET ALTITUDE INFORMATION" Field Encoding

The "TARGET ALTITUDE INFORMATION" field is a 17-bit (bit 8 of byte 31 through bit 8 of byte 33) field composed of subfields as indicated in Table 3-51.

**<u>Table 3-51:</u> "TARGET ALTITUDE INFORMATION" Format**

| Byte 31 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 |
| | | | | | | | **Target Alt. Type** |
| **Byte 32** | | | | | | | |
| Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 |
| **Target Source Indicator (V)** | | **Mode Ind. (V)** | | **Target Altitude Capability** | | (MSB) | |
| **Byte 33** | | | | | | | |
| Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 |
| **-- Target Altitude --** | | | | | | | (LSB) |

#### 3.2.1.5.6.2.1 "Target Altitude Type" Flag Encoding

The "Target Altitude Type" flag is a 1-bit (bit 8 of byte 31) flag that indicates whether the target altitude is barometric pressure altitude or flight level (used for target altitudes above the transition level between altitude types), or a locally corrected altitude (used for target altitudes below the transition level). The "Target Altitude Type" **shall** be encoded as indicated in Table 3-52.

If this indication is present in the UAT Transmitting System, and if the "Target Altitude Type" flag is "unavailable" for the "Data Lifetime" timeout listed for this flag in Table 5-1, then the "Target Altitude Type" field **shall** default to a value of ZERO.

***<u>Note:</u>*** *This flag is set based on the relationship of the Target Altitude to the "transition level."*

**<u>Table 3-52:</u> Target Altitude Type Values**

| Value | Meaning |
|---|---|
| 0 | Pressure Altitude ("Flight Level") – target altitude is above transition level |
| 1 | Baro-Corrected Altitude ("MSL") – target altitude is below transition level |

### 3.2.1.5.6.2.2 "Target Source Indicator (Vertical)" Subfield Encoding

The "Target Source Indicator (Vertical)" is a 2-bit (bits 1 and 2 of byte 32) field that indicates the source of Target Altitude information. The encoding of this field **shall** be as indicated in Table 3-53.

**Table 3-53: "Target Source Indicator (Vertical)" Encoding**

| Bit 1, Byte 32 | Bit 2, Byte 32 | (decimal) | Meaning |
|---|---|---|---|
| 0 | 0 | 0 | No Valid Vertical Target State data is available |
| 0 | 1 | 1 | Autopilot Control Panel selected value such as a Mode Control Panel (MCP) or Flight Control Unit (FCU) |
| 1 | 0 | 2 | Holding Altitude |
| 1 | 1 | 3 | FMS or RNAV system |

If the Target Source Indicator (Vertical) Input is "unavailable" for the "Data Lifetime" value listed for this input in Table 5-1, then the "Target Source Indicator (Vertical)" subfield **shall** default to a value of ALL ZEROs.

### 3.2.1.5.6.2.3 "Mode Indicator (Vertical)" Subfield Encoding

The "Mode Indicator (Vertical)" is a 2-bit (bit 3 and 4 of byte 32) subfield that reflects the aircraft's state relative to the target altitude. The "Mode Indicator (Vertical)" subfield **shall** be encoded as indicated in Table 3-54. If this indication is present in the UAT Transmitting System, and if the "Mode Indicator (Vertical)" is "unavailable" for the "Data Lifetime" timeout listed for this field in Table 5-1, then the "Mode Indicator (Vertical)" subfield **shall** default to a value of ZERO.

**Table 3-54: "Mode Indicator (Vertical)" Subfield Encoding**

| Coding MSB(binary)LSB | Coding (decimal) | Meaning |
|---|---|---|
| 00 | 0 | Mode Indicator Not Available |
| 01 | 1 | Target Altitude being Acquired |
| 10 | 2 | Target Altitude Captured or Maintained |
| 11 | 3 | Reserved |

*[Check in June meeting as to whether a note should be added here as per action taken by SCRSP/SC-186.]*

### 3.2.1.5.6.2.4 "Target Altitude Capability" Subfield Encoding

The "Target Altitude Capability" is a 2-bit (bit 5 and 6 of byte 32) field that describes the value occupying the "Target Altitude" subfield. The encoding of this field **shall** be as indicated in Table 3-55.

If this indication is present in the UAT Transmitting System, and if the "Target Altitude Capability" field is "unavailable" for the "Data Lifetime" timeout listed for this field in Table 5-1, then the "Target Altitude Capability" field **shall** default to a value of ALL ZEROs.

**<u>Table 3-55:</u> "Target Altitude Capability" Encoding**

| Bit 5, Byte 32 | Bit 6, Byte 32 | Meaning |
|---|---|---|
| 0 | 0 | Target Altitude Capability Not Available |
| 0 | 1 | Capability for either holding altitude, or for autopilot control panel selected altitude |
| 1 | 0 | Capability for either holding altitude, for autopilot control panel selected altitude, or for any FMS/RNAV level-off altitude |
| 1 | 1 | Capability for holding altitude only |

### 3.2.1.5.6.2.5 "Target Altitude" Subfield Encoding

"Target Altitude" is a 10-bit (bit 7 of byte 32 through bit 8 of byte 33) field that is the aircraft's next intended level flight altitude if in a climb or descent, or its current intended altitude if commanded to hold altitude. The encoding of this field **shall** be as indicated in Table 3-56.

If this indication is present in the UAT Transmitting System, and if the "Target Altitude" subfield is "unavailable" for the "Data Lifetime" timeout listed for this field in Table 5-1, then both the "Target Altitude" and the Target Source Indicator (Vertical) subfields **shall** default to a value of ALL ZEROs

**<u>Table 3-56:</u> "Target Altitude" Encoding**

| Coding MSB(binary)LSB | Coding (decimal) | Meaning |
|---|---|---|
| 00 0000 0000 | 0 | Target Altitude information unavailable |
| 00 0000 0001 | 1 | Target Altitude = -1000 feet |
| 00 0000 0010 | 2 | Target Altitude = -900 feet |
| … | … | … |
| 00 0000 1010 | 10 | Target Altitude = -100 feet |
| 00 0000 1011 | 11 | Target Altitude = ZERO feet |
| 00 0000 1100 | 12 | Target Altitude = 100 feet |
| … | … | … |
| 11 1111 1110 | 1022 | Target Altitude = 101,100 feet |
| 11 1111 1111 | 1023 | Target Altitude > 101,150 feet |

***<u>Note:</u>*** *Raw data used to establish the Target Altitude subfield will normally have more resolution (i.e., more bits) than that required by the Target Altitude subfield. When converting such data to the Target Altitude subfield, the accuracy of the data **shall** be maintained such that it is not worse than +/- ½ LSB where the LSB is that of the Target Altitude subfield.*

### 3.2.1.5.7 TARGET STATE Element (Payload Type Code "6")

Format for the TARGET STATE element is defined in Table 3-57. This encoding **shall** apply to UAT ADS-B Messages with "PAYLOAD TYPE CODES" of "6." Each of the fields shown are defined in §3.2.1.5.6.1.5 through §3.2.1.5.6.2.5 with the exception of the byte offset indicated in Table 3-57.

**Table 3-57: Format of TARGET STATE Element**

| Payload Byte # | Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 |
|---|---|---|---|---|---|---|---|---|
| . | | | | | | | | |
| . | | | | | | | | |
| 25 | TARGET HEADING or TRACK ANGLE INFORMATION | | | | | | | |
| 26 | | | | | | | | |
| 27 | | | | | | | | |
| 28 | TARGET ALTITUDE INFORMATION | | | | | | | |
| . | | | | | | | | |
| . | | | | | | | | |

### 3.2.1.5.8 TRAJECTORY CHANGE Element

This element contains 96 bits (bytes 18 through 29) that are reserved for future definition. Equipment conforming to this Manual **shall** insert ALL ZEROs in this element whenever present in a transmitted message. See the UAT MOPS, RTCA DO-282, Appendix L to see how this reserved field could be used to meet the requirements of reporting TCR+0 and TCR+1 in the future. *[We will consider additional materials for this section concerning TCR+2 and TCR+3 at the June 2003 meeting.]*

### 3.2.2 UAT Ground Uplink Message Payload

The UAT Ground Uplink Message Payload consists of two components: the first eight bytes that comprise the UAT-Specific Header and bytes 9 through 432 that comprise the Application Data as shown in Table 3-58. Bytes and bits are fed to the interleaving process with the most significant byte, byte #1, transmitted first, and within each byte, the most significant bit, bit #1, transmitted first.

**Table 3-58: Format of the UAT Ground Uplink Message Payload**

| Byte # | Bit 1 | Bit 2 | Bit 3 | Bit 4 | Bit 5 | Bit 6 | Bit 7 | Bit 8 |
|---|---|---|---|---|---|---|---|---|
| 1 | (MSB) | | | | | | | |
| 2 | GROUND STATION LATITUDE (WGS-84) | | | | | | | |
| 3 | | | | | | | (LSB) | (MSB) |
| 4 | | | | | | | | |
| 5 | GROUND STATION LONGITUDE (WGS-84) | | | | | | | |
| 6 | | | | | | | (LSB) | POS VALID |
| 7 | UTC Coupled | Reserved | App Data Valid | (MSB) | | SLOT ID | | (LSB) |
| 8 | (MSB) | TIS-B Site ID | | (LSB) | Reserved | | | |
| 9 | APPLICATION DATA | | | | | | | |
| 432 | | | | | | | | |

[Need to consider the proposal made during the March/April meeting by Chris Moody to have length/type information for each frame within the Application data. If this proposal is adopted, the Application Data Valid field COULD be reserved or reassigned.]

## 3.2.2.1 UAT-Specific Header

### 3.2.2.1.1 "GROUND STATION LATITUDE" Field Encoding

The "GROUND STATION LATITUDE" field is a 23-bit (bit 1 of byte 1 through bit 7 of byte 3) field used to identify the latitude of the ground station. The encoding of this field by the ground station will be the same as defined for latitude information in the UAT ADS-B Message (§3.2.1.5.2.1).

**Note:** *The resolution of this field has been selected to support a potential passive ranging function.*

### 3.2.2.1.2 "GROUND STATION LONGITUDE" Field Encoding

The "GROUND STATION LONGITUDE" field is a 24-bit (bit 8 of byte 3 through bit 7 of byte 6) field used to identify the longitude of the ground station. The encoding of this field by the ground station will be the same as defined for longitude information in the UAT ADS-B Message (§3.2.1.5.2.1).

**Note:** *The resolution of this field has been selected to support a potential passive ranging function.*

#### 3.2.2.1.3 "POSITION VALID" Field Encoding

The "POSITION VALID" field is a 1-bit (bit 8 of byte 6) field used to indicate whether or not the position in the header is valid. An encoding of ONE represents a VALID position. An encoding of ZERO represents an INVALID position.

#### 3.2.2.1.4 "UTC Coupled" Field Encoding

The "UTC Coupled" field is a 1-bit (bit 1 of byte 7) field used to indicate whether or not the ground station 1 Pulse Per Second timing is valid. An encoding of ONE represents that the Ground Station is UTC-Coupled §4.1.1. An encoding of ZERO represents that the Ground Station is not UTC-Coupled.

#### 3.2.2.1.5 Reserved Bits

Bit 2 of byte 7 is reserved for future use and will always be set to ZERO.

#### 3.2.2.1.6 "APPLICATION DATA VALID" Field Encoding

The "APPLICATION DATA VALID" field is a 1-bit (bit 3 of byte 7) field used to indicate whether or not the Application Data is valid for operational use. An encoding of ONE represents VALID Application Data. An encoding of ZERO represents INVALID Application Data.

***Notes:***

1. *Airborne applications should ignore the Application Data field when this bit is set to INVALID.*

2. *This field will allow testing and demonstration of new products without impact to operational airborne systems.*

#### 3.2.2.1.7 "SLOT ID" Field Encoding

The "SLOT ID" field is a 5-bit (bit 4 through bit 8 of byte 7) field used to identify the time slot within which the UAT Ground Uplink Message transmission took place. This field is encoded as a 5-bit unsigned binary numeral.

***Note:*** *The Slot for certain ground station messages may be continually shifted for maximum interference tolerance to other users sharing the band. Airborne receivers do not need a priori knowledge of this shifting scheme; this is for ground service providers to coordinate. The actual Slot ID in use for each uplink message will always be properly encoded by the ground station.*

### 3.2.2.1.8 "TIS-B SITE ID" Field Encoding

The "TIS-B SITE ID" field is a 4-bit (bits 1, through 4 of byte 8) field used to convey the reusable TIS-B Site ID that is also encoded with each TIS-B transmission as shown in Table 3-59:

**<u>Table 3-59:</u> Encoding of TIS-B Site ID**

| Encoding | Meaning |
|---|---|
| 0000 | No TIS-B information transmitted from this site |
| 0001 | Assigned to ground stations that provide TIS-B information by TIS-B administration authority |
| through | |
| 1111 | |

***<u>Note:</u>*** *This field supports TIS-B applications that verify TIS-B transmissions were transmitted from the site located at the Latitude/Longitude encoded in the UAT-Specific Header portion of the Ground Uplink payload. The width of the field was selected based upon analysis of the needs of a potential passive ranging function.*

### 3.2.2.1.9 Reserved Bits

Bits 5 through 8 of byte 8 are reserved for future use and will be set to ALL ZEROs.

### 3.2.2.2 Ground Uplink Application Data

Definition of the Application Data field is beyond the scope of this SARPs document and will be provided by other documents.

[If April proposal by Chris Moody is accepted, the requirements for Frame Definition would go here.]

# 4 System Timing and Message Transmission Procedures

## 4.1 Avionics

### 4.1.1 Procedures for Processing of Time Data

UAT equipment derives its timing for transmitter and receiver functions from GPS/GNSS (or equivalent) time sources. The Time of Applicability of the PVT data is presumed to be within +/- 5 milliseconds of the Leading Edge of the Time Mark signal to which it applies. Time Mark information is utilized by the UAT equipment in the following ways:

a. Any extrapolation of Position data **shall** comply with the requirements of §4.1.4.1 and §4.1.4.2.

b. The UAT transmit message timing **shall** comply with the requirements of §4.2.1 and §4.2.2.

c. The UAT receiver time processing **shall** comply with the requirements of §5.2.1.

***Notes:***

1. *A possible implementation of the GPS/GNSS Time Mark pulse is illustrated in Figure 4-1, adapted from ARINC Characteristic 743A.*

2. *Determination of time source "equivalence" will be made by appropriate Certification Authorities. Useful information concerning recommended accuracy of such a time source may be found in Appendix E.*

### 4.1.1.1 UTC Coupled Condition

The "UTC Coupled" subfield **shall** be set to ONE, except under the conditions discussed in §4.1.2.

***Note:*** *Operation of the UAT system in normal mode presumes GNSS, or equivalent, equipage on system participants to, for example, prevent media access conflict with the UAT ground up-link transmissions. Short term GNSS outages are mitigated by UAT ground infrastructure that provides timing information and/or by the ability of UAT avionics to prevent Airborne UAT Transmitting Subsystems from transmitting in the Ground Uplink Segment for a minimum of 20 minutes in the absence of GNSS (§4.1.2[d]). In areas without ground up-link transmissions, there is no media access conflict.*

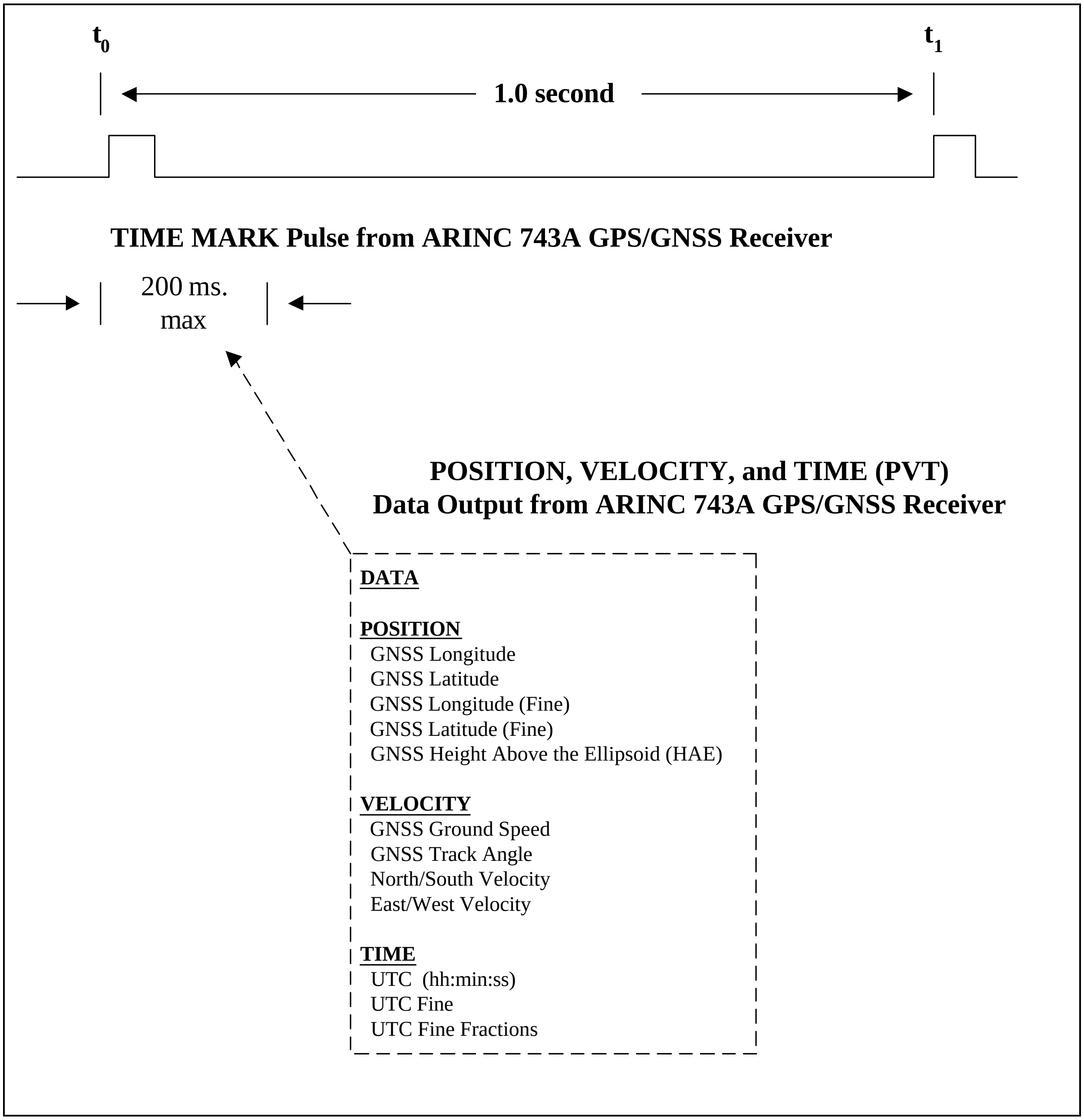



**Figure 4-1: GPS/GNSS Time Mark Pulse**

### 4.1.1.2 Non-UTC Coupled Condition

a. This condition **shall** be entered when the ADS-B equipment has not been provided a GPS/GNSS, or equivalent, time mark. This is not the normal condition; it is a degraded mode of operation.

b. Within 2 seconds of entering the Non-UTC Coupled condition, the UAT equipment **shall** set the “UTC Coupled” subfield to ZERO in any transmitted messages.

c. While in the non-UTC Coupled Condition, Airborne UAT equipment with operational receivers **shall** be capable of aligning to within +/- 6 milliseconds of UTC time based upon successful message reception of any UAT Ground Uplink Message with the “UTC Coupled” bit set.

***Note**: This assumes that the UAT Ground Uplink Message is referenced to UTC 1-second epoch.*

d. While in the non-UTC Coupled Condition when UAT Ground Uplink Messages cannot be received, the UAT transmitter **shall** estimate — or “coast” — time through the outage period such that the drift rate of estimated time, relative to actual UTC-coupled time, is no greater than 12 milliseconds in 20 minutes.

e. While in the non-UTC Coupled Condition, ADS-B transmissions **shall** continue.

f. The UAT equipment **shall** change state to the UTC coupled condition within 2 seconds of availability of the UTC coupled source.

***Notes:***

1. *Item “d” above is consistent with an initial drift rate of 10 PPM in the baud clock over the 12 millisecond air-ground segment guard time. Clock drift can be compensated up to the time coasting begins.*

2. *In the non-UTC Coupled Condition, the estimated 1 second UTC epoch signal does NOT indicate the time of validity of Position, Velocity and Time (PVT) information.*

3. *Any installations of Class A equipment involving separated transmitters and receivers must provide a mechanism to fulfill the requirement stated in subparagraph (c) above.*

4. *This reversionary timing exists for the following reasons:(**a**) to support UAT ADS-B Message transmission using an alternate source of position and velocity, if available; (**b**) to support UAT ADS-B Message transmission in absence of position and velocity data in order that any available fields are conveyed (e.g., barometric altitude) and (**c**) to ensure that a signal is provided in the event the ground network can perform an ADS-B-independent localization of the Aircraft (e.g., multilateration).*

### 4.1.2 ADS-B Media Access Timing

#### 4.1.2.1 The Message Start Opportunity (MSO)

UAT ADS-B Messages **shall** be transmitted at discrete Message Start Opportunities (MSO) chosen by a pseudo-random process. The specific pseudo-random number (*R*) chosen by an aircraft depends on the aircraft’s current position and on the previously chosen random number. Let:

N(0) = 12 L.S.B.’s of the most recent valid “LATITUDE”
N(1) = 12 L.S.B.’s of the most recent valid “LONGITUDE”

where the “LATITUDE” and “LONGITUDE” are as defined in §3.2.1.5.2.1.

The procedure below **shall** be employed to establish the transmission timing for the current UAT frame *m*.

$$R(m) = \{4001 \cdot R(m-1) + N(m \bmod 2)\} \bmod 3200$$

$$R(0) = N(0)$$

1. When in the first frame after power up, and whenever the Vertical Status is determined to be in the AIRBORNE condition, the transmitter **shall** be in the *full MSO range* mode, where the MSO is determined as follows:

   MSO = 752 + R(m)

2. Under all other conditions the transmitter **shall** be in the *restricted MSO range* mode, where the MSO is determined as follows:

   MSO = 752 + R* + R(m)mod800

   With R* = R(k) – R(k)mod800, where "k" is the frame just prior to entering the *restricted MSO range* mode.

***Notes:***

1. *Retention of N(0) and N(1) in non-volatile memory is required to prevent common MSO selections amongst A/Vs when no valid latitude and longitude is currently available.*

2. *The latitude and longitude alternate in providing a changing "seed" for the pseudo-random number generation.*

3. *The restricted range MSO mode makes the choice of MSO more nearly periodic in order to support certain surface applications.*

### 4.1.2.2 Relationship of the MSO to the Modulated Data

The optimum sample point of the first bit of the UAT synchronization sequence at the antenna terminal of the UAT equipment **shall** occur at $T_{TX}$ microseconds after the 1 second UTC epoch according to the following formula:

$$T_{TX} \text{ (microseconds)} = 6000 + (250*\text{MSO})$$

within the following tolerances:

a. +/- 500 nanoseconds for UAT equipment with an internal UTC coupled time source,

b. +/- 500 nanoseconds for UAT equipment with an external UTC coupled time source.

***Notes:***

1. *This is required to support ADS-B range validation by a receiving application. This requirement sets the ultimate timing accuracy of the transmitted messages under the*

*UTC Coupled condition. See Appendix E for a discussion of UAT Timing Considerations.*

2. *Referencing this measurement to the optimum sampling point is convenient since this is the point in time identified during the synchronization process.*

3. *There is no requirement to demonstrate this relationship when in the non-UTC Coupled condition.*

**4.1.3 Scheduling of UAT ADS-B Message Types**

**4.1.3.1 Payload Selection Cycle**

A payload selection cycle is defined to ensure timely transmission of UAT ADS-B messages of up to four different payload types: Payload Selection (PS)-A, PS-B, PS-C, and PS-D.

**4.1.3.2 ADS-B Payload Type Allocation**

If the exemplary equipment classes of Table 2-1 are used, one of the UAT ADS-B Payload Type Codes in the range of "0" through "6" specified in Table 3-3 shall be assigned to each of the 4 Payload Selections (PS) as shown in Table 4-1.

**Table 4-1: Payload Type Code Allocation**

| Equipment Class | PS-A | PS-B | PS-C | PS-D |
|---|---|---|---|---|
| A0, A1L, A1H, B0, B1 | 1 | 0 | 2 | 0 |
| A1H, B1 (see Note 2) | 3 | 6 | 0 | 6 |
| A2 | 1 | 4 | 4 | 4 |
| A3 | 1 | 4 | 5 | 4 |
| B2, B3 | 1 | 0 | 0 | 0 |

***Notes:***

1. *This schedule is to be followed regardless of the unavailability of any payload fields.*

2. *Optional Payload Type Code assignment if the installation can support transmission of Target State information.*

**4.1.4 Time Registration and Latency**

This subparagraph contains requirements imposed on the ADS-B Transmitting Subsystem relative to two parameters. The first relates to the obligation of the transmitter to ensure position data in each ADS-B Message relates to a standard *time of applicability*. The second relates to the obligation of the transmitter to reflect new ADS-B Message data available at the transmitter input into the transmitted ADS-B Message itself. This requirement is expressed as a *cutoff time* by which any updated data presented to the UAT transmitter should be reflected in the message output. Rules for time of applicability and cutoff time vary depending on the quality of SV data being transmitted and whether the transmitter is in the UTC Coupled state. The *Precision* or *Non-Precision* condition for reporting SV data is determined according to the criteria below:

a. Precision condition is in effect when:

   1. The “$NAC_P$” value is “10” or “11,” or

   2. The “NIC” value is “9,” “10” or “11”

b. Otherwise, the Non-Precision condition is in effect.

#### 4.1.4.1 Requirements When in Non-Precision Condition and UTC Coupled

When the UAT Transmitting Subsystem is in the Non-Precision Condition, and is UTC Coupled:

a. At the time of the ADS-B Message transmission, position information encoded in the “LATITUDE,” “LONGITUDE,” and “ALTITUDE” fields **shall** be applicable as of the start of the current 1 second UTC Epoch.

b. Any updated ADS-B Message fields, other than “LATITUDE,” “LONGITUDE” or “ALTITUDE,” that are provided at the ADS-B equipment input interface at least 200 milliseconds prior to the time of a scheduled ADS-B Message transmission that involves those fields, **shall** be reflected in the transmitted message.

***Notes:***

1. *Specifically, any extrapolation of position performed should be to the start of the 1-second UTC Epoch and not the time of transmission.*

2. *Velocity information cannot be extrapolated and may therefore have additional ADS-B imposed latency (generally no more than one extra second).*

#### 4.1.4.2 Requirements When in Precision Condition and UTC Coupled

When the UAT Transmitting Subsystem is in the Precision Condition, and is UTC Coupled:

a. At the time of the ADS-B Message transmission, the position information encoded in the “LATITUDE,” “LONGITUDE,” and “ALTITUDE” fields **shall** be applicable as of the start of the current 0.2 second UTC Epoch.

b. Any updated ADS-B Message fields, other than “LATITUDE,” “LONGITUDE” or “ALTITUDE,” that are provided at the ADS-B equipment input interface at least 200 milliseconds prior to the time of a scheduled ADS-B Message transmission that involves those fields, **shall** be reflected in the transmitted message.

***Notes:***

1. *Specifically, any extrapolation of position performed should be to the start of the 0.2 second UTC Epoch and not the time of transmission.*

2. *Operation in this condition assumes a GPS/GNSS sensor output rate of 5 Hz or greater is available to the ADS-B Transmitting Subsystem.*

#### 4.1.4.3 Requirements When Non-UTC Coupled

When the UAT Transmitting Subsystem is in the Non-UTC Coupled Condition:

a. Any change in an ADS-B Message field provided to the transmitter **shall** be reflected in any transmitted message containing that message field that is transmitted more than 1.0 second after the new value is received by the transmitter.

b. No extrapolation of position **shall** be performed in this condition.

***Note:*** *Even though no extrapolation of position is performed when non-UTC Coupled, the UAT Transmitting Subsystem makes no adjustment to the NIC or NAC that it receives as inputs. Also, it is not expected that a single transmitted message would ever indicate both the Non-UTC Coupled condition and a NIC or $NAC_P$ consistent with the Precision condition.*

#### 4.1.4.4 Data Timeout

At the Time of Applicability for the ADS-B Message transmission, any ADS-B Message fields without an update provided to the transmitter within the Data Lifetime parameter (in seconds) of Table 5-1 **shall** be encoded as "data unavailable" in the subsequent transmitted message containing that message field.

## 4.2 Ground Station

### 4.2.1 Procedures for Processing of Time Data

UAT Ground Station equipment derives its timing for transmitter and receiver functions from GPS/GNSS (or equivalent) time sources. Time Mark information is utilized by the UAT equipment in the following ways:

a. The UAT Ground Station transmitter message timing **shall** comply with the requirements of §4.2.1.1 and §4.2.1.2.

b. The UAT Ground Station receiver time processing **shall** comply with the requirements of §5.2.1.

***Notes:***

*1. A possible implementation of the GPS/GNSS Time Mark pulse is illustrated in Figure 4-1, adapted from ARINC Characteristic 743A.*

*2. Determination of time source "equivalence" will be made by appropriate Certification Authorities. Useful information concerning recommended accuracy of such a time source may be found in Appendix E.*

### 4.2.1.1 UTC Coupled Condition

The "UTC Coupled" subfield **shall** be set to ONE, except under the conditions discussed in §4.1.2.

***Note:*** *Operation of the UAT Ground System in normal mode presumes GNSS, or equivalent timing.*

### 4.2.1.2 Non-UTC Coupled Condition

a. This condition **shall** be entered when the ADS-B equipment has not been provided a GPS/GNSS, or equivalent, time mark. This is not the normal condition; it is a degraded mode of operation.

b. Within 2 seconds of entering the Non-UTC Coupled condition, the UAT equipment **shall** set the "UTC Coupled" subfield to ZERO in any transmitted messages.

## 4.2.2 UAT Ground Station Media Access

### 4.2.2.1 Time Slots

The UAT Ground Station **shall** establish 32 Time Slots for transmission of Ground Uplink messages as defined in Table 4-2.

**Table 4-2: Time Slot Definition for the UAT Ground Segment**

| **Slot ID #** | **Time Slot Span** | | **Slot ID #** | **Time Slot Span** | |
|---|---|---|---|---|---|
| | Starting MSO | Ending MSO | | Starting MSO | Ending MSO |
| **1** | 0 | 22 | **17** | 352 | 374 |
| **2** | 22 | 44 | **18** | 374 | 396 |
| **3** | 44 | 66 | **19** | 396 | 418 |
| **4** | 66 | 88 | **20** | 418 | 440 |
| **5** | 88 | 110 | **21** | 440 | 462 |
| **6** | 110 | 132 | **22** | 462 | 484 |
| **7** | 132 | 154 | **23** | 484 | 506 |
| **8** | 154 | 176 | **24** | 506 | 528 |
| **9** | 176 | 198 | **25** | 528 | 550 |
| **10** | 198 | 220 | **26** | 550 | 572 |
| **11** | 220 | 242 | **27** | 572 | 594 |
| **12** | 242 | 264 | **28** | 594 | 616 |
| **13** | 264 | 286 | **29** | 616 | 638 |
| **14** | 286 | 308 | **30** | 638 | 660 |
| **15** | 308 | 330 | **31** | 660 | 682 |
| **16** | 330 | 352 | **32** | 682 | 704 |

***Note:*** *MSO's represent discrete points in time*

### 4.2.2.2 Time Slot Rotation and "Channels"

a. Time Slot resources assignable to the Ground Station **shall** be made on a continually shifting basis. This assignable resource will be subsequently referred to as a "Channel" to distinguish it from a Time Slot.

b. Channel numbers 1-32 **shall** increment by 1 Time Slot per second (modulo 32).

c. The Channel number and Time Slot number **shall** be equal at midnight GPS time and every 32 seconds thereafter (see Figure 4-2).

***Note:*** *GPS time is convenient because there is never an adjustment for a "leap" second. The Ground Station need not be synchronized to GPS time on an on-going basis in order to meet this requirement.*

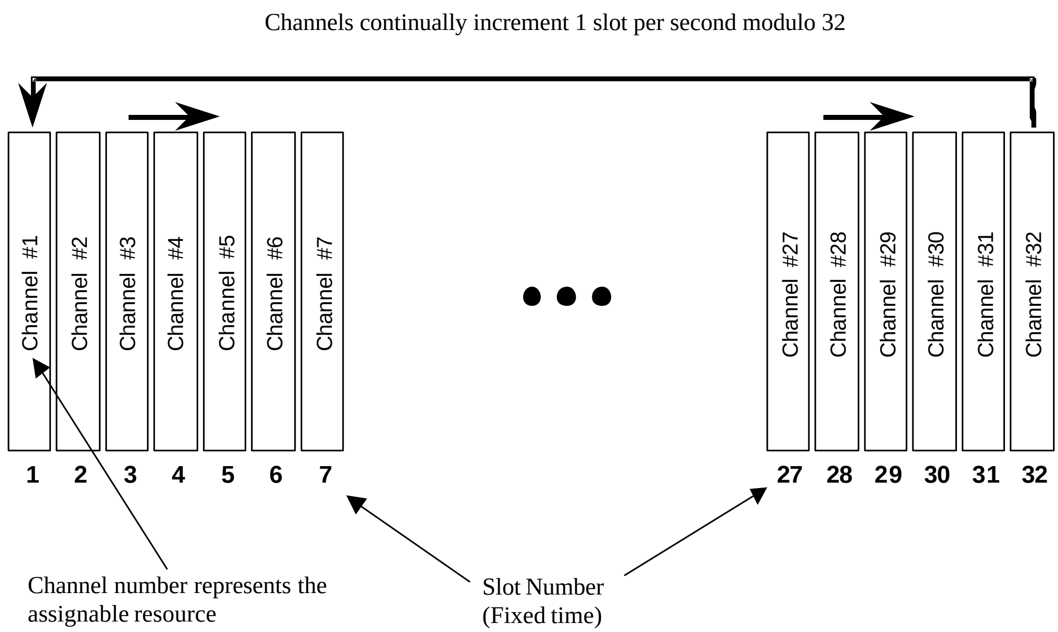



**Figure 4-2: Relationship of "Channel Numbers" to Time Slot Numbers**

***Note:*** *The reason for the Time Slot rotation is to make aircraft reception of Ground Uplink messages from a given Ground Station robust in the presence of time synchronized sources of interference in the band.*

### 4.2.2.3 Transmission of Ground Uplink Message

Ground Uplink message transmissions **shall** begin at the start of the Time Slot determined by the next available assigned Channel.

***Note:*** *The duration of a Ground Uplink message is approximately 1.5 milliseconds less than the Time Slot duration. This additional time provides a propagation guard time when adjacent Channels (Time Slots) are assigned to Ground Station ground station sites with common line of sight to the same aircraft.*

# 5 Interface Requirements for the Airborne Equipment

## 5.1 UAT Transmitter Input Requirements

This subparagraph contains requirements for access by UAT Avionics to the input elements required to compose ADS-B Messages.

a. The UAT ADS-B Transmitting Subsystem **shall** accept the input data elements listed in Table 5-1 via an appropriate data input interface and use such data to establish the corresponding ADS-B Message contents.

b. Data elements indicated as “Optional,” that have no input interface, **shall** always indicate the “data unavailable” condition.

## Table 5-1: UAT ADS-B Transmitter Input Requirements

| Element # | Input Data Element | Relevant Paragraph | Data Lifetime (seconds) | Applicability to UAT Equipment Class | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | A0, B0 | A1L | A1H, B1 | A2 | A3 | B2 | B3 |
| 1 | ICAO 24-bit Address | | No limit | M | M | M | M | M | M [1] | M [1] |
| 2 | Latitude [2] | | 2 | M | M | M | M | M | M | M |
| 3 | Longitude [2] | | 2 | M | M | M | M | M | M | M |
| 4 | Altitude Type Selection (Barometric vs Geometric) | | 60 | O | O | O | O | O | n/a | M |
| 5 | Barometric Pressure Altitude | | 2 | M | M | M | M | M | n/a | n/a |
| 6 | Geometric Altitude | | 2 | M | M | M | M | M | n/a | M |
| 7 | NIC | | 2 | M | M | M | M | M | M | M |
| 8 | Automatic AIRBORNE / ON-GROUND Indication | | 2 | O | O | M | M | M | n/a | n/a |
| 9 | North Velocity [2] | | 2 | M | M | M | M | M | M | M |
| 10 | East Velocity [2] | | 2 | M | M | M | M | M | M | M |
| 11 | Ground Speed | | 2 | O | O | M | M | M | n/a | n/a |
| 12 | Track Angle | | 2 | O | M | M | M | M | n/a | n/a |
| 13 | Heading | | 2 | O | O | M | M | M | n/a | n/a |
| 14 | Barometric Vertical Rate | | 2 | M | M | M | M | M | n/a | n/a |
| 15 | Geometric Vertical Rate [2] | | 2 | O | O | O | O | O | n/a | n/a |
| 16 | A/V Length and Width, and POA | | No limit | O | O | M | M | M | M | O |
| 17 | UTC 1 PPS Timing [2] | | 2 | M | M | M | M | M | M | M |
| 18 | Emitter Category | | No limit | M | M | M | M | M | M | M |
| 19 | Call Sign | | 60 | M | M | M | M | M | O | O |
| 20 | Emergency / Priority Status Selection | | 60 | M | M | M | M | M | O | n/a |
| 21 | SIL | | 60 | M | M | M | M | M | M | M |
| 22 | $NAC_P$ [2] | | 2 | M | M | M | M | M | M | M |
| 23 | $NAC_V$ [2] | | 2 | M | M | M | M | M | n/a | n/a |
| 24 | $NIC_{BARO}$ | | 60 | Can be internally “hard coded” | | M | M | M | n/a | n/a |
| 25 | CDTI Traffic Display Capability | | 60 | M | M | M | M | M | n/a | n/a |
| 26 | TCAS Installed and Operational | | 60 | M | M | M | M | M | n/a | n/a |
| 27 | TCAS/ACAS Resolution Advisory Flag | | 60 | Required only if ADS-B Transmitting Subsystem is intended for installation with TCAS/ACAS; otherwise can be “hard coded” | | | | | | |
| 28 | IDENT Selection | | 60 | M | M | M | M | M | M | n/a |
| 29 | “Receiving ATC Services” Flag | | 60 | M | M | M | M | M | M | n/a |
| 30 | “True/Magnetic Heading” Flag | | 60 | n/a | n/a | O | M | M | M | n/a |
| 31 | Heading / Track Indicator | | 60 | n/a | n/a | O | M | M | n/a | n/a |
| 32 | Target Source Indicator (Horizontal) | | 60 | n/a | n/a | O | M | M | n/a | n/a |
| 33 | Horizontal Mode Indicator (Horizontal) | | 60 | n/a | n/a | O | M | M | n/a | n/a |
| 34 | Target Heading or Track Angle | | 60 | n/a | n/a | O | M | M | n/a | n/a |
| 35 | Target Altitude Type | | 60 | n/a | n/a | O | M | M | n/a | n/a |
| 36 | Target Source Indicator (Vertical) | | 60 | n/a | n/a | O | M | M | n/a | n/a |
| 37 | Mode Indicator (Vertical) | | 60 | n/a | n/a | O | M | M | n/a | n/a |
| 38 | Target Altitude Capability | | 60 | n/a | n/a | O | M | M | n/a | n/a |
| 39 | Target Altitude | | 60 | n/a | n/a | O | M | M | n/a | n/a |
| 40 | Radio Altitude | | 2 | O | O | O | O | O | n/a | n/a |
| 41 | Pressure Altitude Disable | | No limit | M | M | M | M | M | n/a | n/a |

O = Optional

M = Mandatory (the equipment must have the ability to accept the data element)

n/a = not applicable to this equipage class

**Notes:** *[1] Non-Aircraft Identifier may be assigned by Regulatory Authority. [2] If input is not directly accessible, a means to verify the encoding must be demonstrated.*

## 5.2 UAT Receiver Output Requirements (Report Generation)

ADS-B reports are output from the receiver in response to UAT messages received.

### 5.2.1 Receiver Time of Message Receipt

The receiver **shall** declare a Time of Message Receipt (TOMR) and include this as part of the report issued to the on-board application systems. The TOMR value **shall** be reported to within the parameters listed below:

a. Range of at least 25 seconds expressed as seconds since GPS midnight modulo the range.

b. Resolution of 100 nanoseconds or less.

c. Accuracy of +/- 500 nanoseconds of the actual time of receipt for UAT equipment using either an internal, or external UTC coupled time source.

d. The reported TOMR will be equal to the following quantity: seconds since the previous UTC midnight modulo the specified TOMR range.

***Note:*** *TOMR is required to support ADS-B Time of Applicability (TOA) and range validation by a receiving application. See Appendix I for a discussion of UAT Timing Considerations. ADS-B applications derive the TOA from the TOMR as follows:*

1. *If the report indicates UTC Coupled, and is in the Non-Precision Condition, the TOA is the TOMR truncated to the start of the UTC second.*

2. *If the report indicates UTC Coupled, and is in the Precision Condition, the TOA is the TOMR truncated to the start of the 0.20 second UTC epoch containing the TOMR.*

3. *If the report indicates Non-UTC Coupled, the TOA is the TOMR minus one (1) second.*

### 5.2.2 Report Assembly on Receipt of ADS-B Message

Reports **shall** contain the following information:

a. All elements of the received message payload applicable to the ADS-B report type with the range, resolution and units of each payload field preserved.

***Note:*** *Report types are State Vector, Mode Status, Air Reference Velocity, Target State, and Trajectory Change. See RTCA DO-242A and appropriate UAT certification standards for more details on Report types.*

b. The Time of Message Receipt (§5.2.1) value measured by the receiver.

***Note:*** *Time of Applicability may be derived by the receiving application from the Time of Message Receipt.*

### 5.2.3 Report Assembly on Receipt of Ground Uplink Message

Reports may contain the following information:

a. The 432 bytes of unaltered received message payload.

b. The Time of Message Receipt (§5.2.1) value measured by the receiver.

***Note:*** *Time of Applicability may be derived by the receiving application from the Time of Message Receipt.*

### 5.2.4 Message Reception-to-Report Completion Time

All ADS-B Applicable Messages **shall** be output from the Report Assembly Function within 200 milliseconds of message input.

All Ground Uplink Applicable Messages **shall** be output from the Report Assembly Function within 500 milliseconds of message input.

*On further reflection, Chris thinks this section does not meet criteria for belonging in ICAO material.*

### 5.2.5 Response to Mutual Suppression Pulses

UAT equipment **shall not** provide suppression signals.

***Note:*** *Adequate compatibility to other systems is achieved because of the power levels, frequency separation and duty factor of UAT transmissions without providing suppression signals.*

UAT equipment **shall not** respond to suppression signals.

*On further reflection, Chris thinks this section does not meet criteria for belonging in ICAO material.*

## 6 Potential Future Services

Potential future services for UAT-equipped aircraft are described in this section. The services identified here support position determination of UAT-equipped aircraft based on time of message reception (TOMR) of UAT signals. The services are listed below:

- Range validation of ADS-B reported position data, based on the one way propagation time of the ADS-B message. This function can be performed by a single receiving station and relies on both the transmitter and receiver having access to precise timing information (referred to as being in the "UTC coupled" condition"). This is useful mainly to attain some confidence the ADS-B transmission is from a bona fide user and is not a result of "spoofing".

- Localization of a mobile ADS-B transmitter from a fixed ground receiver network. This function requires reception of the ADS-B message by at least 3 ground stations. Each ground station requires precise knowledge of time in order to provide the TOMR with each reception. The TOMR allows a central processor to localize the transmitter via the time-difference-of arrival technique. The mobile transmitter does not require knowledge of its own position nor does it require precise knowledge of time. This capability—coupled with the reported identification and barometric altitude—could provide *backup air-ground surveillance* in the event of widespread outage of GNSS.

- Localization of the mobile (ownship) ADS-B receiver. This is based on [near] simultaneous reception of 3 or more ground station "beacon" transmissions. Each ground station beacon transmission is based on precise knowledge of time. The ownship UAT receiver need not have precise knowledge of time, but determines position from the time-difference-of arrival technique and knowledge of the ground beacon locations encoded in the received messages. This capability could provide a crude form of *backup navigation* in the event of widespread outage of GNSS.

**<u>Table 6-1:</u> Summary of Potential Future Applications of UAT**

| Potential Future UAT Service | UAT Transmitter Requirements | UAT Receiver Requirements | Primary Application | Limitations |
|---|---|---|---|---|
| Range Validation | Nav input, Precise time | Nav input, Precise time | Integrity check of ADS-B | Total timing errors limit range accuracy to ~0.7 NM (see Appendix E) |
| Backup Air-Ground Surveillance | No GNSS dependence | Precise time | Surveillance backup for GNSS | Service available only in areas of significant ground station infrastructure |
| Backup Navigation | Precise time (stable source can operate without GNSS for hours) | No GNSS dependence | Navigation backup for GNSS | Service available only in areas of significant ground station infrastructure |