4.1 CSBee

Comma Separated Bee protocol containing information about tracked aircraft as plain text.

The CSBee protocol is heavily inspired by the Aerobits Aero CSV protocol.

4.1.1 Mode S Aircraft Message

This message contains information about an aircraft being tracked via ADS-B (1090MHz). Aircraft reports are provided once per second, per aircraft, until contact with the aircraft has been lost for 60 seconds.

```
#A:ICAO,FLAGS,CALL,SQUAWK,ECAT,LAT,LON,BARO_ALT,GNSS_ALT,DIR,SPEED,BARO_VRATE,GNSS_VRATE,
NICNAC,ACDIMS,VERSION,SIGS,SIGQ,SFPS,ESFPS,CRC\r\n
```

Field	Description	Format	Example value
#A	Mode S aircraft message start indicator.		
ICAO	ICAO number of aircraft (3 bytes).	Hex Integer	3C65AC
FLAGS	Flags bitfield, see table 4.1.1.1.	Hex Integer	12F356A8
CALL	Callsign of aircraft.	String	N61ZP
SQUAWK	SQUAWK of aircraft.	Octal Integer	7232
ECAT	Emitter category, see table 4.1.1.2.	Integer	14
LAT	Latitude, in degrees.	Float	57.57634
LON	Longitude, in degrees.	Float	17.59554
BARO_ALT	Barometric altitude, in feet.	Integer	5000
GNSS_ALT	Geometric altitude, in feet.	Integer	5000
DIR	Direction of aircraft, in degrees [0,360). Consult bit flags to determine whether this field is true heading, magnetic heading, or track.	Integer	35
SPEED	Horizontal velocity of aircraft, in knots.	Integer	464
BARO_VRATE	Barometric vertical velocity of aircraft, in ft/min.	Integer	-1344
GNSS_VRATE	Geometric vertical velocity of the aircraft, in ft/min	Integer	-1344
NICNAC	Aircraft data integrity. See table 4.1.1.3	Hex Integer	
ACDIMS	Aircraft physical dimensions and system design assurance. See table 4.1.1.4.	Hex Integer	31BE89F2
VERSION	ADS-B protocol version used by the aircraft.	Integer	2
SIGS	Signal strength, in dBm.	Integer	-92
SIGQ	Signal quality, in dB.	Integer	2
SFPS	Number of valid 56-bit Squitter Mode S frames received from the aircraft during the last second.	Integer	2
ESFPS	Number of valid 112-bit Extended Squitter Mode S frames received from the aircraft during the last second.	Integer	5
CRC	CRC16 (described in 4.1.1.5).	Hex Integer	2D3E

4.1.1.1 FLAGS Bitfield

Note: All bits 25-31 are momentary (cleared and updated every reporting interval).

Bit	Bit Name	Meaning if the bit is set (1)
0	IS_AIRBORNE	Emitter is airborne.
1	BARO_ALTITUDE_VALID	Emitter has provided a barometer altitude.
2	GNSS_ALTITUDE_VALID	Emitter has provided a GNSS altitude.
3	POSITION_VALID	Emitter has provided a pair of even and odd Compact Position Reporting packets that were decoded to a location.
4	DIRECTION_VALID	Emitter has provided a direction (may be ground track, magnetic compass heading, or true compass heading).
5	HORIZONTAL_SPEED_VALID	Emitter has provided a horizontal velocity.
6	BARO_VERTICAL_RATE_VALID	Emitter has provided a barometric vertical velocity.
7	GNSS_VERTICAL_RATE_VALID	Emitter has provided a GNSS vertical velocity.
8	IS_MILITARY	Emitter has transmitted at least one packet using a military format, such as Military Extended Squitter (DF=19).
9	IS_CLASS_B2_GROUND_VEHICLE	Emitter is actually a ground vehicle using a Class B2 transponder with a transmission power < 70W.
10	HAS_1090_ES_IN	Emitter has receive capability for 1090MHz Extended Squitter transmissions.
11	HAS_UAT_IN	Emitter has receive capability for UAT (978MHz Universal Access Transceiver) transmissions.
12	TCAS_OPERATIONAL	Emitter has a functional TCAS (Traffic Collision Avoidance System) onboard.
13	SINGLE_ANTENNA	Emitter is using a single antenna, instead antennas above and below the fuselage. Transmissions may be weak or irregular during maneuvering.
14	DIRECTION_IS_HEADING	Surface position messages provided by the aircraft indicate a heading and not a track angle.
15	HEADING_USES_MAGNETIC_NORTH	Heading reported by the aircraft while on the surface uses magnetic north instead of true north.
16	IDENT	The aircraft has its SPI (Special Position Identification) bits set in Mode A/C or Mode S messages. This indicates that the pilot has depressed the momentary IDENT switch on their transponder, most likely at the request of air traffic control.
17	ALERT	The aircraft is issuing either a permanent or momentary alert. This could correspond to an operational mode change or something else.
18	TCAS_RA	The aircraft has an active TCAS resolution advisory (i.e. the aircraft is warning the pilot to take action in order to avoid colliding with another aircraft).
19-22 Reserved		
23	UPDATED_BARO_ALTITUDE	Barometric altitude has been updated within the last reporting interval.
24	UPDATED_GNSS_ALTITUDE	GNSS altitude has been updated within the last reporting interval.
25	UPDATED_POSITION	Position (latitude / longitude) has been updated within the last reporting interval.
26	UPDATED_DIRECTION	Direction has been updated within the last reporting interval.
27	UPDATED_HORIZONTAL_SPEED	Horizontal velocity has been updated within the last reporting interval.
28	UPDATED_BARO_VERTICAL_RATE	Barometric vertical velocity has been updated within the last reporting interval.
29	UPDATED_GNSS_VERTICAL_RATE	GNSS vertical velocity has been updated within the last reporting interval.
30-31 Reserved		

4.1.1.2 ECAT Field

The ECAT field indicates the Emitter Category (i.e. airframe type) for each ADSB emitter that is being tracked. This field contains information about what kind of aircraft, ground vehicle, obstacle, or other airspace user is emitting ADS-B packets, and can be used to understand the emitter's maneuvering capability and potential for wake vortex impact.

ECAT Value	Emitter Category
-1	Invalid
0	No Category Information
1	Light Aircraft (< 7,000kg)
2	Medium 1 (7,000kg – 34,000kg)
3	Medium 2 (34,000kg – 136,000kg)
4	High Vortex Aircraft
5	Heavy (> 136,000kg)
6	High Performance (> 5 G acceleration and > 400 kts speed)
7	Rotorcraft
8	Reserved
9	Glider / Sailplane
10	Lighter Than Air
11	Parachutist / Skydiver
12	Ultralight / Hang Glider / Paraglider
13	Reserved 1
14	Unmanned Aerial Vehicle
15	Space / Transatmospheric Vehicle
16	Reserved 2
17	Surface Emergency Vehicle
18	Surface Service Vehicle
19	Point Obstacle
20	Cluster Obstacle
21	Line Obstacle

4.1.1.3 NICNAC Bitfield

NICNAC Bitfield															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Source Integrity Level (SIL)		Geometric Vertical Accuracy (GVA)		Navigation Accuracy Category: Position (NAC_p)				Navigation Accuracy Category: Velocity (NAC_v)			Navigation Integrity Category: Barometer (NIC_{baro})	Navigation Integrity Category (NIC)			

NICNAC[0-3]: Navigation Integrity Category (NIC)

The radius of containment (NIC) indicates how much trust should be placed in an aircraft's reported location in the horizonal plane. The NIC reports a radius of containment specified by the avionics system of the emitter. The probability that the aircraft is outside of this radius of containment due to its avionics system receiving a faulty signal from one of its inputs (without displaying an error) is provided by another bitfield called the Source Integrity Level (SIL). Combined, the NIC and SIL indicate how likely it is that an aircraft is not actually contained by a bubble of a specified size, centered at the aircraft's reported location, assuming that the avionics onboard the aircraft are functioning correctly but may be given faulty inputs.

A higher NIC value indicates more trust in an aircraft's reported latitude / longitude position.

NIC Value	0	1	2	3	4	5	6	7	8	9	10	11
Radius of Containment	Unknown	< 20 NM	< 8 NM	< 4 NM	< 2 NM	< 1 NM	< 0.6 NM	< 0.2 NM	< 0.1 NM	< 75 m	< 25 m	< 7.5 m

NICNAC [4]: Navigation Integrity Category: Barometer (NIC_{baro})

The barometric altitude integrity (NIC_{baro}) indicates how much trust should be placed in an aircraft's reported altitude. The field is a single bit that indicates whether the aircraft uses an altimeter that has been cross-checked against other sources. Old school encoding altimeters have many parallel wires and output an altitude in a format called a Gillham Code, and have no built-in method of error checking. A single faulty wire can result in erroneous readings, so this bit lets air traffic control know whether to take altitude readings from the aircraft with a grain of salt. A 0 indicates that the transponder is outputting altitude from a Gillham coded source (with no way to cross check the value), while a 1 indicates that the transponder is outputting altitude from a Gillham coded source while using another sensor to cross-check it, or is using a more modern barometer that supports a protocol with built-in error checking.

A higher NIC_{baro} value (i.e. 1 instead of 0) indicates more trust in the aircraft's reported altitude.

NIC_{baro} Value	0	1
Barometric Altitude Integrity	Altitude is from a Gillham-coded input, not cross checked.	Altitude is from a Gillham-coded input that is being cross-checked with another source, or from a non Gillham-coded input with built-in error checking features.

NICNAC [5-7]: Navigation Accuracy Category: Velocity (NAC_v)

The horizontal velocity error (NAC_v) indicates the expected accuracy of the reported velocity of the aircraft when systems are operating nominally. This varies depending on the accuracy capabilities of the measurement equipment onboard the aircraft, and not how often we expect said equipment to fail.

A higher NAC_v indicates a more accurate velocity measurement system.

NAC_v Value	Horizontal Velocity Error
0b000	Unknown or ≥ 10 m/s
0b110	< 10 m/s
0b010	< 3 m/s
0b011	< 1 m/s
0b100	< 0.3 m/s

NICNAC [8-11]: Navigation Accuracy Category: Position (NAC_p)

The estimated position uncertainty (NAC_p) indicates the expected accuracy of the aircraft's reported location when systems are operating nominally. This varies depending on the capabilities of the aircraft's positioning system and not on how often we expect said equipment to fail.

A higher NAC_p indicates a more accurate positioning system.

NAC_p Value	0	1	2	3	4	5	6	7	8	9	10	11
Estimated Position Uncertainty	Unknown or ≥ 10NM	< 10 NM	< 4 NM	< 2 NM	< 1 NM	< 0.5 NM	< 0.3 NM	< 0.1 NM	< 0.5 NM	< 30 m	< 10 m	< 3 m

NICNAC[12-13]: Geometric Vertical Accuracy (GVA)

The geometric vertical accuracy indicates the 95% confidence interval (vertical figure of merit) provided by the aircraft's onboard GNSS system (i.e. assuming some distribution of altitudes, the aircraft's GNSS system is confident that 95 out of 100 times, the aircraft falls within some height of the reported geometric altitude.

GVA Value	0	1	2	3
95% Vertical Figure of Merit (VFOM)	Unknown or ≥ 150 m	< 150 m	≤ 45 m	< 45 m (Was previously "reserved", the actual value of this field may change but is guaranteed to be < 45 m).

NICNAC[14-15]: Source Integrity Level (SIL)

The source integrity level indicates the probability that the aircraft exceeds the bounds of its horizontal radius of containment (NIC) due to a silent fault in signals received by the aircraft (no avionics failure).

SIL Value	Probability of Exceeding NIC Radius of Containment Due to Silent Fault
0	Unknown or > $1x10^{-3}$ per flight hour.
1	≤ $1x10^{-3}$ per flight hour.
2	≤ $1x10^{-5}$ per flight hour.
3	≤ $1x10^{-7}$ per flight hour.
4	Unknown or > $1x10^{-3}$ per sample.
5	≤ $1x10^{-3}$ per sample.
6	≤ $1x10^{-5}$ per sample.
7	≤ $1x10^{-7}$ per sample.

4.1.1.4 ACDIMS Bitfield

ACDIMS Bitfield															
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
GNSS Offset Forward of Reference Point (GOF)								GNSS Offset Right of Reference Point (GOR)							

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Aircraft Length (ACL)							Aircraft Width (ACW)							System Design Assurance (SDA)	

ACDIMS[0-1]: System Design Assurance (SDA)

The system design assurance indicates how robust the aircraft's position reporting systems are to failures of various severities. For instance, SDA = 1, a low SDA value, corresponds to Software and Hardware Design Assurance Level D, which states that a minor failure could cause the aircraft to transmit misleading position information with a probability of $\leq 1x10^{-3}$ per flight hour. A more robust system with SDA = 3, corresponding to Software and Hardware Design Assurance Level B, is expected to transmit misleading position information with a probability of $1x10^{-7}$ per flight hour even under a Hazardous failure condition.

Software Design Assurance categories used in this field are classified under RTCA DO-178B, Airborne Electronic Hardware Design Assurance are classified under RTCA DO-254, and failure classification levels are defined in FAA Advisory Circular AC-23.1309-1E.

SDA Value	Supported Failure Condition	Probability of Undetected Fault causing transmission of False or Misleading Information	Software and Hardware Design Assurance Level
0	Unknown / No Safety Effect	$> 1x10^{-3}$ per flight hour or unknown.	N/A
1	Minor	$\leq 1x10^{-3}$ per flight hour.	D
2	Major	$\leq 1x10^{-5}$ per flight hour.	C
3	Hazardous	$\leq 1x10^{-7}$ per flight hour.	B

ACDIMS[2-8] Aircraft Width (ACW)

Approximate value for the width of the aircraft bounding box, in meters. Can be interpreted as a 7-bit unsigned integer.

ACDIMS[9-15] Aircraft Length (ACL)

Approximate value for the length of the aircraft bounding box, in meters. Can be interpreted as a 7-bit unsigned integer.

ACDIMS[16-23] GNSS Offset Right of Reference Point (GOR)

Signed 8-bit integer representing the left/right offset of the GNSS antenna from the aircraft's reference point. A positive value indicates that the GNSS antenna is to the right of the aircraft reference point.

ACDIMS[24-31] GNSS Offset Forward of Reference Point (GOF)

Signed 8-bit integer representing the forward/back offset of the GNSS antenna from the aircraft's reference point. A positive value indicates that the GNSS antenna is forward of the aircraft's reference point. Always 0 for Mode S aircraft.

4.1.1.5 CRC Field

CSBee messages use a 16-bit Cyclical Redundancy Checksum (CRC-16), which can be calculated using the algorithm in the C++ code snippet below. Note the “swap16” helper function which also needs to be included.

```
uint16_t swap16(uint16_t value) { return (value << 8) | (value >> 8); }

uint16_t CalculateCRC16(const uint8_t *data_p, int32_t length) {
    uint8_t x;
    uint16_t crc = 0xFFFF;
    while (length--) {
        x = crc >> 8 ^ *data_p++;
        x ^= x >> 4;
        crc = (crc << 8) ^ ((uint16_t)(x << 12)) ^ ((uint16_t)(x << 5)) ^ ((uint16_t)x);
    }
    return swap16(crc);
}
```

4.1.2 UAT Aircraft Message

```
#U:ICAO,UAT_FLAGS,CALL,SQUAWK,ECAT,LAT,LON,BARO_ALT,GNSS_ALT,DIR,SPEED,BARO_VRATE,GNSS_VRATE,UAT_EMERG,NICNAC,ACDIMS,VERSION,SIGS,SIGQ,UATFPS,CRC\r\n
```

Field	Description	Format	Example value
#U	UAT aircraft message start indicator.		
ICAO	ICAO number of aircraft (3 bytes).	Hex Integer	3C65AC
UAT_FLAGS	Flags bitfield, see table 4.1.2.1.	Hex Integer	12F356A8
CALL	Callsign of aircraft.	String	N61ZP
SQUAWK	SQUAWK of aircraft.	Octal Integer	7232
ECAT	Emitter category, see table 4.1.1.2.	Integer	14
LAT	Latitude, in degrees.	Float	57.57634
LON	Longitude, in degrees.	Float	17.59554
BARO_ALT	Barometric altitude, in feet.	Integer	5000
GNSS_ALT	Geometric altitude, in feet.	Integer	5000
DIR	Direction of aircraft, in degrees [0,360). Consult bit flags to determine whether this field is true heading, magnetic heading, or track.	Integer	35
SPEED	Horizontal velocity of aircraft, in knots.	Integer	464
BARO_VRATE	Barometric vertical velocity of aircraft, in ft/min.	Integer	-1344
GNSS_VRATE	Geometric vertical velocity of the aircraft, in ft/min	Integer	-1344
UAT_EMERG	Aircraft UAT emergency / priority status. See table.	Integer	0
NICNAC	Aircraft data integrity. See table 4.1.1.3	Hex Integer	
ACDIMS	Aircraft physical dimensions and system design assurance. See table 4.1.1.4.	Hex Integer	31BE89F2
VERSION	UAT protocol version used by the aircraft.	Integer	1
SIGS	Signal strength, in dBm.	Integer	-92
SIGQ	Number of bits corrected using UAT forward error correction. 0 (best), 6 (worst).	Integer	2
UATFPS	Number of valid UAT frames received from the aircraft in the last second.	Integer	1
CRC	CRC16 (described in 4.1.1.5).	Hex Integer	2D3E

NOTE: See Mode S Aircraft message decoding reference for any bitfields not prefixed with “UAT_”.

4.1.2.1 UAT_FLAGS Bitfield

Bit	Bit Name	Meaning if the bit is set (1)
0	IS_AIRBORNE	Emitter is airborne.
1	BARO_ALTITUDE_VALID	Emitter has provided a barometer altitude.
2	GNSS_ALTITUDE_VALID	Emitter has provided a GNSS altitude.
3	POSITION_VALID	Emitter has provided a pair of even and odd Compact Position Reporting packets that were decoded to a location.
4	DIRECTION_VALID	Emitter has provided a direction (may be ground track, magnetic compass heading, or true compass heading).
5	HORIZONTAL_SPEED_VALID	Emitter has provided a horizontal velocity.
6	BARO_VERTICAL_RATE_VALID	Emitter has provided a barometric vertical velocity.
7	GNSS_VERTICAL_RATE_VALID	Emitter has provided a GNSS vertical velocity.
8	HAS_CDTI	Aircraft has Cockpit Display of Traffic Information (CDTI) equipped.
9	TCAS_OPERATIONAL	Aircraft is equipped with an operational TCAS / ACAS system.
10	DIRECTION_IS_HEADING	Surface position messages provided by the aircraft indicate a heading and not a track angle.
11	HEADING_USES_MAGNETIC_NORTH	Heading reported by the aircraft while on the surface uses magnetic north instead of true north.
12	IDENT	The aircraft has its SPI (Special Position Identification) bits set in Mode A/C or Mode S messages. This indicates that the pilot has depressed the momentary IDENT switch on their transponder, most likely at the request of air traffic control.
13-14 Reserved		
15	TCAS_RA	The aircraft has an active TCAS resolution advisory (i.e. the aircraft is warning the pilot to take action in order to avoid colliding with another aircraft).
16	RECEIVING_ATC_SERVICES	
17-22 Reserved		
23	UPDATED_BARO_ALTITUDE	Barometric altitude has been updated within the last reporting interval.
24	UPDATED_GNSS_ALTITUDE	GNSS altitude has been updated within the last reporting interval.
25	UPDATED_POSITION	Position (latitude / longitude) has been updated within the last reporting interval.
26	UPDATED_DIRECTION	Direction has been updated within the last reporting interval.
27	UPDATED_HORIZONTAL_SPEED	Horizontal velocity has been updated within the last reporting interval.
28	UPDATED_BARO_VERTICAL_RATE	Barometric vertical velocity has been updated within the last reporting interval.
29	UPDATED_GNSS_VERTICAL_RATE	GNSS vertical velocity has been updated within the last reporting interval.
30-31 Reserved		

4.1.2.2 UAT_EMERG Bitfield

Contains the emergency / priority status reported by a UAT emitter.

UAT_EMERG Value	Meaning
0	No emergency.
1	General emergency.
2	Lifeguard / medical emergency.
3	Minimum fuel.
4	No communications.
5	Unlawful interference.
6	Downed aircraft.
7	Reserved.

4.1.3 Statistics Message

This message contains some useful statistics about ADSBee's operational status. Format of that frame is shown below:

```
#S:VERSION,DPS,RAW_SFPS,SFPS,RAW_ESFPS,ESFPS,RAW_UATFPS,UATFPS,TSCAL,UPTIME,CRC\r\n
```

Field	Description	Format	Example Value
#S	Statistics message start indicator.		
VERSION	Version of the CSBee protocol being used.	Integer	2
SDPS	Number of attempted Mode S demodulations in the last second.	Integer	106
RAW_SFPS	Number of squitter (56-bit Mode S) frames received in the last second.	Integer	150
SFPS	Number of valid squitter (56-bit Mode S) frames received in the last second.	Integer	20
RAW_ESFPS	Number of extended squitter (112-bit Mode S) frames received in the last second.	Integer	15
ESFPS	Number of valid Mode S frames received in the last second.	Integer	3
RAW_UATFPS	Number of UAT frames received in the last second.	Integer	5
UATFPS	Number of valid UAT frames received in the last second.	Integer	4
NUM_AIRCRAFT	Number of aircraft tracked in the last second.	Integer	20
TSCAL	Calibration value for TS field in raw frames	Integer	13999415
UPTIME	Receiver uptime, in seconds.	Integer	13456
CRC	CRC16 (described in 4.1.3.1).	Hex Integer	2D3E

4.1.3.1 CRC Field

See 4.1.1.5.