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 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,ALT_BARO,ALT_GEO,TRACK,VELH,VELV,SIGS,
SIGQ,ACFPS,SFPS,SYSINFO,CRC\r\n
```

#A	Aircraft message start indicator	Format	Example value
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
ALT_BARO	Barometric altitude, in feet.	Integer	5000
ALT_GEO	Geometric altitude, in feet.	Integer	5000
TRACK	Ground track of aircraft, in degrees [0,360).	Integer	35
VELH	Horizontal velocity of aircraft, in knots.	Integer	464
VELV	Vertical velocity of aircraft, in ft/min.	Integer	-1344
SIGS	Signal strength, in dBm.	Integer	-92
SIGQ	Signal quality, in dB.	Integer	2
ACFPS	Number of valid Mode A and Mode C frames received from the aircraft during the last second.	Integer	2
SFPS	Number of valid Mode S frames received from the aircraft during the last second.	Integer	5
SYSINFO	Aircraft data integrity and physical dimensions, see table 4.1.1.3.	Hex Integer	31BE89F2
CRC	CRC16 (described in 4.1.1.4).	Hex Integer	2D3E

4.1.1.1 FLAGS Bitfield

Note: All bits 17-32 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	POSITION_VALID	Emitter has a valid position (ADSBee has received a valid pair of even and odd Compact Position Reporting packets and decoded an unambiguous location for the aircraft).
2	IS_MILITARY	Emitter has transmitted at least one packet using a military format, such as Military Extended Squitter (DF=19).
3	IS_CLASS_B2_GROUND_VEHICLE	Emitter is actually a ground vehicle using a Class B2 transponder with a transmission power < 70W.
4	HAS_1090_ES_IN	Emitter has receive capability for 1090MHz Extended Squitter transmissions.
5	HAS_UAT_IN	Emitter has receive capability for UAT (978MHz Universal Access Transceiver) transmissions.
6	TCAS_OPERATIONAL	Emitter has a functional TCAS (Traffic Collision Avoidance System) onboard.
7	SINGLE_ANTENNA	Emitter is using a single antenna, instead antennas above and below the fuselage. Transmissions may be weak or irregular during maneuvering.
8	SURFACE_POSITION_USES_HEADING	Surface position messages provided by the aircraft indicate a heading and not a track angle.
9	HEADING_USES_MAGNETIC_NORTH	Heading reported by the aircraft while on the surface uses magnetic north instead of true north.
10	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.
11	ALERT	The aircraft is issuing either a permanent or momentary alert. This could correspond to an operational mode change or something else.
12	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).
13	RESERVED	
14	RESERVED	
15	RESERVED	
16	RESERVED	
17	UPDATED_BARO_ALTITUDE	Barometric altitude has been updated within the last reporting interval.
18	UPDATED_GNSS_ALTITUDE	GNSS altitude has been updated within the last reporting interval.
19	UPDATED_POSITION	Position (latitude / longitude) has been updated within the last reporting interval.
20	UPDATED_TRACK	Track has been updated within the last reporting interval.
21	UPDATED_HORIZONTAL_VELOCITY	Horizontal velocity has been updated within the last reporting interval.
22	UPDATED_VERTICAL_VELOCITY	Vertical velocity has been updated within the last reporting interval.
23		
24		
25		
26		
27		
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29		
30		
31		

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
0	Invalid
1	Reserved
2	No Category Information
3	Surface Emergency Vehicle
4	Surface Service Vehicle
5	Ground Obstruction
6	Glider / Sailplane
7	Parachutist / Skydiver
8	Ultralight / Hang Glider / Paraglider
9	Unmanned Aerial Vehicle
10	Space / Transatmospheric Vehicle
11	Light Aircraft (< 7,000kg)
12	Medium 1 (7,000kg – 34,000kg)
13	Medium 2 (34,000kg – 136,000kg)
14	High Vortex Aircraft
15	Heavy (> 136,000kg)
16	High Performance (> 5 G acceleration and > 400 kts speed)
17	Rotorcraft

4.1.1.3 SYSINFO Bitfield

SYSINFO Bitfield															
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
			Aircraft Maximum Dimension (MDIM)							GNSS Antenna Offset Direction (GAOR)	GNSS Antenna Offset Distance (GAOD)		GNSS Antenna Offset Known (GAOK)	System Design Assurance (SDA)	

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)			

SYSINFO[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

SYSINFO[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.

SYSINFO[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

SYSINFO[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

SYSINFO[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).

SYSINFO[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.

SYSINFO[16-17] 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 ≤ $1x10^{-3}$ 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	≤ $1x10^{-3}$ per flight hour.	D
2	Major	≤ $1x10^{-5}$ per flight hour.	C
3	Hazardous	≤ $1x10^{-7}$ per flight hour.	B

SYSINFO[18] GNSS Antenna Offset Known (GAOK)

This field indicates whether the aircraft has reported the installation location of its GNSS antenna relative to its centerline (roll axis). A field for reporting this value is only available in ADS-B messages emitted by aircraft on the ground, and even then, the aircraft may not report a value in this field.

GANTO Value	Aircraft reported location of its GNSS antenna relative to roll axis?
0	No
1	Yes

SYSINFO[19-20] GNSS Antenna Offset Distance (GAOD)

This field indicates the distance that the GNSS antenna is offset from the centerline (roll axis) of the aircraft. Aircraft only report even values for their GNSS antenna offset distance, between 2-6 meters, so the reported offset distance can be calculated using the equation below.

GNSS antenna offset distance = GAOD << 1

Note that this value is only reported by some aircraft while operating on the ground. Aircraft operating in the air do not report this value. Always check the value of the GAOK bit to see if the value of GAOD is worth paying attention to.

SYSINFO[21] GNSS Antenna Offset Direction (GAOR)

GAOR Value	GNSS Antenna Offset Direction
0	GNSS antenna is offset to the left of centerline (roll axis).
1	GNSS antenna is offset to the right of centerline (roll axis).

This field indicates the value of the maximum dimension (length or width) of an aircraft, and is only reported by aircraft while on the ground. This field has no special coding, and can be interpreted directly as a binary unsigned integer value.

4.1.1.4 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 Statistics Message

This message contains some useful statistics about operation of module. Format of that frame is shown below:

```
#S:DPS,ACFPS,SFPS,TSCAL,UPTIME,CRC\r\n
```

#S	Statistics message start indicator	Example
DPS	Number of attempted demodulations in the last second.	106
ACFPS	Number of MODE-A or MODE-C frames received in the last second.	20
SFPS	Number of valid Mode S frames received in the last second.	3
TSCAL	Calibration value for TS field in raw frames	13999415
UPTIME	Time from last enter to RUN mode, in seconds.	134
CRC	CRC16 (described in 4.1.2.1).	2D3E

4.1.2.1 CRC Field

See 4.1.1.4.