Swift Navigation Binary Protocol

Protocol Specification 4.10.1-alpha

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1 Overview

The Swift Navigation Binary Protocol (SBP) is a fast, simple, and minimal binary protocol for communicating with Swift devices. It is the native binary protocol used by the Piksi GPS receiver to transmit solutions, observations, status, and debugging messages, as well as receive messages from the host operating system, such as differential corrections and the almanac. As such, it is an important interface with your Piksi receiver and the primary integration method with other systems.

This document provides a specification of SBP framing and the payload structures of the messages currently used with Swift devices. SBP client libraries in a variety of programming languages are available at `https://github.com/swift-nav/libsbp` and support information for sbp is available at `https://support.swiftnav.com/customer/en/portal/articles/2492810-swift-binary-protocol`.

2 Message Framing Structure

SBP consists of two pieces:

- an over-the-wire message framing format
- structured payload definitions

As of Version 4.10.1-alpha, the frame consists of a 6-byte binary header section, a variable-sized payload field, and a 16-bit CRC value. All multibyte values are ordered in **little-endian** format. SBP uses the CCITT CRC16 (XMODEM implementation) for error detection[1].

Offset (bytes)	Size (bytes)	Name	Description
0	1	Preamble	Denotes the start of frame transmission. Always 0x55.
1	2	Message Type	Identifies the payload contents.
3	2	Sender	A unique identifier of the sender.[2]
5	1	Length	Length (bytes) of the Payload field.
6	N	Payload	Binary message contents.
N + 6	2	CRC	Cyclic Redundancy Check of the frame's binary data from the Message Type up to the end of Payload (does not include the Preamble).
	N + 8		Total Frame Length

Table 2.0.1: Swift Binary Protocol message structure. N denotes a variable-length size.

3 NMEA-0183

Swift devices, such as the Piksi, also have limited support for the standard NMEA-0183 protocol.

Note that NMEA-0183 doesn't define standardized message string equivalents for many important SBP messages such as observations, baselines and ephemerides. For this reason it is strongly recommended to use SBP for new development. NMEA-0183 output is provided primarily to support legacy devices.

[1] CCITT 16-bit CRC Implementation uses parameters used by XMODEM, i.e. the polynomial: $x^{16} + x^{12} + x^5 + 1$. For more details, please see the implementation at https://github.com/swift-nav/libsbp/blob/master/c/src/edc.c#L59. See also *A Painless Guide to CRC Error Detection Algorithms* at http://www.ross.net/crc/download/crc_v3.txt

[2] By default, clients of 'libsbp' use a sender id value of '0x42' which represents device controllers such as the Piksi Console. On the Piksi, the sender ID is set to the 2 least significant bytes of the device serial number. A stream of SBP messages may also include sender IDs for forwarded messages from other systems. For instance, when using Starling as a hosted software product, Sender 0x1000 (4096) indicates a message originated from the GNSS subsystem, while sender 0x315 (789) indicates a message originated from the sensor fusion subsystem. Sender 0 always indicates the message has been forwarded and contains some form of differential corrections.

4 Basic Formats and Payload Structure

The binary payload of an SBP message decodes into structured data based on the message type defined in the header. SBP uses several primitive numerical and collection types for defining payload contents.

Name	Size (bytes)	Description
s8	1	Signed 8-bit integer
s16	2	Signed 16-bit integer
s32	4	Signed 32-bit integer
s64	8	Signed 64-bit integer
u8	1	Unsigned 8-bit integer
u16	2	Unsigned 16-bit integer
u32	4	Unsigned 32-bit integer
u64	8	Unsigned 64-bit integer
float	4	Single-precision float (IEEE-754)
double	8	Double-precision float (IEEE-754)
array	—	Fixed or variable length array of any fill type
string	—	Fixed or variable length string (NULL padded/terminated)
bitfield	—	A primitive type, typically a u8, can encode boolean and enumerated status flags.

Table 4.0.1: SBP primitive types

Example Message

As an example, consider this framed series of bytes read from a serial port:

`55 0b 02 cc 04 14 70 3d d0 18 cf ef ff ff ef e8 ff ff f0 18 00 00 00 00 05 00 15 dc`

This byte array decodes into a `MSG_BASELINE_ECEF` (see pg. 27), which reports the baseline position solution of the rover receiver relative to the base station receiver in Earth Centered Earth Fixed (ECEF) coordinates. The segments of this byte array and its contents break down as follows:

Field Name	Type	Value	Bytestring Segment
Preamble	u8	0x55	`55`
Message Type	u16	`MSG_BASELINE_ECEF`	`0b 02`
Sender	u16	1228	`cc 04`
Length	u8	20	`14`
Payload		—	`70 3d d0 18 cf ef ff ff ef e8 ff ff f0 18 00 00 00 00 05 00`
`MSG_BASELINE_ECEF`			
.tow	u32	416300400 msec	`70 3d d0 18`
.x	s32	-4145 mm	`cf ef ff ff`
.y	s32	-5905 mm	`ef e8 ff ff`
.z	s32	6384 mm	`f0 18 00 00`
.accuracy	u16	0	`00 00`
.nsats	u8	5	`05`
.flags	u8	0	`00`
CRC	u16	0x9443	`15 dc`

Table 4.0.2: SBP breakdown for `MSG_BASELINE_ECEF`

5 GNSS Signals

Code, Constellation, and Band. Signal descriptions are provided in both RINEX and ICD Conventions.

Value	Rinex Desc.	ICD Desc.	Value	Rinex Desc.	ICD Desc.
0	GPS L1CA	GPS L1 C/A	30	GLO L2P	GLONASS L2SF
1	GPS L2CM	GPS L2C M	31	QZS L1CA	QZS L1 C/A
2	SBAS L1CA	SBAS L1 C/A	32	QZS L1CI	QZS L1C D
3	GLO L1OF	GLONASS L1OF	33	QZS L1CQ	QZS L1C P
4	GLO L2OF	GLONASS L2OF	34	QZS L1CX	QZS L1C D+P
5	GPS L1P	GPS L1 P(Y)	35	QZS L2CM	QZS L2C M
6	GPS L2P	GPS L2 P(Y)	36	QZS L2CL	QZS L2C L
7	GPS L2CL	GPS L2C L	37	QZS L2CX	QZS L2C ML
8	GPS L2CX	GPS L2C M+L	38	QZS L5I	QZS L5 I
9	GPS L5I	GPS L5 I	39	QZS L5Q	QZS L5 Q
10	GPS L5Q	GPS L5 Q	40	QZS L5X	QZS L5 I+Q
11	GPS L5X	GPS L5 I+Q	41	SBAS L5I	SBAS L5 I
12	BDS2 B1	BDS B1I	42	SBAS L5Q	SBAS L5 Q
13	BDS2 B2	BDS B2I	43	SBAS L5X	SBAS L5 I+Q
14	GAL E1B	GAL E1 B	44	BDS3 B1CI	BDS B1C D
15	GAL E1C	GAL E1 C	45	BDS3 B1CQ	BDS B1C P
16	GAL E1X	GAL E1 B+C	46	BDS3 B1CX	BDS B1C D+P
17	GAL E6B	GAL E6 B	47	BDS3 B5I	BDS B2a D
18	GAL E6C	GAL E6 C	48	BDS3 B5Q	BDS B2a P
19	GAL E6X	GAL E6 B+C	49	BDS3 B5X	BDS B2a D+P
20	GAL E7I	GAL E5b I	50	BDS3 B7I	BDS B2b D
21	GAL E7Q	GAL E5b Q	51	BDS3 B7Q	BDS B2b P
22	GAL E7X	GAL E5b I+Q	52	BDS3 B7X	BDS B2b D+P
23	GAL E8I	GAL E5a+b I	53	BDS3 B3I	BDS B3I
24	GAL E8I	GAL E5a+b Q	54	BDS3 B3Q	BDS B3Q
25	GAL E8X	GAL E5a+b I+Q	55	BDS3 B3X	BDS B3 I+Q
26	GAL E5I	GAL E5a I	56	GPS L1CI	GPS L1C D
27	GAL E5Q	GAL E5a Q	57	GPS L1CQ	GPS L1C P
28	GAL E5X	GAL E5a I+Q	58	GPS L1CX	GPS L1C D+P
29	GLO L1P	GLONASS L1SF			

Table 5.0.2: GNSS Signals Table

6 Signal and Tracking Mode Identifier

Signals encoded following Swift RTCM specifications (DF380, DF381, DF382 and DF467). Code, Constellation, and Band. Signal descriptions are provided in both RINEX and RTCM Conventions.

Signal	GPS		GALILEO		BEIDOU	
	Rinex Desc.	RTCM Desc.	Rinex Desc.	RTCM Desc.	Rinex Desc.	RTCM Desc.
0	GPS L1CA	L1 C/A	GAL E1A	E1 A	BDS2 B1I	B1 I
1	GPS L1P	L1 P	GAL E1B	E1 B I/NAV		
2	GPS L1W	L1 Z-tracking	GAL E1C	E1 C		
3			GAL E1X	E1 B+C	BDS3 B3I	B3
4			GAL E1Z	E1 A+B+C	BDS3 B3Q	B3 Q
5	GPS L2C	L2 C/A	GAL E5I	E5a I F/NAV	BDS3 B3X	B3 I+Q
6	GPS L2D	L2 L1(C/A)+(P2-P1)	GAL E5Q	E5a Q	BDS2 B2	B2 I
7	GPS L2CM	L2 L2C (M)	GAL E5X	E5a I+Q		
8	GPS L2CL	L2 L2C (L)	GAL E7I	E5b I I/NAV		
9	GPS L2CX	L2 L2C (M+L)	GAL E7Q	E5b Q		
10	GPS L2P	L2 P	GAL E7X	E5b I+Q		
11	GPS L2W	L2 Z-tracking	GAL E8I	E5 I		
12			GAL E8Q	E5 Q	BDS3 B5I	B2a (D)
13			GAL E8X	E5 I+Q	BDS3 B5Q	B2a (P)
14	GPS L5I	L5 I	GAL E6A	E6 A	BDS3 B5X	B2a (D+P)
15	GPS L5Q	L5 Q	GAL E6B	E6 B C/NAV	BDS3 B1CI	B1C I
16	GPS L5X	L5 I+Q	GAL E6C	E6 C	BDS3 B1CQ	B1C Q
17	GPS L1CI	L1C (D)	GAL E6X	E6 B+C	BDS3 B1CX	B1C I+Q
18	GPS L1CQ	L1C (P)	GAL E6Z	E6 A+B+C		
19	GPS L1CX	L1C (D+P)				

Table 6.0.2: Signal and Tracking Mode Identifier

7 Message Types

Packages define a logical collection of SBP messages. The contents and layout of messages in packages marked **stable** are unlikely to change in the future. **Draft** messages *will change with future development* and are detailed purely for *informational purposes only*. Many draft messages are implementation-defined, and some collections, such as the acquisition package, are used for internal development.

Package	Msg ID	Name	Size (bytes)	Description
Stable				
Ext Events	257	MSG_EXT_EVENT	12	Reports timestamped external pin event
Imu	2304	MSG_IMU_RAW	17	Raw IMU data
	2305	MSG_IMU_AUX	4	Auxiliary IMU data
Logging	1025	MSG_LOG	$N+1$	Plaintext logging messages with levels
	1026	MSG_FWD	$N+2$	Wrapper for FWD a separate stream of information over SBP
Mag	2306	MSG_MAG_RAW	11	Raw magnetometer data
Navigation	258	MSG_GPS_TIME	11	GPS Time
	260	MSG_GPS_TIME_GNSS	11	GPS Time
	259	MSG_UTC_TIME	16	UTC Time
	261	MSG_UTC_TIME_GNSS	16	UTC Time
	520	MSG_DOPS	15	Dilution of Precision
	521	MSG_POS_ECEF	32	Single-point position in ECEF
	532	MSG_POS_ECEF_COV	54	Single-point position in ECEF
	522	MSG_POS_LLH	34	Geodetic Position
	529	MSG_POS_LLH_COV	54	Geodetic Position
	536	MSG_POS_LLH_ACC	67	Geodetic Position and Accuracy
	523	MSG_BASELINE_ECEF	20	Baseline Position in ECEF
	524	MSG_BASELINE_NED	22	Baseline in NED
	525	MSG_VEL_ECEF	20	Velocity in ECEF
	533	MSG_VEL_ECEF_COV	42	Velocity in ECEF
	526	MSG_VEL_NED	22	Velocity in NED
	530	MSG_VEL_NED_COV	42	Velocity in NED
	553	MSG_POS_ECEF_GNSS	32	GNSS-only Position in ECEF
	564	MSG_POS_ECEF_COV_GNSS	54	GNSS-only Position in ECEF
	554	MSG_POS_LLH_GNSS	34	GNSS-only Geodetic Position
	561	MSG_POS_LLH_COV_GNSS	54	GNSS-only Geodetic Position
	557	MSG_VEL_ECEF_GNSS	20	GNSS-only Velocity in ECEF
	565	MSG_VEL_ECEF_COV_GNSS	42	GNSS-only Velocity in ECEF
	558	MSG_VEL_NED_GNSS	22	GNSS-only Velocity in NED
	562	MSG_VEL_NED_COV_GNSS	42	GNSS-only Velocity in NED
	531	MSG_VEL_BODY	42	Velocity in User Frame
	540	MSG_VEL_COG	30	Velocity expressed as course over ground
	528	MSG_AGE_CORRECTIONS	6	Age of corrections
	570	MSG_UTC_LEAP_SECOND	14	Leap second SBP message.
	580	MSG_REFERENCE_FRAME_PARAM	124	Reference Frame Transformation Parameters
	581	MSG_POSE_RELATIVE	90	Relative Pose
Observation	74	MSG_OBS	$17N+11$	GPS satellite observations
	68	MSG_BASE_POS_LLH	24	Base station position
	72	MSG_BASE_POS_ECEF	24	Base station position in ECEF
	129	MSG_EPHEMERIS_GPS_DEP_E	185	Satellite broadcast ephemeris for GPS
	134	MSG_EPHEMERIS_GPS_DEP_F	183	Deprecated
	138	MSG_EPHEMERIS_GPS	139	Satellite broadcast ephemeris for GPS
	142	MSG_EPHEMERIS_QZSS	139	Satellite broadcast ephemeris for QZSS
	137	MSG_EPHEMERIS_BDS	147	Satellite broadcast ephemeris for BDS
	149	MSG_EPHEMERIS_GAL_DEP_A	152	Deprecated
	141	MSG_EPHEMERIS_GAL	153	Satellite broadcast ephemeris for Galileo
	130	MSG_EPHEMERIS_SBAS_DEP_A	112	Satellite broadcast ephemeris for SBAS
	131	MSG_EPHEMERIS_GLO_DEP_A	112	Satellite broadcast ephemeris for GLO
	132	MSG_EPHEMERIS_SBAS_DEP_B	110	Deprecated

	140	MSG_EPHEMERIS_SBAS	74	Satellite broadcast ephemeris for SBAS
	133	MSG_EPHEMERIS_GLO_DEP_B	110	Satellite broadcast ephemeris for GLO
	135	MSG_EPHEMERIS_GLO_DEP_C	119	Satellite broadcast ephemeris for GLO
	136	MSG_EPHEMERIS_GLO_DEP_D	120	Deprecated
	139	MSG_EPHEMERIS_GLO	92	Satellite broadcast ephemeris for GLO
	144	MSG_IONO	70	Iono corrections
	145	MSG_SV_CONFIGURATION_GPS_DEP	10	L2C capability mask
	150	MSG_GNSS_CAPB	110	GNSS capabilities
	146	MSG_GROUP_DELAY_DEP_A	14	Group Delay
	147	MSG_GROUP_DELAY_DEP_B	17	Group Delay
	148	MSG_GROUP_DELAY	15	Group Delay
	114	MSG_ALMANAC_GPS	94	Satellite broadcast ephemeris for GPS
	115	MSG_ALMANAC_GLO	78	Satellite broadcast ephemeris for GLO
	117	MSG_GLO_BIASES	9	GLONASS L1/L2 Code-Phase biases
	151	MSG_SV_AZ_EL	4N	Satellite azimuths and elevations
	1600	MSG_OSR	19N + 11	OSR corrections
Settings	161	MSG_SETTINGS_SAVE	0	Save settings to flash
	160	MSG_SETTINGS_WRITE	N	Write device configuration settings
	175	MSG_SETTINGS_WRITE_RESP	N + 1	Acknowledgement with status of MSG_SETTINGS_WRITE
	164	MSG_SETTINGS_READ_REQ	N	Read device configuration settings
	165	MSG_SETTINGS_READ_RESP	N	Read device configuration settings
	162	MSG_SETTINGS_READ_BY_INDEX_REQ	2	Read setting by direct index
	167	MSG_SETTINGS_READ_BY_INDEX_RESP	N + 2	Read setting by direct index
	166	MSG_SETTINGS_READ_BY_INDEX_DONE	0	Finished reading settings
Solution Meta	65294	MSG_SOLN_META	2N + 16	Solution Sensors Metadata
System	65280	MSG_STARTUP	4	System start-up message
	65282	MSG_DGNSS_STATUS	N + 4	Status of received corrections
	65535	MSG_HEARTBEAT	4	System heartbeat message
	65534	MSG_STATUS_REPORT	4N + 12	Status report message
	65533	MSG_STATUS_JOURNAL	8N + 9	Status report journal
	65283	MSG_INS_STATUS	4	Inertial Navigation System status message
	65287	MSG_GNSS_TIME_OFFSET	9	Offset of the local time with respect to GNSS time
	65288	MSG_PPS_TIME	9	Local time at detection of PPS pulse
	65289	MSG_SENSOR_AID_EVENT	15	Sensor state and update status data
	65290	MSG_GROUP_META	2N + 3	Solution Group Metadata
Draft				
Acquisition	47	MSG_ACQ_RESULT	14	Satellite acquisition result
	46	MSG_ACQ_SV_PROFILE	33N	Acquisition perfomance measurement and debug
File IO	168	MSG_FILEIO_READ_REQ	N + 9	Read file from the file system
	163	MSG_FILEIO_READ_RESP	N + 4	File read from the file system
	169	MSG_FILEIO_READ_DIR_REQ	N + 8	List files in a directory
	170	MSG_FILEIO_READ_DIR_RESP	N + 4	Files listed in a directory
	172	MSG_FILEIO_REMOVE	N	Delete a file from the file system
	173	MSG_FILEIO_WRITE_REQ	N + 9	Write to file
	171	MSG_FILEIO_WRITE_RESP	4	File written to
	4097	MSG_FILEIO_CONFIG_REQ	4	Request advice on the optimal configuration for FileIO
	4098	MSG_FILEIO_CONFIG_RESP	16	Response with advice on the optimal configuration for FileIO.
Integrity	3001	MSG_SSR_FLAG_HIGH_LEVEL	31	High level integrity flags
	3005	MSG_SSR_FLAG_SATELLITES	N + 12	List of satellites which are faulty, per constellation
	3011	MSG_SSR_FLAG_TROPO_GRID_POINTS	2N + 15	List of grid points which are faulty
	3015	MSG_SSR_FLAG_IONO_GRID_POINTS	2N + 15	List of grid points which are faulty
	3021	MSG_SSR_FLAG_IONO_TILE_SAT_LOS	2N + 15	List of all the LOS which are faulty
	3025	MSG_SSR_FLAG_IONO_GRID_POINT_SAT_LOS	2N + 17	List of all the grid points to satellite which are faulty

	3026	MSG_ACKNOWLEDGE	11	Acknowledgement message in response to a request for corrections
Orientation	527	MSG_BASELINE_HEADING	10	Heading relative to True North
	544	MSG_ORIENT_QUAT	37	Quaternion 4 component vector
	545	MSG_ORIENT_EULER	29	Euler angles
	546	MSG_ANGULAR_RATE	17	Vehicle Body Frame instantaneous angular rates
Piksi	105	MSG_ALMANAC	0	Legacy message to load satellite almanac
	104	MSG_SET_TIME	0	Send GPS time from host
	182	MSG_RESET	4	Reset the device
	178	MSG_RESET_DEP	0	Reset the device
	192	MSG_CW_RESULTS	0	Legacy message for CW interference channel (Piksi => host)
	193	MSG_CW_START	0	Legacy message for CW interference channel
	34	MSG_RESET_FILTERS	1	Reset IAR filters
	35	MSG_INIT_BASE_DEP	0	Deprecated
	23	MSG_THREAD_STATE	26	State of an RTOS thread
	29	MSG_UART_STATE	74	State of the UART channels
	24	MSG_UART_STATE_DEPA	58	Deprecated
	25	MSG_IAR_STATE	4	State of the Integer Ambiguity Resolution (IAR) process
	43	MSG_MASK_SATELLITE	3	Mask a satellite from use in Piksi subsystems
	181	MSG_DEVICE_MONITOR	10	Device temperature and voltage levels
	184	MSG_COMMAND_REQ	$N + 4$	Execute a command
	185	MSG_COMMAND_RESP	8	Exit code from executed command (device => host)
	188	MSG_COMMAND_OUTPUT	$N + 4$	Command output
	186	MSG_NETWORK_STATE_REQ	0	Request state of Piksi network interfaces
	187	MSG_NETWORK_STATE_RESP	50	State of network interface
	189	MSG_NETWORK_BANDWIDTH_USAGE	$40N$	Bandwidth usage reporting message
	190	MSG_CELL_MODEM_STATUS	$N + 5$	Cell modem information update message
	81	MSG_SPECAN	$N + 28$	Spectrum analyzer
	191	MSG_FRONT_END_GAIN	16	RF AGC status
Sbas	30583	MSG_SBAS_RAW	34	Raw SBAS data
Signing	3073	MSG_ED25519_SIGNATURE_DEP	$4N + 84$	Deprecated
	3074	MSG_ED25519_CERTIFICATE	$N + 21$	ED25519 certificate, split over multiple messages
	3075	MSG_ED25519_SIGNATURE	$4N + 86$	ED25519 signature for groups of RTCM messages
Ssr	1501	MSG_SSR_ORBIT_CLOCK	50	Precise orbit and clock correction
	1505	MSG_SSR_CODE_BIASES	$3N + 10$	Precise code biases correction
	1510	MSG_SSR_PHASE_BIASES	$8N + 15$	Precise phase biases correction
	1531	MSG_SSR_STEC_CORRECTION_DEP	$11N + 14$	STEC correction polynomial coefficients
	1533	MSG_SSR_STEC_CORRECTION	$11N + 16$	STEC correction polynomial coefficients
	1532	MSG_SSR_GRIDDED_CORRECTION	$5N + 23$	Gridded troposphere and STEC correction residuals
	1534	MSG_SSR_GRIDDED_CORRECTION_BOUNDS	$9N + 27$	Gridded troposhere and STEC correction residuals bounds
	1526	MSG_SSR_TILE_DEFINITION_DEP_A	24	Definition of a SSR atmospheric correction tile.
	1527	MSG_SSR_TILE_DEFINITION_DEP_B	25	Definition of a SSR atmospheric correction tile.
	1528	MSG_SSR_TILE_DEFINITION	33	Definition of a SSR atmospheric correction tile.
	1540	MSG_SSR_SATELLITE_APC_DEP	$32N$	Satellite antenna phase center corrections
	1541	MSG_SSR_SATELLITE_APC	$32N + 9$	Satellite antenna phase center corrections
	1502	MSG_SSR_ORBIT_CLOCK_BOUNDS	$9N + 13$	Combined Orbit and Clock Bound
	1516	MSG_SSR_CODE_PHASE_BIASES_BOUNDS	$6N + 13$	Combined Code and Phase Biases Bounds
	1503	MSG_SSR_ORBIT_CLOCK_BOUNDS_DEGRADATION	28	Combined Orbit and Clock Bound Degradation Parameter
Tracking	65	MSG_TRACKING_STATE	$4N$	Signal tracking channel states
	97	MSG_MEASUREMENT_STATE	$3N$	Measurement Engine signal tracking channel states
	45	MSG_TRACKING_IQ	$4N + 3$	Tracking channel correlations
	44	MSG_TRACKING_IQ_DEP_B	$8N + 3$	Tracking channel correlations

User	2048	MSG_USER_DATA	N	User data
Vehicle	2307	MSG_ODOMETRY	9	Vehicle forward (x-axis) velocity
	2308	MSG_WHEELTICK	14	Accumulated wheeltick count message

Table 7.0.2: SBP message types

8 Stable Message Definitions

8.1 Ext Events

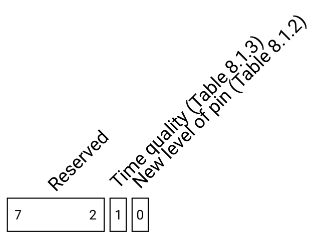
Messages reporting accurately-timestamped external events, e.g. camera shutter time.

MSG_EXT_EVENT — 0x0101 — 257

Reports detection of an external event, the GPS time it occurred, which pin it was and whether it was rising or falling.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16	weeks	`wn`	GPS week number
2	4	u32	ms	`tow`	GPS time of week rounded to the nearest millisecond
6	4	s32	ns	`ns_residual`	Nanosecond residual of millisecond-rounded TOW (ranges from -500000 to 500000)
10	1	u8		`flags`	Flags
11	1	u8		`pin`	Pin number. 0..9 = DEBUG0..9.
	12				Total Payload Length

Table 8.1.1: MSG_EXT_EVENT 0x0101 message structure



Field 8.1.1: Flags (`flags`)

Value	Description
0	Low (falling edge)
1	High (rising edge)

Table 8.1.2: New level of pin values (`flags[0]`)

Value	Description
0	Unknown - don't have nav solution
1	Good (< 1 microsecond)

Table 8.1.3: Time quality values (`flags[1]`)

8.2 Imu

Inertial Measurement Unit (IMU) messages.

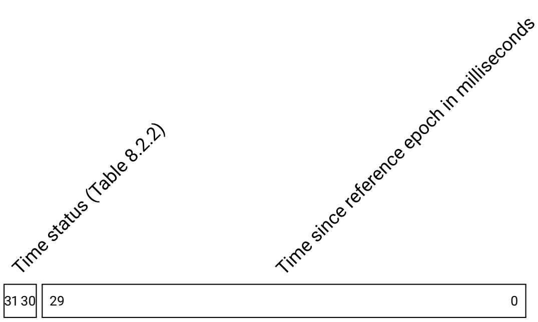
MSG_IMU_RAW — 0x0900 — 2304

Raw data from the Inertial Measurement Unit, containing accelerometer and gyroscope readings. The sense of the measurements are to be aligned with the indications on the device itself. Measurement units, which are specific to the device hardware and settings, are communicated via the MSG_IMU_AUX message. If using "time since startup" time tags, the receiving end will expect a 'MSG_GNSS_TIME_OFFSET' when a PVT fix becomes available to synchronise IMU measurements with GNSS. The timestamp must wrap around to zero when reaching one week (604800 seconds).

The time-tagging mode should not change throughout a run.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		`tow`	Milliseconds since reference epoch and time status.
4	1	u8	ms / 256	`tow_f`	Milliseconds since reference epoch, fractional part
5	2	s16		`acc_x`	Acceleration in the IMU frame X axis
7	2	s16		`acc_y`	Acceleration in the IMU frame Y axis
9	2	s16		`acc_z`	Acceleration in the IMU frame Z axis
11	2	s16		`gyr_x`	Angular rate around IMU frame X axis
13	2	s16		`gyr_y`	Angular rate around IMU frame Y axis
15	2	s16		`gyr_z`	Angular rate around IMU frame Z axis
	17				Total Payload Length

Table 8.2.1: MSG_IMU_RAW 0x0900 message structure



Field 8.2.1: Milliseconds since reference epoch and time status. (`tow`)

Value	Description
0	Reference epoch is start of current GPS week
1	Reference epoch is time of system startup
2	Reference epoch is unknown
3	Reference epoch is last PPS

Table 8.2.2: Time status values (`tow[30:31]`)

MSG_IMU_AUX — 0x0901 — 2305

Auxiliary data specific to a particular IMU. The ‘imu_type‘ field will always be consistent but the rest of the payload is device specific and depends on the value of ‘imu_type‘.

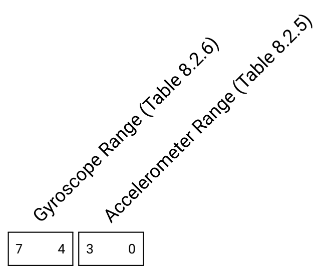
Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`imu_type`	IMU type
1	2	s16		`temp`	Raw IMU temperature
3	1	u8		`imu_conf`	IMU configuration
	4				Total Payload Length

Table 8.2.3: MSG_IMU_AUX 0x0901 message structure

Field 8.2.2: IMU type (`imu_type`)

Value	Description
0	Bosch BMI160
1	ST Microelectronics ASM330LLH

Table 8.2.4: IMU Type values (`imu_type[0:7]`)



Field 8.2.3: IMU configuration (`imu_conf`)

Value	Description
0	+/- 2g
1	+/- 4g
2	+/- 8g
3	+/- 16g

Table 8.2.5: Accelerometer Range values (`imu_conf[0:3]`)

Value	Description
0	+/- 2000 deg / s
1	+/- 1000 deg / s
2	+/- 500 deg / s
3	+/- 250 deg / s
4	+/- 125 deg / s

Table 8.2.6: Gyroscope Range values (`imu_conf[4:7]`)

8.3 Logging

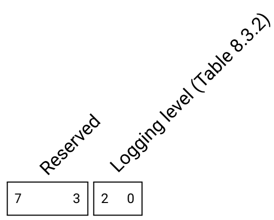
Logging and debugging messages from the device.

MSG_LOG — 0x0401 — 1025

This message contains a human-readable payload string from the device containing errors, warnings and informational messages at ERROR, WARNING, DEBUG, INFO logging levels.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`level`	Logging level
1	N	string		`text`	Human-readable string
	$N+1$				Total Payload Length

Table 8.3.1: MSG_LOG 0x0401 message structure



Field 8.3.1: Logging level (`level`)

Value	Description
0	EMERG
1	ALERT
2	CRIT
3	ERROR
4	WARN
5	NOTICE
6	INFO
7	DEBUG

Table 8.3.2: Logging level values (`level[0:2]`)

MSG_FWD — 0x0402 — 1026

This message provides the ability to forward messages over SBP. This may take the form of wrapping up SBP messages received by Piksi for logging purposes or wrapping another protocol with SBP.

The source identifier indicates from what interface a forwarded stream derived. The protocol identifier identifies what the expected protocol the forwarded msg contains. Protocol 0 represents SBP and the remaining values are implementation defined.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		source	source identifier
1	1	u8		protocol	protocol identifier
2	N	u8[N]		fwd_payload	variable length wrapped binary message
	$N + 2$				Total Payload Length

Table 8.3.3: MSG_FWD 0x0402 message structure

8.4 Mag

Magnetometer (mag) messages.

MSG_MAG_RAW — 0x0902 — 2306

Raw data from the magnetometer.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	tow	Milliseconds since start of GPS week. If the high bit is set, the time is unknown or invalid.
4	1	u8	ms / 256	tow_f	Milliseconds since start of GPS week, fractional part
5	2	s16	microteslas	mag_x	Magnetic field in the body frame X axis
7	2	s16	microteslas	mag_y	Magnetic field in the body frame Y axis
9	2	s16	microteslas	mag_z	Magnetic field in the body frame Z axis
	11				Total Payload Length

Table 8.4.1: MSG_MAG_RAW 0x0902 message structure

8.5 Navigation

Geodetic navigation messages reporting GPS time, position, velocity, and baseline position solutions. For position solutions, these messages define several different position solutions: single-point (SPP), RTK, and pseudo-absolute position solutions.

The SPP is the standalone, absolute GPS position solution using only a single receiver. The RTK solution is the differential GPS solution, which can use either a fixed/integer or floating carrier phase ambiguity. The pseudo-absolute position solution uses a user-provided, well-surveyed base station position (if available) and the RTK solution in tandem.

When the inertial navigation mode indicates that the IMU is used, all messages are reported in the vehicle body frame as defined by device settings. By default, the vehicle body frame is configured to be coincident with the antenna phase center. When there is no inertial navigation, the solution will be reported at the phase center of the antenna. There is no inertial navigation capability on Piksi Multi or Duro.

The tow field, when valid, is most often the Time of Measurement. When this is the case, the 5th bit of flags is set to the default value of 0. When this is not the case, the tow may be a time of arrival or a local system timestamp, irrespective of the time reference (GPS Week or else), but not a Time of Measurement.

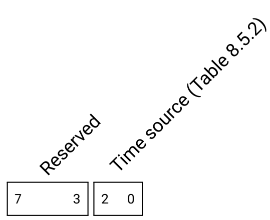
MSG_GPS_TIME — 0x0102 — 258

This message reports the GPS time, representing the time since the GPS epoch began on midnight January 6, 1980 UTC. GPS time counts the weeks and seconds of the week. The weeks begin at the Saturday/Sunday transition. GPS week 0 began at the beginning of the GPS time scale.

Within each week number, the GPS time of the week is between between 0 and 604800 seconds (=60*60*24*7). Note that GPS time does not accumulate leap seconds, and as of now, has a small offset from UTC. In a message stream, this message precedes a set of other navigation messages referenced to the same time (but lacking the ns field) and indicates a more precise time of these messages.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16	weeks	`wn`	GPS week number
2	4	u32	ms	`tow`	GPS time of week rounded to the nearest millisecond
6	4	s32	ns	`ns_residual`	Nanosecond residual of millisecond-rounded TOW (ranges from -500000 to 500000)
10	1	u8		`flags`	Status flags (reserved)
	11				Total Payload Length

Table 8.5.1: MSG_GPS_TIME 0x0102 message structure



Field 8.5.1: Status flags (reserved) (`flags`)

Value	Description
0	None (invalid)
1	GNSS Solution
2	Propagated

Table 8.5.2: Time source values (`flags[0:2]`)

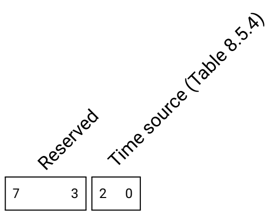
MSG_GPS_TIME_GNSS — 0x0104 — 260

This message reports the GPS time, representing the time since the GPS epoch began on midnight January 6, 1980 UTC. GPS time counts the weeks and seconds of the week. The weeks begin at the Saturday/Sunday transition. GPS week 0 began at the beginning of the GPS time scale.

Within each week number, the GPS time of the week is between between 0 and 604800 seconds (=60*60*24*7). Note that GPS time does not accumulate leap seconds, and as of now, has a small offset from UTC. In a message stream, this message precedes a set of other navigation messages referenced to the same time (but lacking the ns field) and indicates a more precise time of these messages.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16	weeks	`wn`	GPS week number
2	4	u32	ms	`tow`	GPS time of week rounded to the nearest millisecond
6	4	s32	ns	`ns_residual`	Nanosecond residual of millisecond-rounded TOW (ranges from -500000 to 500000)
10	1	u8		`flags`	Status flags (reserved)
	11				Total Payload Length

Table 8.5.3: MSG_GPS_TIME_GNSS 0x0104 message structure



Field 8.5.2: Status flags (reserved) (`flags`)

Value	Description
0	None (invalid)
1	GNSS Solution
2	Propagated

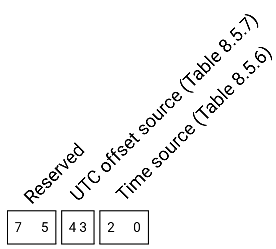
Table 8.5.4: Time source values (`flags[0:2]`)

MSG_UTC_TIME — 0x0103 — 259

This message reports the Universal Coordinated Time (UTC). Note the flags which indicate the source of the UTC offset value and source of the time fix.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`flags`	Indicates source and time validity
1	4	u32	ms	`tow`	GPS time of week rounded to the nearest millisecond
5	2	u16	year	`year`	Year
7	1	u8	months	`month`	Month (range 1 .. 12)
8	1	u8	day	`day`	days in the month (range 1-31)
9	1	u8	hours	`hours`	hours of day (range 0-23)
10	1	u8	minutes	`minutes`	minutes of hour (range 0-59)
11	1	u8	seconds	`seconds`	seconds of minute (range 0-60) rounded down
12	4	u32	nanoseconds	`ns`	nanoseconds of second (range 0-999999999)
	16				Total Payload Length

Table 8.5.5: MSG_UTC_TIME 0x0103 message structure



Field 8.5.3: Indicates source and time validity (`flags`)

Value	Description
0	None (invalid)
1	GNSS Solution
2	Propagated

Table 8.5.6: Time source values (`flags[0:2]`)

Value	Description
0	Factory Default
1	Non Volatile Memory
2	Decoded this Session

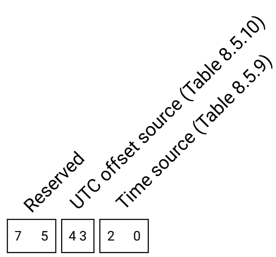
Table 8.5.7: UTC offset source values (`flags[3:4]`)

MSG_UTC_TIME_GNSS — 0x0105 — 261

This message reports the Universal Coordinated Time (UTC). Note the flags which indicate the source of the UTC offset value and source of the time fix.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		flags	Indicates source and time validity
1	4	u32	ms	tow	GPS time of week rounded to the nearest millisecond
5	2	u16	year	year	Year
7	1	u8	months	month	Month (range 1 .. 12)
8	1	u8	day	day	days in the month (range 1-31)
9	1	u8	hours	hours	hours of day (range 0-23)
10	1	u8	minutes	minutes	minutes of hour (range 0-59)
11	1	u8	seconds	seconds	seconds of minute (range 0-60) rounded down
12	4	u32	nanoseconds	ns	nanoseconds of second (range 0-999999999)
	16				Total Payload Length

Table 8.5.8: MSG_UTC_TIME_GNSS 0x0105 message structure



Field 8.5.4: Indicates source and time validity (flags)

Value	Description
0	None (invalid)
1	GNSS Solution
2	Propagated

Table 8.5.9: Time source values (flags[0:2])

Value	Description
0	Factory Default
1	Non Volatile Memory
2	Decoded this Session

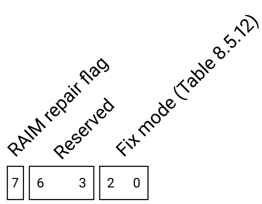
Table 8.5.10: UTC offset source values (flags[3:4])

MSG_DOPS — 0x0208 — 520

This dilution of precision (DOP) message describes the effect of navigation satellite geometry on positional measurement precision. The flags field indicated whether the DOP reported corresponds to differential or SPP solution.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	2	u16	0.01	`gdop`	Geometric Dilution of Precision
6	2	u16	0.01	`pdop`	Position Dilution of Precision
8	2	u16	0.01	`tdop`	Time Dilution of Precision
10	2	u16	0.01	`hdop`	Horizontal Dilution of Precision
12	2	u16	0.01	`vdop`	Vertical Dilution of Precision
14	1	u8		`flags`	Indicates the position solution with which the DOPS message corresponds
	15				Total Payload Length

Table 8.5.11: MSG_DOPS 0x0208 message structure



Field 8.5.5: Indicates the position solution with which the DOPS message corresponds (`flags`)

Value	Description
0	Invalid
1	Single Point Position (SPP)
2	Differential GNSS (DGNSS)
3	Float RTK
4	Fixed RTK
5	Undefined
6	SBAS Position

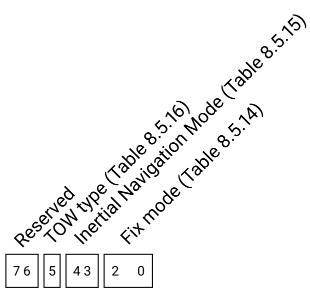
Table 8.5.12: Fix mode values (`flags[0:2]`)

MSG_POS_ECEF — 0x0209 — 521

The position solution message reports absolute Earth Centered Earth Fixed (ECEF) coordinates and the status (single point vs pseudo-absolute RTK) of the position solution. If the rover receiver knows the surveyed position of the base station and has an RTK solution, this reports a pseudo-absolute position solution using the base station position and the rover's RTK baseline vector. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	8	double	m	`x`	ECEF X coordinate
12	8	double	m	`y`	ECEF Y coordinate
20	8	double	m	`z`	ECEF Z coordinate
28	2	u16	mm	`accuracy`	Position estimated standard deviation
30	1	u8		`n_sats`	Number of satellites used in solution
31	1	u8		`flags`	Status flags
	32				Total Payload Length

Table 8.5.13: MSG_POS_ECEF 0x0209 message structure



Field 8.5.6: Status flags (`flags`)

Value	Description
0	Invalid
1	Single Point Position (SPP)
2	Differential GNSS (DGNSS)
3	Float RTK
4	Fixed RTK
5	Dead Reckoning
6	SBAS Position

Table 8.5.14: Fix mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

Table 8.5.15: Inertial Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

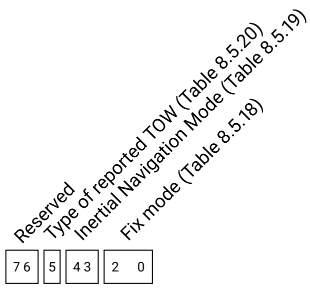
Table 8.5.16: TOW type values (`flags[5:5]`)

MSG_POS_ECEF_COV — 0x0214 — 532

The position solution message reports absolute Earth Centered Earth Fixed (ECEF) coordinates and the status (single point vs pseudo-absolute RTK) of the position solution. The message also reports the upper triangular portion of the 3x3 covariance matrix. If the receiver knows the surveyed position of the base station and has an RTK solution, this reports a pseudo-absolute position solution using the base station position and the rover's RTK baseline vector. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	8	double	m	`x`	ECEF X coordinate
12	8	double	m	`y`	ECEF Y coordinate
20	8	double	m	`z`	ECEF Z coordinate
28	4	float	m^2	`cov_x_x`	Estimated variance of x
32	4	float	m^2	`cov_x_y`	Estimated covariance of x and y
36	4	float	m^2	`cov_x_z`	Estimated covariance of x and z
40	4	float	m^2	`cov_y_y`	Estimated variance of y
44	4	float	m^2	`cov_y_z`	Estimated covariance of y and z
48	4	float	m^2	`cov_z_z`	Estimated variance of z
52	1	u8		`n_sats`	Number of satellites used in solution
53	1	u8		`flags`	Status flags
	54				Total Payload Length

Table 8.5.17: MSG_POS_ECEF_COV 0x0214 message structure



Field 8.5.7: Status flags (`flags`)

Value	Description
0	Invalid
1	Single Point Position (SPP)
2	Differential GNSS (DGNSS)
3	Float RTK
4	Fixed RTK
5	Dead Reckoning
6	SBAS Position

Table 8.5.18: Fix mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

Table 8.5.19: Inertial Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

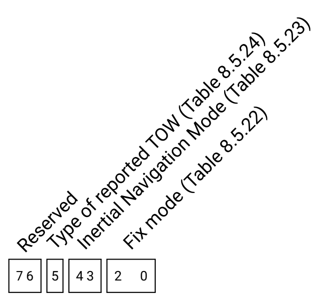
Table 8.5.20: Type of reported TOW values (`flags[5:5]`)

MSG_POS_LLH — 0x020A — 522

This position solution message reports the absolute geodetic coordinates and the status (single point vs pseudo-absolute RTK) of the position solution. If the rover receiver knows the surveyed position of the base station and has an RTK solution, this reports a pseudo-absolute position solution using the base station position and the rover's RTK baseline vector. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	8	double	deg	`lat`	Latitude
12	8	double	deg	`lon`	Longitude
20	8	double	m	`height`	Height above WGS84 ellipsoid
28	2	u16	mm	`h_accuracy`	Horizontal position estimated standard deviation
30	2	u16	mm	`v_accuracy`	Vertical position estimated standard deviation
32	1	u8		`n_sats`	Number of satellites used in solution.
33	1	u8		`flags`	Status flags
	34				Total Payload Length

Table 8.5.21: MSG_POS_LLH 0x020A message structure



Field 8.5.8: Status flags (`flags`)

Value	Description
0	Invalid
1	Single Point Position (SPP)
2	Differential GNSS (DGNSS)
3	Float RTK
4	Fixed RTK
5	Dead Reckoning
6	SBAS Position

Table 8.5.22: Fix mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

Table 8.5.23: Inertial Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

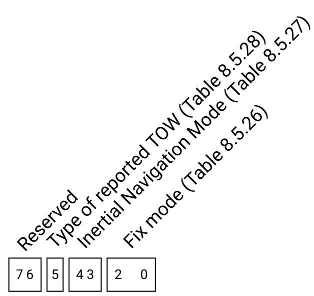
Table 8.5.24: Type of reported TOW values (`flags[5:5]`)

MSG_POS_LLH_COV — 0x0211 — 529

This position solution message reports the absolute geodetic coordinates and the status (single point vs pseudo-absolute RTK) of the position solution as well as the upper triangle of the 3x3 covariance matrix. The position information and Fix Mode flags follow the MSG_POS_LLH message. Since the covariance matrix is computed in the local-level North, East, Down frame, the covariance terms follow that convention. Thus, covariances are reported against the "downward" measurement and care should be taken with the sign convention.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	8	double	deg	`lat`	Latitude
12	8	double	deg	`lon`	Longitude
20	8	double	m	`height`	Height above WGS84 ellipsoid
28	4	float	m^2	`cov_n_n`	Estimated variance of northing
32	4	float	m^2	`cov_n_e`	Covariance of northing and easting
36	4	float	m^2	`cov_n_d`	Covariance of northing and downward measurement
40	4	float	m^2	`cov_e_e`	Estimated variance of easting
44	4	float	m^2	`cov_e_d`	Covariance of easting and downward measurement
48	4	float	m^2	`cov_d_d`	Estimated variance of downward measurement
52	1	u8		`n_sats`	Number of satellites used in solution.
53	1	u8		`flags`	Status flags
	54				Total Payload Length

Table 8.5.25: MSG_POS_LLH_COV 0x0211 message structure



Field 8.5.9: Status flags (`flags`)

Value	Description
0	Invalid
1	Single Point Position (SPP)
2	Differential GNSS (DGNSS)
3	Float RTK
4	Fixed RTK
5	Dead Reckoning
6	SBAS Position

Table 8.5.26: Fix mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

Table 8.5.27: Inertial Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

Table 8.5.28: Type of reported TOW values (`flags[5:5]`)

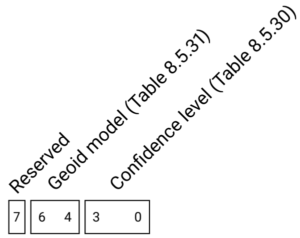
MSG_POS_LLH_ACC — 0x0218 — 536

This position solution message reports the absolute geodetic coordinates and the status (single point vs pseudo-absolute RTK) of the position solution as well as the estimated horizontal, vertical, cross-track and along-track errors. The position information and Fix Mode flags follow the MSG_POS_LLH message. Since the covariance matrix is computed in the local-level North, East, Down frame, the estimated error terms follow that convention.

The estimated errors are reported at a user-configurable confidence level. The user-configured percentile is encoded in the percentile field.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	tow	GPS Time of Week
4	8	double	deg	lat	Latitude
12	8	double	deg	lon	Longitude
20	8	double	m	height	Height above WGS84 ellipsoid
28	8	double	m	orthometric_height	Height above the geoid (i.e. height above mean sea level). See confidence_and_geoid for geoid model used.
36	4	float	m	h_accuracy	Estimated horizontal error at the user-configured confidence level; zero implies invalid.
40	4	float	m	v_accuracy	Estimated vertical error at the user-configured confidence level; zero implies invalid.
44	4	float	m	ct_accuracy	Estimated cross-track error at the user-configured confidence level; zero implies invalid.
48	4	float	m	at_accuracy	Estimated along-track error at the user-configured confidence level; zero implies invalid.
52	4	float	m	h_ellipse.semi_major	The semi major axis of the estimated horizontal error ellipse at the user-configured confidence level; zero implies invalid.
56	4	float	m	h_ellipse.semi_minor	The semi minor axis of the estimated horizontal error ellipse at the user-configured confidence level; zero implies invalid.
60	4	float	deg	h_ellipse.orientation	The orientation of the semi major axis of the estimated horizontal error ellipse with respect to North.
64	1	u8		confidence_and_geoid	The lower bits describe the configured confidence level for the estimated position error. The middle bits describe the geoid model used to calculate the orthometric height.
65	1	u8		n_sats	Number of satellites used in solution.
66	1	u8		flags	Status flags
	67				Total Payload Length

Table 8.5.29: MSG_POS_LLH_ACC 0x0218 message structure



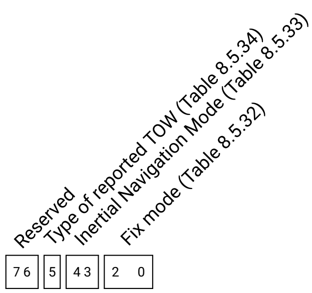
Field 8.5.10: The lower bits describe the configured confidence level for the estimated position error. The middle bits describe the geoid model used to calculate the orthometric height. (`confidence_and_geoid`)

Value	Description
0	reserved
1	39.35%
2	68.27%
3	95.45%

Table 8.5.30: Confidence level values (`confidence_and_geoid[0:3]`)

Value	Description
0	No model
1	EGM96
2	EGM2008

Table 8.5.31: Geoid model values (`confidence_and_geoid[4:6]`)



Field 8.5.11: Status flags (`flags`)

Value	Description
0	Invalid
1	Single Point Position (SPP)
2	Differential GNSS (DGNSS)
3	Float RTK
4	Fixed RTK
5	Dead Reckoning
6	SBAS Position

Table 8.5.32: Fix mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

Table 8.5.33: Inertial Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

Table 8.5.34: Type of reported TOW values (`flags[5:5]`)

MSG_BASELINE_ECEF — 0x020B — 523

This message reports the baseline solution in Earth Centered Earth Fixed (ECEF) coordinates. This baseline is the relative vector distance from the base station to the rover receiver. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	4	s32	mm	`x`	Baseline ECEF X coordinate
8	4	s32	mm	`y`	Baseline ECEF Y coordinate
12	4	s32	mm	`z`	Baseline ECEF Z coordinate
16	2	u16	mm	`accuracy`	Position estimated standard deviation
18	1	u8		`n_sats`	Number of satellites used in solution
19	1	u8		`flags`	Status flags
	20				Total Payload Length

Table 8.5.35: MSG_BASELINE_ECEF 0x020B message structure

Field 8.5.12: Status flags (`flags`)

Value	Description
0	Invalid
1	Reserved
2	Differential GNSS (DGNSS)
3	Float RTK
4	Fixed RTK
5	Reserved
6	Reserved

Table 8.5.36: Fix mode values (`flags[0:2]`)

MSG_BASELINE_NED — 0x020C — 524

This message reports the baseline solution in North East Down (NED) coordinates. This baseline is the relative vector distance from the base station to the rover receiver, and NED coordinate system is defined at the local WGS84 tangent plane centered at the base station position. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	4	s32	mm	`n`	Baseline North coordinate
8	4	s32	mm	`e`	Baseline East coordinate
12	4	s32	mm	`d`	Baseline Down coordinate
16	2	u16	mm	`h_accuracy`	Horizontal position estimated standard deviation
18	2	u16	mm	`v_accuracy`	Vertical position estimated standard deviation
20	1	u8		`n_sats`	Number of satellites used in solution
21	1	u8		`flags`	Status flags
	22				Total Payload Length

Table 8.5.37: MSG_BASELINE_NED 0x020C message structure

Field 8.5.13: Status flags (`flags`)

Value	Description
0	Invalid
1	Reserved
2	Differential GNSS (DGNSS)
3	Float RTK
4	Fixed RTK
5	Reserved
6	Reserved

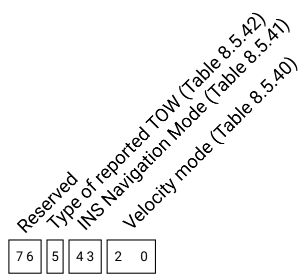
Table 8.5.38: Fix mode values (`flags[0:2]`)

MSG_VEL_ECEF — 0x020D — 525

This message reports the velocity in Earth Centered Earth Fixed (ECEF) coordinates. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	tow	GPS Time of Week
4	4	s32	mm/s	x	Velocity ECEF X coordinate
8	4	s32	mm/s	y	Velocity ECEF Y coordinate
12	4	s32	mm/s	z	Velocity ECEF Z coordinate
16	2	u16	mm/s	accuracy	Velocity estimated standard deviation
18	1	u8		n_sats	Number of satellites used in solution
19	1	u8		flags	Status flags
	20				Total Payload Length

Table 8.5.39: MSG_VEL_ECEF 0x020D message structure



Field 8.5.14: Status flags (`flags`)

Value	Description
0	Invalid
1	Measured Doppler derived
2	Computed Doppler derived
3	Dead Reckoning

Table 8.5.40: Velocity mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

Table 8.5.41: INS Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

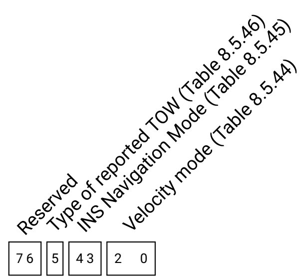
Table 8.5.42: Type of reported TOW values (`flags[5:5]`)

MSG_VEL_ECEF_COV — 0x0215 — 533

This message reports the velocity in Earth Centered Earth Fixed (ECEF) coordinates. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	4	s32	mm/s	`x`	Velocity ECEF X coordinate
8	4	s32	mm/s	`y`	Velocity ECEF Y coordinate
12	4	s32	mm/s	`z`	Velocity ECEF Z coordinate
16	4	float	m^2/s^2	`cov_x_x`	Estimated variance of x
20	4	float	m^2/s^2	`cov_x_y`	Estimated covariance of x and y
24	4	float	m^2/s^2	`cov_x_z`	Estimated covariance of x and z
28	4	float	m^2/s^2	`cov_y_y`	Estimated variance of y
32	4	float	m^2/s^2	`cov_y_z`	Estimated covariance of y and z
36	4	float	m^2/s^2	`cov_z_z`	Estimated variance of z
40	1	u8		`n_sats`	Number of satellites used in solution
41	1	u8		`flags`	Status flags
	42				Total Payload Length

Table 8.5.43: MSG_VEL_ECEF_COV 0x0215 message structure



Field 8.5.15: Status flags (`flags`)

Value	Description
0	Invalid
1	Measured Doppler derived
2	Computed Doppler derived
3	Dead Reckoning

Table 8.5.44: Velocity mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

Table 8.5.45: INS Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

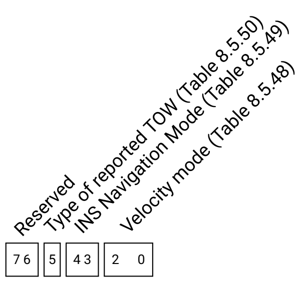
Table 8.5.46: Type of reported TOW values (`flags[5:5]`)

MSG_VEL_NED — 0x020E — 526

This message reports the velocity in local North East Down (NED) coordinates. The NED coordinate system is defined as the local WGS84 tangent plane centered at the current position. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	4	s32	mm/s	`n`	Velocity North coordinate
8	4	s32	mm/s	`e`	Velocity East coordinate
12	4	s32	mm/s	`d`	Velocity Down coordinate
16	2	u16	mm/s	`h_accuracy`	Horizontal velocity estimated standard deviation
18	2	u16	mm/s	`v_accuracy`	Vertical velocity estimated standard deviation
20	1	u8		`n_sats`	Number of satellites used in solution
21	1	u8		`flags`	Status flags
	22				Total Payload Length

Table 8.5.47: MSG_VEL_NED 0x020E message structure



Field 8.5.16: Status flags (`flags`)

Value	Description
0	Invalid
1	Measured Doppler derived
2	Computed Doppler derived
3	Dead Reckoning

Table 8.5.48: Velocity mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

Table 8.5.49: INS Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

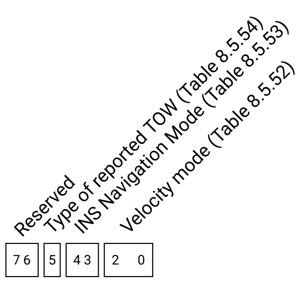
Table 8.5.50: Type of reported TOW values (`flags[5:5]`)

MSG_VEL_NED_COV — 0x0212 — 530

This message reports the velocity in local North East Down (NED) coordinates. The NED coordinate system is defined as the local WGS84 tangent plane centered at the current position. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow). This message is similar to the MSG_VEL_NED, but it includes the upper triangular portion of the 3x3 covariance matrix.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	4	s32	mm/s	`n`	Velocity North coordinate
8	4	s32	mm/s	`e`	Velocity East coordinate
12	4	s32	mm/s	`d`	Velocity Down coordinate
16	4	float	m^2	`cov_n_n`	Estimated variance of northward measurement
20	4	float	m^2	`cov_n_e`	Covariance of northward and eastward measurement
24	4	float	m^2	`cov_n_d`	Covariance of northward and downward measurement
28	4	float	m^2	`cov_e_e`	Estimated variance of eastward measurement
32	4	float	m^2	`cov_e_d`	Covariance of eastward and downward measurement
36	4	float	m^2	`cov_d_d`	Estimated variance of downward measurement
40	1	u8		`n_sats`	Number of satellites used in solution
41	1	u8		`flags`	Status flags
	42				Total Payload Length

Table 8.5.51: MSG_VEL_NED_COV 0x0212 message structure



Field 8.5.17: Status flags (`flags`)

Value	Description
0	Invalid
1	Measured Doppler derived
2	Computed Doppler derived
3	Dead Reckoning

Table 8.5.52: Velocity mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

Table 8.5.53: INS Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

Table 8.5.54: Type of reported TOW values (`flags[5:5]`)

MSG_POS_ECEF_GNSS — 0x0229 — 553

The position solution message reports absolute Earth Centered Earth Fixed (ECEF) coordinates and the status (single point vs pseudo-absolute RTK) of the position solution. If the rover receiver knows the surveyed position of the base station and has an RTK solution, this reports a pseudo-absolute position solution using the base station position and the rover's RTK baseline vector. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	8	double	m	`x`	ECEF X coordinate
12	8	double	m	`y`	ECEF Y coordinate
20	8	double	m	`z`	ECEF Z coordinate
28	2	u16	mm	`accuracy`	Position estimated standard deviation
30	1	u8		`n_sats`	Number of satellites used in solution
31	1	u8		`flags`	Status flags
	32				Total Payload Length

Table 8.5.55: MSG_POS_ECEF_GNSS 0x0229 message structure

Field 8.5.18: Status flags (`flags`)

Value	Description
0	Invalid
1	Single Point Position (SPP)
2	Differential GNSS (DGNSS)
3	Float RTK
4	Fixed RTK
5	Reserved
6	SBAS Position

Table 8.5.56: Fix mode values (`flags[0:2]`)

MSG_POS_ECEF_COV_GNSS — 0x0234 — 564

The position solution message reports absolute Earth Centered Earth Fixed (ECEF) coordinates and the status (single point vs pseudo-absolute RTK) of the position solution. The message also reports the upper triangular portion of the 3x3 covariance matrix. If the receiver knows the surveyed position of the base station and has an RTK solution, this reports a pseudo-absolute position solution using the base station position and the rover's RTK baseline vector. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	8	double	m	`x`	ECEF X coordinate
12	8	double	m	`y`	ECEF Y coordinate
20	8	double	m	`z`	ECEF Z coordinate
28	4	float	m^2	`cov_x_x`	Estimated variance of x
32	4	float	m^2	`cov_x_y`	Estimated covariance of x and y
36	4	float	m^2	`cov_x_z`	Estimated covariance of x and z
40	4	float	m^2	`cov_y_y`	Estimated variance of y
44	4	float	m^2	`cov_y_z`	Estimated covariance of y and z
48	4	float	m^2	`cov_z_z`	Estimated variance of z
52	1	u8		`n_sats`	Number of satellites used in solution
53	1	u8		`flags`	Status flags
	54				Total Payload Length

Table 8.5.57: MSG_POS_ECEF_COV_GNSS 0x0234 message structure

Field 8.5.19: Status flags (`flags`)

Value	Description
0	Invalid
1	Single Point Position (SPP)
2	Differential GNSS (DGNSS)
3	Float RTK
4	Fixed RTK
5	Reserved
6	SBAS Position

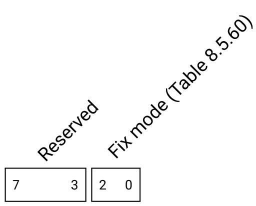
Table 8.5.58: Fix mode values (`flags[0:2]`)

MSG_POS_LLH_GNSS — 0x022A — 554

This position solution message reports the absolute geodetic coordinates and the status (single point vs pseudo-absolute RTK) of the position solution. If the rover receiver knows the surveyed position of the base station and has an RTK solution, this reports a pseudo-absolute position solution using the base station position and the rover's RTK baseline vector. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	8	double	deg	`lat`	Latitude
12	8	double	deg	`lon`	Longitude
20	8	double	m	`height`	Height above WGS84 ellipsoid
28	2	u16	mm	`h_accuracy`	Horizontal position estimated standard deviation
30	2	u16	mm	`v_accuracy`	Vertical position estimated standard deviation
32	1	u8		`n_sats`	Number of satellites used in solution.
33	1	u8		`flags`	Status flags
	34				Total Payload Length

Table 8.5.59: MSG_POS_LLH_GNSS 0x022A message structure



Field 8.5.20: Status flags (`flags`)

Value	Description
0	Invalid
1	Single Point Position (SPP)
2	Differential GNSS (DGNSS)
3	Float RTK
4	Fixed RTK
5	Reserved
6	SBAS Position

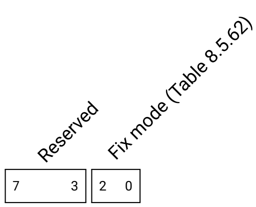
Table 8.5.60: Fix mode values (`flags[0:2]`)

MSG_POS_LLH_COV_GNSS — 0x0231 — 561

This position solution message reports the absolute geodetic coordinates and the status (single point vs pseudo-absolute RTK) of the position solution as well as the upper triangle of the 3x3 covariance matrix. The position information and Fix Mode flags should follow the MSG_POS_LLH message. Since the covariance matrix is computed in the local-level North, East, Down frame, the covariance terms follow with that convention. Thus, covariances are reported against the ”downward” measurement and care should be taken with the sign convention.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	8	double	deg	`lat`	Latitude
12	8	double	deg	`lon`	Longitude
20	8	double	m	`height`	Height above WGS84 ellipsoid
28	4	float	m^2	`cov_n_n`	Estimated variance of northing
32	4	float	m^2	`cov_n_e`	Covariance of northing and easting
36	4	float	m^2	`cov_n_d`	Covariance of northing and downward measurement
40	4	float	m^2	`cov_e_e`	Estimated variance of easting
44	4	float	m^2	`cov_e_d`	Covariance of easting and downward measurement
48	4	float	m^2	`cov_d_d`	Estimated variance of downward measurement
52	1	u8		`n_sats`	Number of satellites used in solution.
53	1	u8		`flags`	Status flags
	54				Total Payload Length

Table 8.5.61: MSG_POS_LLH_COV_GNSS 0x0231 message structure



Field 8.5.21: Status flags (`flags`)

Value	Description
0	Invalid
1	Single Point Position (SPP)
2	Differential GNSS (DGNSS)
3	Float RTK
4	Fixed RTK
5	Dead Reckoning
6	SBAS Position

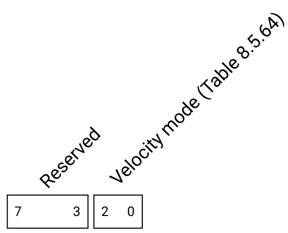
Table 8.5.62: Fix mode values (`flags[0:2]`)

MSG_VEL_ECEF_GNSS — 0x022D — 557

This message reports the velocity in Earth Centered Earth Fixed (ECEF) coordinates. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	4	s32	mm/s	`x`	Velocity ECEF X coordinate
8	4	s32	mm/s	`y`	Velocity ECEF Y coordinate
12	4	s32	mm/s	`z`	Velocity ECEF Z coordinate
16	2	u16	mm/s	`accuracy`	Velocity estimated standard deviation
18	1	u8		`n_sats`	Number of satellites used in solution
19	1	u8		`flags`	Status flags
	20				Total Payload Length

Table 8.5.63: MSG_VEL_ECEF_GNSS 0x022D message structure



Field 8.5.22: Status flags (`flags`)

Value	Description
0	Invalid
1	Measured Doppler derived
2	Computed Doppler derived
3	Reserved

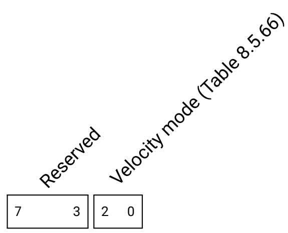
Table 8.5.64: Velocity mode values (`flags[0:2]`)

MSG_VEL_ECEF_COV_GNSS — 0x0235 — 565

This message reports the velocity in Earth Centered Earth Fixed (ECEF) coordinates. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	4	s32	mm/s	`x`	Velocity ECEF X coordinate
8	4	s32	mm/s	`y`	Velocity ECEF Y coordinate
12	4	s32	mm/s	`z`	Velocity ECEF Z coordinate
16	4	float	m^2/s^2	`cov_x_x`	Estimated variance of x
20	4	float	m^2/s^2	`cov_x_y`	Estimated covariance of x and y
24	4	float	m^2/s^2	`cov_x_z`	Estimated covariance of x and z
28	4	float	m^2/s^2	`cov_y_y`	Estimated variance of y
32	4	float	m^2/s^2	`cov_y_z`	Estimated covariance of y and z
36	4	float	m^2/s^2	`cov_z_z`	Estimated variance of z
40	1	u8		`n_sats`	Number of satellites used in solution
41	1	u8		`flags`	Status flags
	42				Total Payload Length

Table 8.5.65: MSG_VEL_ECEF_COV_GNSS 0x0235 message structure



Field 8.5.23: Status flags (`flags`)

Value	Description
0	Invalid
1	Measured Doppler derived
2	Computed Doppler derived
3	Reserved

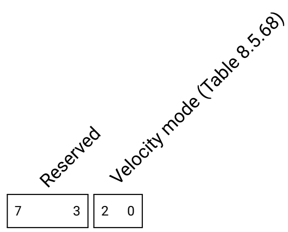
Table 8.5.66: Velocity mode values (`flags[0:2]`)

MSG_VEL_NED_GNSS — 0x022E — 558

This message reports the velocity in local North East Down (NED) coordinates. The NED coordinate system is defined as the local WGS84 tangent plane centered at the current position. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	4	s32	mm/s	`n`	Velocity North coordinate
8	4	s32	mm/s	`e`	Velocity East coordinate
12	4	s32	mm/s	`d`	Velocity Down coordinate
16	2	u16	mm/s	`h_accuracy`	Horizontal velocity estimated standard deviation
18	2	u16	mm/s	`v_accuracy`	Vertical velocity estimated standard deviation
20	1	u8		`n_sats`	Number of satellites used in solution
21	1	u8		`flags`	Status flags
	22				Total Payload Length

Table 8.5.67: MSG_VEL_NED_GNSS 0x022E message structure



Field 8.5.24: Status flags (`flags`)

Value	Description
0	Invalid
1	Measured Doppler derived
2	Computed Doppler derived
3	Reserved

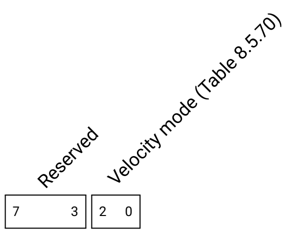
Table 8.5.68: Velocity mode values (`flags[0:2]`)

MSG_VEL_NED_COV_GNSS — 0x0232 — 562

This message reports the velocity in local North East Down (NED) coordinates. The NED coordinate system is defined as the local WGS84 tangent plane centered at the current position. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow). This message is similar to the MSG_VEL_NED, but it includes the upper triangular portion of the 3x3 covariance matrix.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	4	s32	mm/s	`n`	Velocity North coordinate
8	4	s32	mm/s	`e`	Velocity East coordinate
12	4	s32	mm/s	`d`	Velocity Down coordinate
16	4	float	m^2	`cov_n_n`	Estimated variance of northward measurement
20	4	float	m^2	`cov_n_e`	Covariance of northward and eastward measurement
24	4	float	m^2	`cov_n_d`	Covariance of northward and downward measurement
28	4	float	m^2	`cov_e_e`	Estimated variance of eastward measurement
32	4	float	m^2	`cov_e_d`	Covariance of eastward and downward measurement
36	4	float	m^2	`cov_d_d`	Estimated variance of downward measurement
40	1	u8		`n_sats`	Number of satellites used in solution
41	1	u8		`flags`	Status flags
	42				Total Payload Length

Table 8.5.69: MSG_VEL_NED_COV_GNSS 0x0232 message structure



Field 8.5.25: Status flags (`flags`)

Value	Description
0	Invalid
1	Measured Doppler derived
2	Computed Doppler derived
3	Reserved

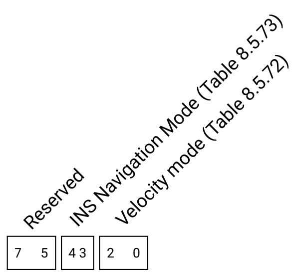
Table 8.5.70: Velocity mode values (`flags[0:2]`)

MSG_VEL_BODY — 0x0213 — 531

This message reports the velocity in the Vehicle Body Frame. By convention, the x-axis should point out the nose of the vehicle and represent the forward direction, while as the y-axis should point out the right hand side of the vehicle. Since this is a right handed system, z should point out the bottom of the vehicle. The orientation and origin of the Vehicle Body Frame are specified via the device settings. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow). This message is only produced by inertial versions of Swift products and is not available from Piksi Multi or Duro.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	4	s32	mm/s	`x`	Velocity in x direction
8	4	s32	mm/s	`y`	Velocity in y direction
12	4	s32	mm/s	`z`	Velocity in z direction
16	4	float	m^2	`cov_x_x`	Estimated variance of x
20	4	float	m^2	`cov_x_y`	Covariance of x and y
24	4	float	m^2	`cov_x_z`	Covariance of x and z
28	4	float	m^2	`cov_y_y`	Estimated variance of y
32	4	float	m^2	`cov_y_z`	Covariance of y and z
36	4	float	m^2	`cov_z_z`	Estimated variance of z
40	1	u8		`n_sats`	Number of satellites used in solution
41	1	u8		`flags`	Status flags
	42				Total Payload Length

Table 8.5.71: MSG_VEL_BODY 0x0213 message structure



Field 8.5.26: Status flags (`flags`)

Value	Description
0	Invalid
1	Measured Doppler derived
2	Computed Doppler derived
3	Dead Reckoning

Table 8.5.72: Velocity mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

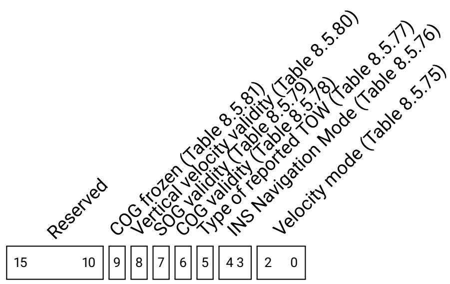
Table 8.5.73: INS Navigation Mode values (`flags[3:4]`)

MSG_VEL_COG — 0x021C — 540

This message reports the receiver course over ground (COG) and speed over ground (SOG) based on the horizontal (N-E) components of the NED velocity vector. It also includes the vertical velocity coordinate. A flag is provided to indicate whether the COG value has been frozen. When the flag is set to true, the COG field is set to its last valid value until the system exceeds a minimum velocity threshold. No other fields are affected by this flag. The NED coordinate system is defined as the local WGS84 tangent plane centered at the current position. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow). Note: course over ground represents the receiver's direction of travel, but not necessarily the device heading.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	4	u32	microdegrees	`cog`	Course over ground relative to north direction
8	4	u32	mm/s	`sog`	Speed over ground (based on horizontal velocity)
12	4	s32	mm/s	`v_up`	Vertical velocity component (positive up)
16	4	u32	microdegrees	`cog_accuracy`	Course over ground estimated standard deviation
20	4	u32	mm/s	`sog_accuracy`	Speed over ground estimated standard deviation
24	4	u32	mm/s	`v_up_accuracy`	Vertical velocity estimated standard deviation
28	2	u16		`flags`	Status flags
	30				Total Payload Length

Table 8.5.74: MSG_VEL_COG 0x021C message structure



Field 8.5.27: Status flags (`flags`)

Value	Description
0	Invalid
1	Measured Doppler derived
2	Computed Doppler derived
3	Dead Reckoning

Table 8.5.75: Velocity mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

Table 8.5.76: INS Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

Table 8.5.77: Type of reported TOW values (`flags[5]`)

Value	Description
0	Invalid
1	COG valid

Table 8.5.78: COG validity values (`flags[6]`)

Value	Description
0	Invalid
1	SOG valid

Table 8.5.79: SOG validity values (`flags[7]`)

Value	Description
0	Invalid
1	Vertical velocity valid

Table 8.5.80: Vertical velocity validity values (`flags[8]`)

Value	Description
0	Not frozen
1	Frozen

Table 8.5.81: COG frozen values (`flags[9]`)

MSG_AGE_CORRECTIONS — 0x0210 — 528

This message reports the Age of the corrections used for the current Differential solution.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	tow	GPS Time of Week
4	2	u16	deciseconds	age	Age of the corrections (0xFFFF indicates invalid)
	6				Total Payload Length

Table 8.5.82: MSG_AGE_CORRECTIONS 0x0210 message structure

MSG_UTC_LEAP_SECOND — 0x023A — 570

UTC-GPST leap seconds before and after the most recent (past, or future, for announced insertions) UTC leap second insertion.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	s16		reserved_0	Reserved.
2	2	s16		reserved_1	Reserved.
4	1	s8		reserved_2	Reserved.
5	1	s8	s	count_before	Leap second count before insertion.
6	2	u16		reserved_3	Reserved.
8	2	u16		reserved_4	Reserved.
10	2	u16	weeks	ref_wn	Leap second reference GPS week number.
12	1	u8	days	ref_dn	Leap second reference day number.
13	1	s8	s	count_after	Leap second count after insertion.
	14				Total Payload Length

Table 8.5.83: MSG_UTC_LEAP_SECOND 0x023A message structure

MSG_REFERENCE_FRAME_PARAM — 0x0244 — 580

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		ssr_iod	SSR IOD parameter.
1	32	string		sn	Name of source coordinate-system.
33	32	string		tn	Name of target coordinate-system.
65	1	u8		sin	System Identification Number.
66	2	u16		utn	Utilized Transformation Message.
68	2	u16	1 day	re_t0	Reference Epoch t0 for transformation parameter set given as Modified Julian Day (MJD) Number minus 44244 days.
70	4	s32	0.001 m	delta_X0	Translation in X for Reference Epoch t0.
74	4	s32	0.001 m	delta_Y0	Translation in Y for Reference Epoch t0.
78	4	s32	0.001 m	delta_Z0	Translation in Z for Reference Epoch t0.
82	4	s32	0.00002 ”	theta_01	Rotation around the X-axis for Reference Epoch t0.
86	4	s32	0.00002 ”	theta_02	Rotation around the Y-axis for Reference Epoch t0.
90	4	s32	0.00002 ”	theta_03	Rotation around the Z-axis for Reference Epoch t0.
94	4	s32	0.00001 ppm	scale	Scale correction for Reference Epoch t0.
98	4	s32	0.00002 m/yr	dot_delta_X0	Rate of change of translation in X.
102	4	s32	0.00002 m/yr	dot_delta_Y0	Rate of change of translation in Y.
106	4	s32	0.00002 m/yr	dot_delta_Z0	Rate of change of translation in Z.
110	4	s32	0.0000004 ”/yr	dot_theta_01	Rate of change of rotation around the X-axis.
114	4	s32	0.0000004 ”/yr	dot_theta_02	Rate of change of rotation around the Y-axis.
118	4	s32	0.0000004 ”/yr	dot_theta_03	Rate of change of rotation around the Z-axis.
122	2	s16	0.0000002 ppm/yr	dot_scale	Rate of change of scale correction.
	124				Total Payload Length

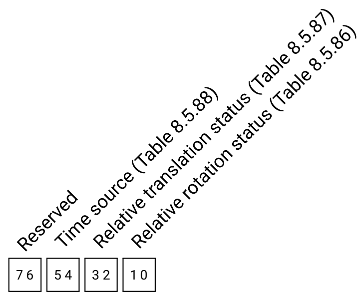
Table 8.5.84: MSG_REFERENCE_FRAME_PARAM 0x0244 message structure

MSG_POSE_RELATIVE — 0x0245 — 581

This solution message reports the relative pose of a sensor between two time instances. The relative pose comprises of a rotation and a translation which relates the sensor (e.g. camera) frame at a given time (first keyframe) to the sensor frame at another time (second keyframe). The relative translations is a 3x1 vector described in the first keyframe. Relative rotation is described by a quaternion from second keyframe to the first keyframe.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	1	u8		`sensor_id`	ID of the sensor producing this message
5	4	u32	ms	`timestamp_1`	Timestamp of first keyframe
9	4	u32	ms	`timestamp_2`	Timestamp of second keyframe
13	12	s32[3]	mm	`trans`	Relative translation [x,y,z] described in first keyframe
25	4	s32	2^-31	`w`	Real component of quaternion to describe relative rotation (second to first keyframe)
29	4	s32	2^-31	`x`	1st imaginary component of quaternion to describe relative rotation (second to first keyframe)
33	4	s32	2^-31	`y`	2nd imaginary component of quaternion to describe relative rotation (second to first keyframe)
37	4	s32	2^-31	`z`	3rd imaginary component of quaternion to describe relative rotation (second to first keyframe)
41	4	float	m^2	`cov_r_x_x`	Estimated variance of x (relative translation)
45	4	float	m^2	`cov_r_x_y`	Covariance of x and y (relative translation)
49	4	float	m^2	`cov_r_x_z`	Covariance of x and z (relative translation)
53	4	float	m^2	`cov_r_y_y`	Estimated variance of y (relative translation)
57	4	float	m^2	`cov_r_y_z`	Covariance of y and z (relative translation)
61	4	float	m^2	`cov_r_z_z`	Estimated variance of z (relative translation)
65	4	float	rad^2	`cov_c_x_x`	Estimated variance of x (relative rotation)
69	4	float	rad^2	`cov_c_x_y`	Covariance of x and y (relative rotation)
73	4	float	rad^2	`cov_c_x_z`	Covariance of x and z (relative rotation)
77	4	float	rad^2	`cov_c_y_y`	Estimated variance of y (relative rotation)
81	4	float	rad^2	`cov_c_y_z`	Covariance of y and z (relative rotation)
85	4	float	rad^2	`cov_c_z_z`	Estimated variance of z (relative rotation)
89	1	u8		`flags`	Status flags of relative translation and rotation
	90				Total Payload Length

Table 8.5.85: MSG_POSE_RELATIVE 0x0245 message structure



Field 8.5.28: Status flags of relative translation and rotation (`flags`)

Value	Description
0	Invalid
1	Valid

Table 8.5.86: Relative rotation status values (`flags[0:1]`)

Value	Description
0	Invalid
1	Valid

Table 8.5.87: Relative translation status values (`flags[2:3]`)

Value	Description
0	None (invalid)
1	GNSS Solution (ms in week)
2	Local CPU Time (ms)

Table 8.5.88: Time source values (`flags[4:5]`)

8.6 Observation

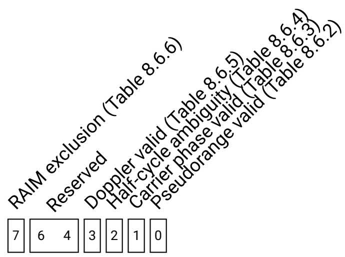
Satellite observation messages from the device. The SBP sender ID of 0 indicates remote observations from a GNSS base station, correction network, or Skylark, Swift's cloud GNSS correction product.

MSG_OBS — 0x004A — 74

The GPS observations message reports all the raw pseudorange and carrier phase observations for the satellites being tracked by the device. Carrier phase observation here is represented as a 40-bit fixed point number with Q32.8 layout (i.e. 32-bits of whole cycles and 8-bits of fractional cycles). The observations are be interoperable with 3rd party receivers and conform with typical RTCMv3 GNSS observations.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`header.t.tow`	Milliseconds since start of GPS week
4	4	s32	ns	`header.t.ns_residual`	Nanosecond residual of millisecond-rounded TOW (ranges from -500000 to 500000)
8	2	u16	week	`header.t.wn`	GPS week number
10	1	u8		`header.n_obs`	Total number of observations. First nibble is the size of the sequence (n), second nibble is the zero-indexed counter (ith packet of n)
$17N + 11$	4	u32	2 cm	`obs[N].P`	Pseudorange observation
$17N + 15$	4	s32	cycles	`obs[N].L.i`	Carrier phase whole cycles
$17N + 19$	1	u8	cycles / 256	`obs[N].L.f`	Carrier phase fractional part
$17N + 20$	2	s16	Hz	`obs[N].D.i`	Doppler whole Hz
$17N + 22$	1	u8	Hz / 256	`obs[N].D.f`	Doppler fractional part
$17N + 23$	1	u8	dB Hz / 4	`obs[N].cn0`	Carrier-to-Noise density. Zero implies invalid cn0.
$17N + 24$	1	u8		`obs[N].lock`	Lock timer. This value gives an indication of the time for which a signal has maintained continuous phase lock. Whenever a signal has lost and regained lock, this value is reset to zero. It is encoded according to DF402 from the RTCM 10403.2 Amendment 2 specification. Valid values range from 0 to 15 and the most significant nibble is reserved for future use.
$17N + 25$	1	u8		`obs[N].flags`	Measurement status flags. A bit field of flags providing the status of this observation. If this field is 0 it means only the Cn0 estimate for the signal is valid.
$17N + 26$	1	u8		`obs[N].sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
$17N + 27$	1	u8		`obs[N].sid.code`	Signal constellation, band and code (see pg. 4)
	$17N + 11$				Total Payload Length

Table 8.6.1: MSG_OBS 0x004A message structure



Field 8.6.1: Measurement status flags. A bit field of flags providing the status of this observation. If this field is 0 it means only the Cn0 estimate for the signal is valid. (`flags`)

Value	Description
0	Invalid pseudorange measurement
1	Valid pseudorange measurement and coarse TOW decoded

Table 8.6.2: Pseudorange valid values (`flags[0]`)

Value	Description
0	Invalid carrier phase measurement
1	Valid carrier phase measurement

Table 8.6.3: Carrier phase valid values (`flags[1]`)

Value	Description
0	Half cycle phase ambiguity unresolved
1	Half cycle phase ambiguity resolved

Table 8.6.4: Half-cycle ambiguity values (`flags[2]`)

Value	Description
0	Invalid doppler measurement
1	Valid doppler measurement

Table 8.6.5: Doppler valid values (`flags[3]`)

Value	Description
0	No exclusion
1	Measurement was excluded by SPP RAIM, use with care

Table 8.6.6: RAIM exclusion values (`flags[7]`)

MSG_BASE_POS_LLH — 0x0044 — 68

The base station position message is the position reported by the base station itself. It is used for pseudo-absolute RTK positioning, and is required to be a high-accuracy surveyed location of the base station. Any error here will result in an error in the pseudo-absolute position output.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	8	double	deg	`lat`	Latitude
8	8	double	deg	`lon`	Longitude
16	8	double	m	`height`	Height
	24				Total Payload Length

Table 8.6.7: MSG_BASE_POS_LLH 0x0044 message structure

MSG_BASE_POS_ECEF — 0x0048 — 72

The base station position message is the position reported by the base station itself in absolute Earth Centered Earth Fixed coordinates. It is used for pseudo-absolute RTK positioning, and is required to be a high-accuracy surveyed location of the base station. Any error here will result in an error in the pseudo-absolute position output.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	8	double	m	x	ECEF X coordinate
8	8	double	m	y	ECEF Y coordinate
16	8	double	m	z	ECEF Z coordinate
	24				Total Payload Length

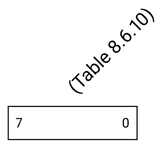
Table 8.6.8: MSG_BASE_POS_ECEF 0x0048 message structure

MSG_EPHEMERIS_GPS_DEP_E — 0x0081 — 129

The ephemeris message returns a set of satellite orbit parameters that is used to calculate GPS satellite position, velocity, and clock offset. Please see the Navstar GPS Space Segment/Navigation user interfaces (ICD-GPS-200, Table 20-III) for more details.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16		common.sid.sat	Constellation-specific satellite identifier. Note: unlike GnssSignal, GPS satellites are encoded as (PRN - 1). Other constellations do not have this offset.
2	1	u8		common.sid.code	Signal constellation, band and code
3	1	u8		common.sid.reserved	Reserved
4	4	u32	ms	common.toe.tow	Milliseconds since start of GPS week
8	2	u16	week	common.toe.wn	GPS week number
10	8	double	m	common.ura	User Range Accuracy
18	4	u32	s	common.fit_interval	Curve fit interval
22	1	u8		common.valid	Status of ephemeris, 1 = valid, 0 = invalid
23	1	u8		common.health_bits	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 SBAS: 0 = valid, non-zero = invalid GLO: 0 = valid, non-zero = invalid
24	8	double	s	tgd	Group delay differential between L1 and L2
32	8	double	m	c_rs	Amplitude of the sine harmonic correction term to the orbit radius
40	8	double	m	c_rc	Amplitude of the cosine harmonic correction term to the orbit radius
48	8	double	rad	c_uc	Amplitude of the cosine harmonic correction term to the argument of latitude
56	8	double	rad	c_us	Amplitude of the sine harmonic correction term to the argument of latitude
64	8	double	rad	c_ic	Amplitude of the cosine harmonic correction term to the angle of inclination
72	8	double	rad	c_is	Amplitude of the sine harmonic correction term to the angle of inclination
80	8	double	rad/s	dn	Mean motion difference
88	8	double	rad	m0	Mean anomaly at reference time
96	8	double		ecc	Eccentricity of satellite orbit
104	8	double	m^(1/2)	sqrta	Square root of the semi-major axis of orbit
112	8	double	rad	omega0	Longitude of ascending node of orbit plane at weekly epoch
120	8	double	rad/s	omegadot	Rate of right ascension
128	8	double	rad	w	Argument of perigee
136	8	double	rad	inc	Inclination
144	8	double	rad/s	inc_dot	Inclination first derivative
152	8	double	s	af0	Polynomial clock correction coefficient (clock bias)
160	8	double	s/s	af1	Polynomial clock correction coefficient (clock drift)
168	8	double	s/s^2	af2	Polynomial clock correction coefficient (rate of clock drift)
176	4	u32	ms	toc.tow	Milliseconds since start of GPS week
180	2	u16	week	toc.wn	GPS week number
182	1	u8		iode	Issue of ephemeris data
183	2	u16		iodc	Issue of clock data
	185				Total Payload Length

Table 8.6.9: MSG_EPHEMERIS_GPS_DEP_E 0x0081 message structure



Field 8.6.2: Signal constellation, band and code (`common.sid.code`)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P

Table 8.6.10: values (`common.sid.code[0:7]`)

MSG_EPHEMERIS_GPS_DEP_F — 0x0086 — 134

This observation message has been deprecated in favor of ephemeris message using floats for size reduction.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		common.sid.sat	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
1	1	u8		common.sid.code	Signal constellation, band and code (see pg. 4)
2	4	u32	s	common.toe.tow	Seconds since start of GPS week
6	2	u16	week	common.toe.wn	GPS week number
8	8	double	m	common.ura	User Range Accuracy
16	4	u32	s	common.fit_interval	Curve fit interval
20	1	u8		common.valid	Status of ephemeris, 1 = valid, 0 = invalid
21	1	u8		common.health_bits	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 Others: 0 = valid, non-zero = invalid
22	8	double	s	tgd	Group delay differential between L1 and L2
30	8	double	m	c_rs	Amplitude of the sine harmonic correction term to the orbit radius
38	8	double	m	c_rc	Amplitude of the cosine harmonic correction term to the orbit radius
46	8	double	rad	c_uc	Amplitude of the cosine harmonic correction term to the argument of latitude
54	8	double	rad	c_us	Amplitude of the sine harmonic correction term to the argument of latitude
62	8	double	rad	c_ic	Amplitude of the cosine harmonic correction term to the angle of inclination
70	8	double	rad	c_is	Amplitude of the sine harmonic correction term to the angle of inclination
78	8	double	rad/s	dn	Mean motion difference
86	8	double	rad	m0	Mean anomaly at reference time
94	8	double		ecc	Eccentricity of satellite orbit
102	8	double	m^(1/2)	sqrta	Square root of the semi-major axis of orbit
110	8	double	rad	omega0	Longitude of ascending node of orbit plane at weekly epoch
118	8	double	rad/s	omegadot	Rate of right ascension
126	8	double	rad	w	Argument of perigee
134	8	double	rad	inc	Inclination
142	8	double	rad/s	inc_dot	Inclination first derivative
150	8	double	s	af0	Polynomial clock correction coefficient (clock bias)
158	8	double	s/s	af1	Polynomial clock correction coefficient (clock drift)
166	8	double	s/s^2	af2	Polynomial clock correction coefficient (rate of clock drift)
174	4	u32	s	toc.tow	Seconds since start of GPS week
178	2	u16	week	toc.wn	GPS week number
180	1	u8		iode	Issue of ephemeris data
181	2	u16		iodc	Issue of clock data
	183				Total Payload Length

Table 8.6.11: MSG_EPHEMERIS_GPS_DEP_F 0x0086 message structure

MSG_EPHEMERIS_GPS — 0x008A — 138

The ephemeris message returns a set of satellite orbit parameters that is used to calculate GPS satellite position, velocity, and clock offset. Please see the Navstar GPS Space Segment/Navigation user interfaces (ICD-GPS-200, Table 20-III) for more details.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`common.sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
1	1	u8		`common.sid.code`	Signal constellation, band and code (see pg. 4)
2	4	u32	s	`common.toe.tow`	Seconds since start of GPS week
6	2	u16	week	`common.toe.wn`	GPS week number
8	4	float	m	`common.ura`	User Range Accuracy
12	4	u32	s	`common.fit_interval`	Curve fit interval
16	1	u8		`common.valid`	Status of ephemeris, 1 = valid, 0 = invalid
17	1	u8		`common.health_bits`	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 SBAS: 0 = valid, non-zero = invalid GLO: 0 = valid, non-zero = invalid
18	4	float	s	`tgd`	Group delay differential between L1 and L2
22	4	float	m	`c_rs`	Amplitude of the sine harmonic correction term to the orbit radius
26	4	float	m	`c_rc`	Amplitude of the cosine harmonic correction term to the orbit radius
30	4	float	rad	`c_uc`	Amplitude of the cosine harmonic correction term to the argument of latitude
34	4	float	rad	`c_us`	Amplitude of the sine harmonic correction term to the argument of latitude
38	4	float	rad	`c_ic`	Amplitude of the cosine harmonic correction term to the angle of inclination
42	4	float	rad	`c_is`	Amplitude of the sine harmonic correction term to the angle of inclination
46	8	double	rad/s	`dn`	Mean motion difference
54	8	double	rad	`m0`	Mean anomaly at reference time
62	8	double		`ecc`	Eccentricity of satellite orbit
70	8	double	mˆ(1/2)	`sqrta`	Square root of the semi-major axis of orbit
78	8	double	rad	`omega0`	Longitude of ascending node of orbit plane at weekly epoch
86	8	double	rad/s	`omegadot`	Rate of right ascension
94	8	double	rad	`w`	Argument of perigee
102	8	double	rad	`inc`	Inclination
110	8	double	rad/s	`inc_dot`	Inclination first derivative
118	4	float	s	`af0`	Polynomial clock correction coefficient (clock bias)
122	4	float	s/s	`af1`	Polynomial clock correction coefficient (clock drift)
126	4	float	s/sˆ2	`af2`	Polynomial clock correction coefficient (rate of clock drift)
130	4	u32	s	`toc.tow`	Seconds since start of GPS week
134	2	u16	week	`toc.wn`	GPS week number
136	1	u8		`iode`	Issue of ephemeris data
137	2	u16		`iodc`	Issue of clock data
	139				Total Payload Length

Table 8.6.12: MSG_EPHEMERIS_GPS 0x008A message structure

MSG_EPHEMERIS_QZSS — 0x008E — 142

The ephemeris message returns a set of satellite orbit parameters that is used to calculate QZSS satellite position, velocity, and clock offset.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`common.sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
1	1	u8		`common.sid.code`	Signal constellation, band and code (see pg. 4)
2	4	u32	s	`common.toe.tow`	Seconds since start of GPS week
6	2	u16	week	`common.toe.wn`	GPS week number
8	4	float	m	`common.ura`	User Range Accuracy
12	4	u32	s	`common.fit_interval`	Curve fit interval
16	1	u8		`common.valid`	Status of ephemeris, 1 = valid, 0 = invalid
17	1	u8		`common.health_bits`	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 SBAS: 0 = valid, non-zero = invalid GLO: 0 = valid, non-zero = invalid
18	4	float	s	`tgd`	Group delay differential between L1 and L2
22	4	float	m	`c_rs`	Amplitude of the sine harmonic correction term to the orbit radius
26	4	float	m	`c_rc`	Amplitude of the cosine harmonic correction term to the orbit radius
30	4	float	rad	`c_uc`	Amplitude of the cosine harmonic correction term to the argument of latitude
34	4	float	rad	`c_us`	Amplitude of the sine harmonic correction term to the argument of latitude
38	4	float	rad	`c_ic`	Amplitude of the cosine harmonic correction term to the angle of inclination
42	4	float	rad	`c_is`	Amplitude of the sine harmonic correction term to the angle of inclination
46	8	double	rad/s	`dn`	Mean motion difference
54	8	double	rad	`m0`	Mean anomaly at reference time
62	8	double		`ecc`	Eccentricity of satellite orbit
70	8	double	m^(1/2)	`sqrta`	Square root of the semi-major axis of orbit
78	8	double	rad	`omega0`	Longitude of ascending node of orbit plane at weekly epoch
86	8	double	rad/s	`omegadot`	Rate of right ascension
94	8	double	rad	`w`	Argument of perigee
102	8	double	rad	`inc`	Inclination
110	8	double	rad/s	`inc_dot`	Inclination first derivative
118	4	float	s	`af0`	Polynomial clock correction coefficient (clock bias)
122	4	float	s/s	`af1`	Polynomial clock correction coefficient (clock drift)
126	4	float	s/s^2	`af2`	Polynomial clock correction coefficient (rate of clock drift)
130	4	u32	s	`toc.tow`	Seconds since start of GPS week
134	2	u16	week	`toc.wn`	GPS week number
136	1	u8		`iode`	Issue of ephemeris data
137	2	u16		`iodc`	Issue of clock data
	139				Total Payload Length

Table 8.6.13: MSG_EPHEMERIS_QZSS 0x008E message structure

MSG_EPHEMERIS_BDS — 0x0089 — 137

The ephemeris message returns a set of satellite orbit parameters that is used to calculate BDS satellite position, velocity, and clock offset. Please see the BeiDou Navigation Satellite System SIS-ICD Version 2.1, Table 5-9 for more details.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`common.sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
1	1	u8		`common.sid.code`	Signal constellation, band and code (see pg. 4)
2	4	u32	s	`common.toe.tow`	Seconds since start of GPS week
6	2	u16	week	`common.toe.wn`	GPS week number
8	4	float	m	`common.ura`	User Range Accuracy
12	4	u32	s	`common.fit_interval`	Curve fit interval
16	1	u8		`common.valid`	Status of ephemeris, 1 = valid, 0 = invalid
17	1	u8		`common.health_bits`	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 SBAS: 0 = valid, non-zero = invalid GLO: 0 = valid, non-zero = invalid
18	4	float	s	`tgd1`	Group delay differential for B1
22	4	float	s	`tgd2`	Group delay differential for B2
26	4	float	m	`c_rs`	Amplitude of the sine harmonic correction term to the orbit radius
30	4	float	m	`c_rc`	Amplitude of the cosine harmonic correction term to the orbit radius
34	4	float	rad	`c_uc`	Amplitude of the cosine harmonic correction term to the argument of latitude
38	4	float	rad	`c_us`	Amplitude of the sine harmonic correction term to the argument of latitude
42	4	float	rad	`c_ic`	Amplitude of the cosine harmonic correction term to the angle of inclination
46	4	float	rad	`c_is`	Amplitude of the sine harmonic correction term to the angle of inclination
50	8	double	rad/s	`dn`	Mean motion difference
58	8	double	rad	`m0`	Mean anomaly at reference time
66	8	double		`ecc`	Eccentricity of satellite orbit
74	8	double	m^(1/2)	`sqrta`	Square root of the semi-major axis of orbit
82	8	double	rad	`omega0`	Longitude of ascending node of orbit plane at weekly epoch
90	8	double	rad/s	`omegadot`	Rate of right ascension
98	8	double	rad	`w`	Argument of perigee
106	8	double	rad	`inc`	Inclination
114	8	double	rad/s	`inc_dot`	Inclination first derivative
122	8	double	s	`af0`	Polynomial clock correction coefficient (clock bias)
130	4	float	s/s	`af1`	Polynomial clock correction coefficient (clock drift)
134	4	float	s/s^2	`af2`	Polynomial clock correction coefficient (rate of clock drift)
138	4	u32	s	`toc.tow`	Seconds since start of GPS week
142	2	u16	week	`toc.wn`	GPS week number
144	1	u8		`iode`	Issue of ephemeris data Calculated from the navigation data parameter t_oe per RTCM/CSNO recommendation: IODE = mod (t_oe / 720, 240)
145	2	u16		`iodc`	Issue of clock data Calculated from the navigation data parameter t_oe per RTCM/CSNO recommendation: IODE = mod (t_oc / 720, 240)
	147				Total Payload Length

Table 8.6.14: MSG_EPHEMERIS_BDS 0x0089 message structure

MSG_EPHEMERIS_GAL_DEP_A — 0x0095 — 149

This observation message has been deprecated in favor of an ephemeris message with explicit source of NAV data.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`common.sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
1	1	u8		`common.sid.code`	Signal constellation, band and code (see pg. 4)
2	4	u32	s	`common.toe.tow`	Seconds since start of GPS week
6	2	u16	week	`common.toe.wn`	GPS week number
8	4	float	m	`common.ura`	User Range Accuracy
12	4	u32	s	`common.fit_interval`	Curve fit interval
16	1	u8		`common.valid`	Status of ephemeris, 1 = valid, 0 = invalid
17	1	u8		`common.health_bits`	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 SBAS: 0 = valid, non-zero = invalid GLO: 0 = valid, non-zero = invalid
18	4	float	s	`bgd_e1e5a`	E1-E5a Broadcast Group Delay
22	4	float	s	`bgd_e1e5b`	E1-E5b Broadcast Group Delay
26	4	float	m	`c_rs`	Amplitude of the sine harmonic correction term to the orbit radius
30	4	float	m	`c_rc`	Amplitude of the cosine harmonic correction term to the orbit radius
34	4	float	rad	`c_uc`	Amplitude of the cosine harmonic correction term to the argument of latitude
38	4	float	rad	`c_us`	Amplitude of the sine harmonic correction term to the argument of latitude
42	4	float	rad	`c_ic`	Amplitude of the cosine harmonic correction term to the angle of inclination
46	4	float	rad	`c_is`	Amplitude of the sine harmonic correction term to the angle of inclination
50	8	double	rad/s	`dn`	Mean motion difference
58	8	double	rad	`m0`	Mean anomaly at reference time
66	8	double		`ecc`	Eccentricity of satellite orbit
74	8	double	m^(1/2)	`sqrta`	Square root of the semi-major axis of orbit
82	8	double	rad	`omega0`	Longitude of ascending node of orbit plane at weekly epoch
90	8	double	rad/s	`omegadot`	Rate of right ascension
98	8	double	rad	`w`	Argument of perigee
106	8	double	rad	`inc`	Inclination
114	8	double	rad/s	`inc_dot`	Inclination first derivative
122	8	double	s	`af0`	Polynomial clock correction coefficient (clock bias)
130	8	double	s/s	`af1`	Polynomial clock correction coefficient (clock drift)
138	4	float	s/s^2	`af2`	Polynomial clock correction coefficient (rate of clock drift)
142	4	u32	s	`toc.tow`	Seconds since start of GPS week
146	2	u16	week	`toc.wn`	GPS week number
148	2	u16		`iode`	Issue of data (IODnav)
150	2	u16		`iodc`	Issue of data (IODnav). Always equal to iode
	152				Total Payload Length

Table 8.6.15: MSG_EPHEMERIS_GAL_DEP_A 0x0095 message structure

MSG_EPHEMERIS_GAL — 0x008D — 141

The ephemeris message returns a set of satellite orbit parameters that is used to calculate Galileo satellite position, velocity, and clock offset. Please see the Signal In Space ICD OS SIS ICD, Issue 1.3, December 2016 for more details.

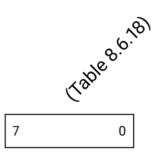
Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		common.sid.sat	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
1	1	u8		common.sid.code	Signal constellation, band and code (see pg. 4)
2	4	u32	s	common.toe.tow	Seconds since start of GPS week
6	2	u16	week	common.toe.wn	GPS week number
8	4	float	m	common.ura	User Range Accuracy
12	4	u32	s	common.fit_interval	Curve fit interval
16	1	u8		common.valid	Status of ephemeris, 1 = valid, 0 = invalid
17	1	u8		common.health_bits	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 SBAS: 0 = valid, non-zero = invalid GLO: 0 = valid, non-zero = invalid
18	4	float	s	bgd_e1e5a	E1-E5a Broadcast Group Delay
22	4	float	s	bgd_e1e5b	E1-E5b Broadcast Group Delay
26	4	float	m	c_rs	Amplitude of the sine harmonic correction term to the orbit radius
30	4	float	m	c_rc	Amplitude of the cosine harmonic correction term to the orbit radius
34	4	float	rad	c_uc	Amplitude of the cosine harmonic correction term to the argument of latitude
38	4	float	rad	c_us	Amplitude of the sine harmonic correction term to the argument of latitude
42	4	float	rad	c_ic	Amplitude of the cosine harmonic correction term to the angle of inclination
46	4	float	rad	c_is	Amplitude of the sine harmonic correction term to the angle of inclination
50	8	double	rad/s	dn	Mean motion difference
58	8	double	rad	m0	Mean anomaly at reference time
66	8	double		ecc	Eccentricity of satellite orbit
74	8	double	m^(1/2)	sqrta	Square root of the semi-major axis of orbit
82	8	double	rad	omega0	Longitude of ascending node of orbit plane at weekly epoch
90	8	double	rad/s	omegadot	Rate of right ascension
98	8	double	rad	w	Argument of perigee
106	8	double	rad	inc	Inclination
114	8	double	rad/s	inc_dot	Inclination first derivative
122	8	double	s	af0	Polynomial clock correction coefficient (clock bias)
130	8	double	s/s	af1	Polynomial clock correction coefficient (clock drift)
138	4	float	s/s^2	af2	Polynomial clock correction coefficient (rate of clock drift)
142	4	u32	s	toc.tow	Seconds since start of GPS week
146	2	u16	week	toc.wn	GPS week number
148	2	u16		iode	Issue of data (IODnav)
150	2	u16		iodc	Issue of data (IODnav). Always equal to iode
152	1	u8		source	0=I/NAV, 1=F/NAV
	153				Total Payload Length

Table 8.6.16: MSG_EPHEMERIS_GAL 0x008D message structure

MSG_EPHEMERIS_SBAS_DEP_A — 0x0082 — 130

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16		`common.sid.sat`	Constellation-specific satellite identifier. Note: unlike GnssSignal, GPS satellites are encoded as (PRN - 1). Other constellations do not have this offset.
2	1	u8		`common.sid.code`	Signal constellation, band and code
3	1	u8		`common.sid.reserved`	Reserved
4	4	u32	ms	`common.toe.tow`	Milliseconds since start of GPS week
8	2	u16	week	`common.toe.wn`	GPS week number
10	8	double	m	`common.ura`	User Range Accuracy
18	4	u32	s	`common.fit_interval`	Curve fit interval
22	1	u8		`common.valid`	Status of ephemeris, 1 = valid, 0 = invalid
23	1	u8		`common.health_bits`	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 SBAS: 0 = valid, non-zero = invalid GLO: 0 = valid, non-zero = invalid
24	24	double[3]	m	`pos`	Position of the GEO at time toe
48	24	double[3]	m/s	`vel`	Velocity of the GEO at time toe
72	24	double[3]	m/s^2	`acc`	Acceleration of the GEO at time toe
96	8	double	s	`a_gf0`	Time offset of the GEO clock w.r.t. SBAS Network Time
104	8	double	s/s	`a_gf1`	Drift of the GEO clock w.r.t. SBAS Network Time
	112				Total Payload Length

Table 8.6.17: MSG_EPHEMERIS_SBAS_DEP_A 0x0082 message structure



Field 8.6.3: Signal constellation, band and code (`common.sid.code`)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P

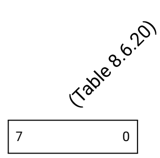
Table 8.6.18: values (`common.sid.code[0:7]`)

MSG_EPHEMERIS_GLO_DEP_A — 0x0083 — 131

The ephemeris message returns a set of satellite orbit parameters that is used to calculate GLO satellite position, velocity, and clock offset. Please see the GLO ICD 5.1 ”Table 4.5 Characteristics of words of immediate information (ephemeris parameters)” for more details.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16		`common.sid.sat`	Constellation-specific satellite identifier. Note: unlike GnssSignal, GPS satellites are encoded as (PRN - 1). Other constellations do not have this offset.
2	1	u8		`common.sid.code`	Signal constellation, band and code
3	1	u8		`common.sid.reserved`	Reserved
4	4	u32	ms	`common.toe.tow`	Milliseconds since start of GPS week
8	2	u16	week	`common.toe.wn`	GPS week number
10	8	double	m	`common.ura`	User Range Accuracy
18	4	u32	s	`common.fit_interval`	Curve fit interval
22	1	u8		`common.valid`	Status of ephemeris, 1 = valid, 0 = invalid
23	1	u8		`common.health_bits`	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 SBAS: 0 = valid, non-zero = invalid GLO: 0 = valid, non-zero = invalid
24	8	double		`gamma`	Relative deviation of predicted carrier frequency from nominal
32	8	double	s	`tau`	Correction to the SV time
40	24	double[3]	m	`pos`	Position of the SV at tb in PZ-90.02 coordinates system
64	24	double[3]	m/s	`vel`	Velocity vector of the SV at tb in PZ-90.02 coordinates system
88	24	double[3]	m/sˆ2	`acc`	Acceleration vector of the SV at tb in PZ-90.02 coordinates sys
	112				Total Payload Length

Table 8.6.19: MSG_EPHEMERIS_GLO_DEP_A 0x0083 message structure



Field 8.6.4: Signal constellation, band and code (`common.sid.code`)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P

Table 8.6.20: values (`common.sid.code[0:7]`)

MSG_EPHEMERIS_SBAS_DEP_B — 0x0084 — 132

This observation message has been deprecated in favor of ephemeris message using floats for size reduction.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		common.sid.sat	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
1	1	u8		common.sid.code	Signal constellation, band and code (see pg. 4)
2	4	u32	s	common.toe.tow	Seconds since start of GPS week
6	2	u16	week	common.toe.wn	GPS week number
8	8	double	m	common.ura	User Range Accuracy
16	4	u32	s	common.fit_interval	Curve fit interval
20	1	u8		common.valid	Status of ephemeris, 1 = valid, 0 = invalid
21	1	u8		common.health_bits	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 Others: 0 = valid, non-zero = invalid
22	24	double[3]	m	pos	Position of the GEO at time toe
46	24	double[3]	m/s	vel	Velocity of the GEO at time toe
70	24	double[3]	m/s^2	acc	Acceleration of the GEO at time toe
94	8	double	s	a_gf0	Time offset of the GEO clock w.r.t. SBAS Network Time
102	8	double	s/s	a_gf1	Drift of the GEO clock w.r.t. SBAS Network Time
	110				Total Payload Length

Table 8.6.21: MSG_EPHEMERIS_SBAS_DEP_B 0x0084 message structure

MSG_EPHEMERIS_SBAS — 0x008C — 140

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		common.sid.sat	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
1	1	u8		common.sid.code	Signal constellation, band and code (see pg. 4)
2	4	u32	s	common.toe.tow	Seconds since start of GPS week
6	2	u16	week	common.toe.wn	GPS week number
8	4	float	m	common.ura	User Range Accuracy
12	4	u32	s	common.fit_interval	Curve fit interval
16	1	u8		common.valid	Status of ephemeris, 1 = valid, 0 = invalid
17	1	u8		common.health_bits	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 SBAS: 0 = valid, non-zero = invalid GLO: 0 = valid, non-zero = invalid
18	24	double[3]	m	pos	Position of the GEO at time toe
42	12	float[3]	m/s	vel	Velocity of the GEO at time toe
54	12	float[3]	m/s^2	acc	Acceleration of the GEO at time toe
66	4	float	s	a_gf0	Time offset of the GEO clock w.r.t. SBAS Network Time
70	4	float	s/s	a_gf1	Drift of the GEO clock w.r.t. SBAS Network Time
	74				Total Payload Length

Table 8.6.22: MSG_EPHEMERIS_SBAS 0x008C message structure

MSG_EPHEMERIS_GLO_DEP_B — 0x0085 — 133

The ephemeris message returns a set of satellite orbit parameters that is used to calculate GLO satellite position, velocity, and clock offset. Please see the GLO ICD 5.1 ”Table 4.5 Characteristics of words of immediate information (ephemeris parameters)” for more details.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`common.sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
1	1	u8		`common.sid.code`	Signal constellation, band and code (see pg. 4)
2	4	u32	s	`common.toe.tow`	Seconds since start of GPS week
6	2	u16	week	`common.toe.wn`	GPS week number
8	8	double	m	`common.ura`	User Range Accuracy
16	4	u32	s	`common.fit_interval`	Curve fit interval
20	1	u8		`common.valid`	Status of ephemeris, 1 = valid, 0 = invalid
21	1	u8		`common.health_bits`	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 Others: 0 = valid, non-zero = invalid
22	8	double		`gamma`	Relative deviation of predicted carrier frequency from nominal
30	8	double	s	`tau`	Correction to the SV time
38	24	double[3]	m	`pos`	Position of the SV at tb in PZ-90.02 coordinates system
62	24	double[3]	m/s	`vel`	Velocity vector of the SV at tb in PZ-90.02 coordinates system
86	24	double[3]	m/s^2	`acc`	Acceleration vector of the SV at tb in PZ-90.02 coordinates sys
	110				Total Payload Length

Table 8.6.23: MSG_EPHEMERIS_GLO_DEP_B 0x0085 message structure

MSG_EPHEMERIS_GLO_DEP_C — 0x0087 — 135

The ephemeris message returns a set of satellite orbit parameters that is used to calculate GLO satellite position, velocity, and clock offset. Please see the GLO ICD 5.1 ”Table 4.5 Characteristics of words of immediate information (ephemeris parameters)” for more details.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		common.sid.sat	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
1	1	u8		common.sid.code	Signal constellation, band and code (see pg. 4)
2	4	u32	s	common.toe.tow	Seconds since start of GPS week
6	2	u16	week	common.toe.wn	GPS week number
8	8	double	m	common.ura	User Range Accuracy
16	4	u32	s	common.fit_interval	Curve fit interval
20	1	u8		common.valid	Status of ephemeris, 1 = valid, 0 = invalid
21	1	u8		common.health_bits	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 Others: 0 = valid, non-zero = invalid
22	8	double		gamma	Relative deviation of predicted carrier frequency from nominal
30	8	double	s	tau	Correction to the SV time
38	8	double	s	d_tau	Equipment delay between L1 and L2
46	24	double[3]	m	pos	Position of the SV at tb in PZ-90.02 coordinates system
70	24	double[3]	m/s	vel	Velocity vector of the SV at tb in PZ-90.02 coordinates system
94	24	double[3]	m/s^2	acc	Acceleration vector of the SV at tb in PZ-90.02 coordinates sys
118	1	u8		fcn	Frequency slot. FCN+8 (that is [1..14]). 0 or 0xFF for invalid
	119				Total Payload Length

Table 8.6.24: MSG_EPHEMERIS_GLO_DEP_C 0x0087 message structure

MSG_EPHEMERIS_GLO_DEP_D — 0x0088 — 136

This observation message has been deprecated in favor of ephemeris message using floats for size reduction.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		common.sid.sat	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
1	1	u8		common.sid.code	Signal constellation, band and code (see pg. 4)
2	4	u32	s	common.toe.tow	Seconds since start of GPS week
6	2	u16	week	common.toe.wn	GPS week number
8	8	double	m	common.ura	User Range Accuracy
16	4	u32	s	common.fit_interval	Curve fit interval
20	1	u8		common.valid	Status of ephemeris, 1 = valid, 0 = invalid
21	1	u8		common.health_bits	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 Others: 0 = valid, non-zero = invalid
22	8	double		gamma	Relative deviation of predicted carrier frequency from nominal
30	8	double	s	tau	Correction to the SV time
38	8	double	s	d_tau	Equipment delay between L1 and L2
46	24	double[3]	m	pos	Position of the SV at tb in PZ-90.02 coordinates system
70	24	double[3]	m/s	vel	Velocity vector of the SV at tb in PZ-90.02 coordinates system
94	24	double[3]	m/sˆ2	acc	Acceleration vector of the SV at tb in PZ-90.02 coordinates sys
118	1	u8		fcn	Frequency slot. FCN+8 (that is [1..14]). 0 or 0xFF for invalid
119	1	u8		iod	Issue of data. Equal to the 7 bits of the immediate data word t_b
	120				Total Payload Length

Table 8.6.25: MSG_EPHEMERIS_GLO_DEP_D 0x0088 message structure

MSG_EPHEMERIS_GLO — 0x008B — 139

The ephemeris message returns a set of satellite orbit parameters that is used to calculate GLO satellite position, velocity, and clock offset. Please see the GLO ICD 5.1 ”Table 4.5 Characteristics of words of immediate information (ephemeris parameters)” for more details.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`common.sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
1	1	u8		`common.sid.code`	Signal constellation, band and code (see pg. 4)
2	4	u32	s	`common.toe.tow`	Seconds since start of GPS week
6	2	u16	week	`common.toe.wn`	GPS week number
8	4	float	m	`common.ura`	User Range Accuracy
12	4	u32	s	`common.fit_interval`	Curve fit interval
16	1	u8		`common.valid`	Status of ephemeris, 1 = valid, 0 = invalid
17	1	u8		`common.health_bits`	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 SBAS: 0 = valid, non-zero = invalid GLO: 0 = valid, non-zero = invalid
18	4	float		`gamma`	Relative deviation of predicted carrier frequency from nominal
22	4	float	s	`tau`	Correction to the SV time
26	4	float	s	`d_tau`	Equipment delay between L1 and L2
30	24	double[3]	m	`pos`	Position of the SV at tb in PZ-90.02 coordinates system
54	24	double[3]	m/s	`vel`	Velocity vector of the SV at tb in PZ-90.02 coordinates system
78	12	float[3]	m/s^2	`acc`	Acceleration vector of the SV at tb in PZ-90.02 coordinates sys
90	1	u8		`fcn`	Frequency slot. FCN+8 (that is [1..14]). 0 or 0xFF for invalid
91	1	u8		`iod`	Issue of data. Equal to the 7 bits of the immediate data word t_b
	92				Total Payload Length

Table 8.6.26: MSG_EPHEMERIS_GLO 0x008B message structure

MSG_IONO — 0x0090 — 144

The ionospheric parameters which allow the ”L1 only” or ”L2 only” user to utilize the ionospheric model for computation of the ionospheric delay. Please see ICD-GPS-200 (Chapter 20.3.3.5.1.7) for more details.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	`t_nmct.tow`	Seconds since start of GPS week
4	2	u16	week	`t_nmct.wn`	GPS week number
6	8	double	s	`a0`	
14	8	double	s/semi-circle	`a1`	
22	8	double	s/(semi-circle)ˆ2	`a2`	
30	8	double	s/(semi-circle)ˆ3	`a3`	
38	8	double	s	`b0`	
46	8	double	s/semi-circle	`b1`	
54	8	double	s/(semi-circle)ˆ2	`b2`	
62	8	double	s/(semi-circle)ˆ3	`b3`	
	70				Total Payload Length

Table 8.6.27: MSG_IONO 0x0090 message structure

MSG_SV_CONFIGURATION_GPS_DEP — 0x0091 — 145

Please see ICD-GPS-200 (Chapter 20.3.3.5.1.4) for more details.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	t_nmct.tow	Seconds since start of GPS week
4	2	u16	week	t_nmct.wn	GPS week number
6	4	u32		l2c_mask	L2C capability mask, SV32 bit being MSB, SV1 bit being LSB
	10				Total Payload Length

Table 8.6.28: MSG_SV_CONFIGURATION_GPS_DEP 0x0091 message structure

MSG_GNSS_CAPB — 0x0096 — 150

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	t_nmct.tow	Seconds since start of GPS week
4	2	u16	week	t_nmct.wn	GPS week number
6	8	u64		gc.gps_active	GPS SV active mask
14	8	u64		gc.gps_l2c	GPS L2C active mask
22	8	u64		gc.gps_l5	GPS L5 active mask
30	4	u32		gc.glo_active	GLO active mask
34	4	u32		gc.glo_l2of	GLO L2OF active mask
38	4	u32		gc.glo_l3	GLO L3 active mask
42	8	u64		gc.sbas_active	SBAS active mask (PRNs 120..158, AN 7/62.2.2-18/18 Table B-23, https://www.caat.or.th/wp-content/uploads/2018/03/SL-2018.18.E-1.pdf)
50	8	u64		gc.sbas_l5	SBAS L5 active mask (PRNs 120..158, AN 7/62.2.2-18/18 Table B-23, https://www.caat.or.th/wp-content/uploads/2018/03/SL-2018.18.E-1.pdf)
58	8	u64		gc.bds_active	BDS active mask
66	8	u64		gc.bds_d2nav	BDS D2NAV active mask
74	8	u64		gc.bds_b2	BDS B2 active mask
82	8	u64		gc.bds_b2a	BDS B2A active mask
90	4	u32		gc.qzss_active	QZSS active mask
94	8	u64		gc.gal_active	GAL active mask
102	8	u64		gc.gal_e5	GAL E5 active mask
	110				Total Payload Length

Table 8.6.29: MSG_GNSS_CAPB 0x0096 message structure

MSG_GROUP_DELAY_DEP_A — 0x0092 — 146

Please see ICD-GPS-200 (30.3.3.3.1.1) for more details.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	t_op.tow	Milliseconds since start of GPS week
4	2	u16	week	t_op.wn	GPS week number
6	1	u8		prn	Satellite number
7	1	u8		valid	bit-field indicating validity of the values, LSB indicating tgd validity etc. 1 = value is valid, 0 = value is not valid.
8	2	s16	s * 2ˆ-35	tgd	
10	2	s16	s * 2ˆ-35	isc_l1ca	
12	2	s16	s * 2ˆ-35	isc_l2c	
	14				Total Payload Length

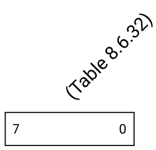
Table 8.6.30: MSG_GROUP_DELAY_DEP_A 0x0092 message structure

MSG_GROUP_DELAY_DEP_B — 0x0093 — 147

Please see ICD-GPS-200 (30.3.3.3.1.1) for more details.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	`t_op.tow`	Seconds since start of GPS week
4	2	u16	week	`t_op.wn`	GPS week number
6	2	u16		`sid.sat`	Constellation-specific satellite identifier. Note: unlike GnssSignal, GPS satellites are encoded as (PRN - 1). Other constellations do not have this offset.
8	1	u8		`sid.code`	Signal constellation, band and code
9	1	u8		`sid.reserved`	Reserved
10	1	u8		`valid`	bit-field indicating validity of the values, LSB indicating tgd validity etc. 1 = value is valid, 0 = value is not valid.
11	2	s16	s * 2^-35	`tgd`	
13	2	s16	s * 2^-35	`isc_l1ca`	
15	2	s16	s * 2^-35	`isc_l2c`	
	17				Total Payload Length

Table 8.6.31: MSG_GROUP_DELAY_DEP_B 0x0093 message structure



Field 8.6.5: Signal constellation, band and code (`sid.code`)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P

Table 8.6.32: values (`sid.code[0:7]`)

MSG_GROUP_DELAY — 0x0094 — 148

Please see ICD-GPS-200 (30.3.3.3.1.1) for more details.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	t_op.tow	Seconds since start of GPS week
4	2	u16	week	t_op.wn	GPS week number
6	1	u8		sid.sat	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
7	1	u8		sid.code	Signal constellation, band and code (see pg. 4)
8	1	u8		valid	bit-field indicating validity of the values, LSB indicating tgd validity etc. 1 = value is valid, 0 = value is not valid.
9	2	s16	s * 2^-35	tgd	
11	2	s16	s * 2^-35	isc_l1ca	
13	2	s16	s * 2^-35	isc_l2c	
	15				Total Payload Length

Table 8.6.33: MSG_GROUP_DELAY 0x0094 message structure

MSG_ALMANAC_GPS — 0x0072 — 114

The almanac message returns a set of satellite orbit parameters. Almanac data is not very precise and is considered valid for up to several months. Please see the Navstar GPS Space Segment/Navigation user interfaces (ICD-GPS-200, Chapter 20.3.3.5.1.2 Almanac Data) for more details.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`common.sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
1	1	u8		`common.sid.code`	Signal constellation, band and code (see pg. 4)
2	4	u32	s	`common.toa.tow`	Seconds since start of GPS week
6	2	u16	week	`common.toa.wn`	GPS week number
8	8	double	m	`common.ura`	User Range Accuracy
16	4	u32	s	`common.fit_interval`	Curve fit interval
20	1	u8		`common.valid`	Status of almanac, 1 = valid, 0 = invalid
21	1	u8		`common.health_bits`	Satellite health status for GPS: - bits 5-7: NAV data health status. See IS-GPS-200H Table 20-VII: NAV Data Health Indications. - bits 0-4: Signal health status. See IS-GPS-200H Table 20-VIII. Codes for Health of SV Signal Components. Satellite health status for GLO (see GLO ICD 5.1 table 5.1 for details): - bit 0: C(n), "unhealthy" flag that is transmitted within non-immediate data and indicates overall constellation status at the moment of almanac uploading. '0' indicates malfunction of n-satellite. '1' indicates that n-satellite is operational. - bit 1: Bn(ln), '0' indicates the satellite is operational and suitable for navigation.
22	8	double	rad	`m0`	Mean anomaly at reference time
30	8	double		`ecc`	Eccentricity of satellite orbit
38	8	double	m^(1/2)	`sqrta`	Square root of the semi-major axis of orbit
46	8	double	rad	`omega0`	Longitude of ascending node of orbit plane at weekly epoch
54	8	double	rad/s	`omegadot`	Rate of right ascension
62	8	double	rad	`w`	Argument of perigee
70	8	double	rad	`inc`	Inclination
78	8	double	s	`af0`	Polynomial clock correction coefficient (clock bias)
86	8	double	s/s	`af1`	Polynomial clock correction coefficient (clock drift)
	94				Total Payload Length

Table 8.6.34: MSG_ALMANAC_GPS 0x0072 message structure

MSG_ALMANAC_GLO — 0x0073 — 115

The almanac message returns a set of satellite orbit parameters. Almanac data is not very precise and is considered valid for up to several months. Please see the GLO ICD 5.1 ”Chapter 4.5 Non-immediate information and almanac” for details.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`common.sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
1	1	u8		`common.sid.code`	Signal constellation, band and code (see pg. 4)
2	4	u32	s	`common.toa.tow`	Seconds since start of GPS week
6	2	u16	week	`common.toa.wn`	GPS week number
8	8	double	m	`common.ura`	User Range Accuracy
16	4	u32	s	`common.fit_interval`	Curve fit interval
20	1	u8		`common.valid`	Status of almanac, 1 = valid, 0 = invalid
21	1	u8		`common.health_bits`	Satellite health status for GPS: - bits 5-7: NAV data health status. See IS-GPS-200H Table 20-VII: NAV Data Health Indications. - bits 0-4: Signal health status. See IS-GPS-200H Table 20-VIII. Codes for Health of SV Signal Components. Satellite health status for GLO (see GLO ICD 5.1 table 5.1 for details): - bit 0: C(n), ”unhealthy” flag that is transmitted within non-immediate data and indicates overall constellation status at the moment of almanac uploading. ’0’ indicates malfunction of n-satellite. ’1’ indicates that n-satellite is operational. - bit 1: Bn(ln), ’0’ indicates the satellite is operational and suitable for navigation.
22	8	double	rad	`lambda_na`	Longitude of the first ascending node of the orbit in PZ-90.02 coordinate system
30	8	double	s	`t_lambda_na`	Time of the first ascending node passage
38	8	double	rad	`i`	Value of inclination at instant of t_lambda
46	8	double	s/orbital period	`t`	Value of Draconian period at instant of t_lambda
54	8	double	s/(orbital period^2)	`t_dot`	Rate of change of the Draconian period
62	8	double		`epsilon`	Eccentricity at instant of t_lambda
70	8	double	rad	`omega`	Argument of perigee at instant of t_lambda
	78				Total Payload Length

Table 8.6.35: MSG_ALMANAC_GLO 0x0073 message structure

MSG_GLO_BIASES — 0x0075 — 117

The GLONASS L1/L2 Code-Phase biases allows to perform GPS+GLONASS integer ambiguity resolution for baselines with mixed receiver types (e.g. receiver of different manufacturers).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8	boolean	`mask`	GLONASS FDMA signals mask
1	2	s16	m * 0.02	`l1ca_bias`	GLONASS L1 C/A Code-Phase Bias
3	2	s16	m * 0.02	`l1p_bias`	GLONASS L1 P Code-Phase Bias
5	2	s16	m * 0.02	`l2ca_bias`	GLONASS L2 C/A Code-Phase Bias
7	2	s16	m * 0.02	`l2p_bias`	GLONASS L2 P Code-Phase Bias
	9				Total Payload Length

Table 8.6.36: MSG_GLO_BIASES 0x0075 message structure

MSG_SV_AZ_EL — 0x0097 — 151

Azimuth and elevation angles of all the visible satellites that the device does have ephemeris or almanac for.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
$4N + 0$	1	u8		`azel[N].sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
$4N + 1$	1	u8		`azel[N].sid.code`	Signal constellation, band and code (see pg. 4)
$4N + 2$	1	u8	deg * 2	`azel[N].az`	Azimuth angle (range 0..179)
$4N + 3$	1	s8	deg	`azel[N].el`	Elevation angle (range -90..90)
	4N				Total Payload Length

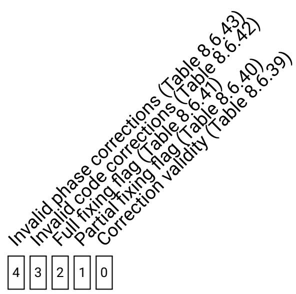
Table 8.6.37: MSG_SV_AZ_EL 0x0097 message structure

MSG_OSR — 0x0640 — 1600

The OSR message contains network corrections in an observation-like format.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	header.t.tow	Milliseconds since start of GPS week
4	4	s32	ns	header.t.ns_residual	Nanosecond residual of millisecond-rounded TOW (ranges from -500000 to 500000)
8	2	u16	week	header.t.wn	GPS week number
10	1	u8		header.n_obs	Total number of observations. First nibble is the size of the sequence (n), second nibble is the zero-indexed counter (ith packet of n)
$19N + 11$	4	u32	2 cm	obs[N].P	Pseudorange observation
$19N + 15$	4	s32	cycles	obs[N].L.i	Carrier phase whole cycles
$19N + 19$	1	u8	cycles / 256	obs[N].L.f	Carrier phase fractional part
$19N + 20$	1	u8		obs[N].lock	Lock timer. This value gives an indication of the time for which a signal has maintained continuous phase lock. Whenever a signal has lost and regained lock, this value is reset to zero. It is encoded according to DF402 from the RTCM 10403.2 Amendment 2 specification. Valid values range from 0 to 15 and the most significant nibble is reserved for future use.
$19N + 21$	1	u8		obs[N].flags	Correction flags.
$19N + 22$	1	u8		obs[N].sid.sat	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
$19N + 23$	1	u8		obs[N].sid.code	Signal constellation, band and code (see pg. 4)
$19N + 24$	2	u16	5 mm	obs[N].iono_std	Slant ionospheric correction standard deviation
$19N + 26$	2	u16	5 mm	obs[N].tropo_std	Slant tropospheric correction standard deviation
$19N + 28$	2	u16	5 mm	obs[N].range_std	Orbit/clock/bias correction projected on range standard deviation
	$19N + 11$				Total Payload Length

Table 8.6.38: MSG_OSR 0x0640 message structure



Field 8.6.6: Correction flags. (`flags`)

Value	Description
0	Do not use signal
1	Valid signal

Table 8.6.39: Correction validity values (`flags[0]`)

Value	Description
0	Partial fixing unavailable
1	Partial fixing available

Table 8.6.40: Partial fixing flag values (`flags[1]`)

Value	Description
0	Full fixing unavailable
1	Full fixing available

Table 8.6.41: Full fixing flag values (`flags[2]`)

Value	Description
0	Valid code corrections
1	Do not use code corrections

Table 8.6.42: Invalid code corrections values (`flags[3]`)

Value	Description
0	Valid phase corrections
1	Do not use phase corrections

Table 8.6.43: Invalid phase corrections values (`flags[4]`)

8.7 Settings

Messages for reading, writing, and discovering device settings. Settings with a ”string” field have multiple values in this field delimited with a null character (the c style null terminator). For instance, when querying the ’firmware_version’ setting in the ’system_info’ section, the following array of characters needs to be sent for the string field in MSG_SETTINGS_READ: ”system_info\0firmware_version\0”, where the delimiting null characters are specified with the escape sequence ’\0’ and all quotation marks should be omitted.

In the message descriptions below, the generic strings SECTION_SETTING and SETTING are used to refer to the two strings that comprise the identifier of an individual setting.In firmware_version example above, SECTION_SETTING is the ’system_info’, and the SETTING portion is ’firmware_version’. See the ”Software Settings Manual” on support.swiftnav.com for detailed documentation about all settings and sections available for each Swift firmware version. Settings manuals are available for each firmware version at the following link: Piksi Multi Specifications. The latest settings document is also available at the following link: Latest settings document . See lastly settings.py , the open source python command line utility for reading, writing, and saving settings in the piksi_tools repository on github as a helpful reference and example.

MSG_SETTINGS_SAVE — 0x00A1 — 161

The save settings message persists the device’s current settings configuration to its onboard flash memory file system.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
	0				Total Payload Length

Table 8.7.1: MSG_SETTINGS_SAVE 0x00A1 message structure

MSG_SETTINGS_WRITE — 0x00A0 — 160

The setting message writes the device configuration for a particular setting via A NULL-terminated and NULL-delimited string with contents ”SECTION_SETTING\0SETTING\0VALUE\0” where the ’\0’ escape sequence denotes the NULL character and where quotation marks are omitted. A device will only process to this message when it is received from sender ID 0x42. An example string that could be sent to a device is ”solution\0soln_freq\010\0”.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	N	string		`setting`	A NULL-terminated and NULL-delimited string with contents ”SECTION_SETTING\0SETTING\0VALUE\0”
	N				Total Payload Length

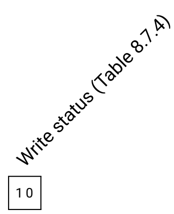
Table 8.7.2: MSG_SETTINGS_WRITE 0x00A0 message structure

MSG_SETTINGS_WRITE_RESP — 0x00AF — 175

Return the status of a write request with the new value of the setting. If the requested value is rejected, the current value will be returned. The string field is a NULL-terminated and NULL-delimited string with contents ”SECTION_SETTING\0SETTING\0VALUE\ where the ’\0’ escape sequence denotes the NULL character and where quotation marks are omitted. An example string that could be sent from device is ”solution\0soln_freq\010\0”.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`status`	Write status
1	N	string		`setting`	A NULL-terminated and delimited string with contents ”SECTION_SETTING\0SETTING\0VALUE\0”
	N + 1				Total Payload Length

Table 8.7.3: MSG_SETTINGS_WRITE_RESP 0x00AF message structure



Field 8.7.1: Write status (`status`)

Value	Description
0	Accepted; value updated
1	Rejected; value unparsable or out-of-range
2	Rejected; requested setting does not exist
3	Rejected; setting name could not be parsed
4	Rejected; setting is read only
5	Rejected; modification is temporarily disabled
6	Rejected; unspecified error

Table 8.7.4: Write status values (`status[0:1]`)

MSG_SETTINGS_READ_REQ — 0x00A4 — 164

The setting message that reads the device configuration. The string field is a NULL-terminated and NULL-delimited string with contents ”SECTION_SETTING\0SETTING\0” where the ’\0’ escape sequence denotes the NULL character and where quotation marks are omitted. An example string that could be sent to a device is ”solution\0soln_freq\0”. A device will only respond to this message when it is received from sender ID 0x42. A device should respond with a MSG_SETTINGS_READ_RESP message (msg_id 0x00A5).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	N	string		`setting`	A NULL-terminated and NULL-delimited string with contents ”SECTION_SETTING\0SETTING\0”
	N				Total Payload Length

Table 8.7.5: MSG_SETTINGS_READ_REQ 0x00A4 message structure

MSG_SETTINGS_READ_RESP — 0x00A5 — 165

The setting message with which the device responds after a MSG_SETTING_READ_REQ is sent to device. The string field is a NULL-terminated and NULL-delimited string with contents ”SECTION_SETTING\0SETTING\0VALUE\0” where the ’\0’ escape sequence denotes the NULL character and where quotation marks are omitted. An example string that could be sent from device is ”solution\0soln_freq\010\0”.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	N	string		setting	A NULL-terminated and NULL-delimited string with contents ”SECTION_SETTING\0SETTING\0VALUE\0”
	N				Total Payload Length

Table 8.7.6: MSG_SETTINGS_READ_RESP 0x00A5 message structure

MSG_SETTINGS_READ_BY_INDEX_REQ — 0x00A2 — 162

The settings message for iterating through the settings values. A device will respond to this message with a ”MSG_SETTINGS_READ_

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16		`index`	An index into the device settings, with values ranging from 0 to length(settings).
	2				Total Payload Length

Table 8.7.7: MSG_SETTINGS_READ_BY_INDEX_REQ 0x00A2 message structure

MSG_SETTINGS_READ_BY_INDEX_RESP — 0x00A7 — 167

The settings message that reports the value of a setting at an index.

In the string field, it reports NULL-terminated and delimited string with contents ”SECTION_SETTING\0SETTING\0VALUE\0FORM where the ’\0’ escape sequence denotes the NULL character and where quotation marks are omitted. The FORMAT_TYPE field is optional and denotes possible string values of the setting as a hint to the user. If included, the format type portion of the string has the format ”enum:value1,value2,value3”. An example string that could be sent from the device is ”simulator\0enabled\0True\0enum:True,False\0”.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16		`index`	An index into the device settings, with values ranging from 0 to length(settings)
2	N	string		`setting`	A NULL-terminated and delimited string with contents ”SECTION_SETTING\0SETTING\0VALUE\0FORMAT_TYPE\0
	$N+2$				Total Payload Length

Table 8.7.8: MSG_SETTINGS_READ_BY_INDEX_RESP 0x00A7 message structure

MSG_SETTINGS_READ_BY_INDEX_DONE — 0x00A6 — 166

The settings message for indicating end of the settings values.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
	0				Total Payload Length

Table 8.7.9: MSG_SETTINGS_READ_BY_INDEX_DONE 0x00A6 message structure

8.8 Solution Meta

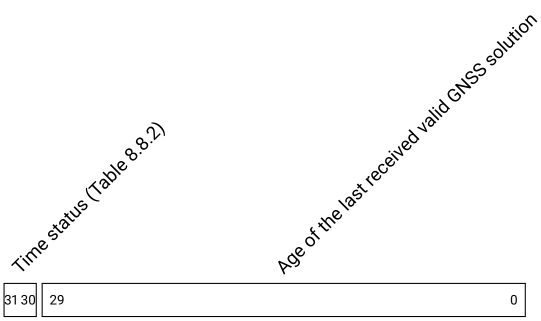
Standardized Metadata messages for Fuzed Solution from Swift Navigation devices.

MSG_SOLN_META — 0xFF0E — 65294

This message contains all metadata about the sensors received and/or used in computing the sensorfusion solution. It focuses primarily, but not only, on GNSS metadata. Regarding the age of the last received valid GNSS solution, the highest two bits are time status, indicating whether age gnss can or can not be used to retrieve time of measurement (noted TOM, also known as time of validity) If it can, subtract 'age gnss' from 'tow' in navigation messages to get TOM. Can be used before alignment is complete in the Fusion Engine, when output solution is the last received valid GNSS solution and its tow is not a TOM.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS time of week rounded to the nearest millisecond
4	2	u16	0.01	`pdop`	Position Dilution of Precision as per last available DOPS from PVT engine (0xFFFF indicates invalid)
6	2	u16	0.01	`hdop`	Horizontal Dilution of Precision as per last available DOPS from PVT engine (0xFFFF indicates invalid)
8	2	u16	0.01	`vdop`	Vertical Dilution of Precision as per last available DOPS from PVT engine (0xFFFF indicates invalid)
10	2	u16	deciseconds	`age_corrections`	Age of corrections as per last available AGE_CORRECTIONS from PVT engine (0xFFFF indicates invalid)
12	4	u32	ms	`age_gnss`	Age and Time Status of the last received valid GNSS solution.
$2N + 16$	1	u8		`sol_in[N].sensor_type`	The type of sensor
$2N + 17$	1	u8	(XX)InputType	`sol_in[N].flags`	Refer to each InputType description
	$2N + 16$				Total Payload Length

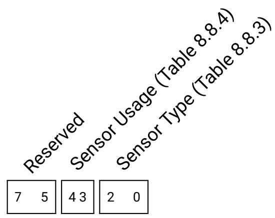
Table 8.8.1: MSG_SOLN_META 0xFF0E message structure



Field 8.8.1: Age and Time Status of the last received valid GNSS solution. (`age_gnss`)

Value	Description
0	Age can not be used to retrieve TOM
1	Age can be used to retrieve TOM
2	Reserved
3	Reserved

Table 8.8.2: Time status values (`age_gnss[30:31]`)



Field 8.8.2: The type of sensor (`sol_in[N].sensor_type`)

Value	Description
0	Invalid
1	GNSS Position (see GNSSInputType)
2	GNSS Velocity Displacement (see GNSSInputType)
3	GNSS Velocity Doppler (see GNSSInputType)
4	Odometry Ticks (see OdoInputType)
5	Odometry Speed (see OdoInputType)
6	IMU Sensor (see IMUInputType)
7	Reserved

Table 8.8.3: Sensor Type values (`sol_in[N].sensor_type[0:2]`)

Value	Description
0	Unknown
1	Received and used
2	Received but not used

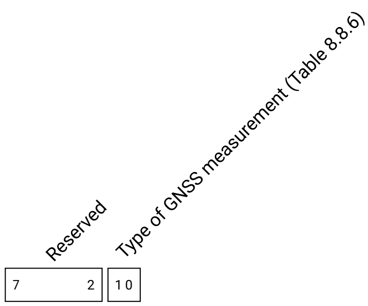
Table 8.8.4: Sensor Usage values (`sol_in[N].sensor_type[3:4]`)

GNSSInputType

Metadata around the GNSS sensors involved in the fuzed solution. Accessible through sol_in[N].flags in a MSG_SOLN_META.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`flags`	flags that store all relevant info specific to this sensor type.
	1				Total Payload Length

Table 8.8.5: GNSSInputType message structure



Field 8.8.3: flags that store all relevant info specific to this sensor type. (`flags`)

Value	Description
0	GNSS Position
1	GNSS Velocity Doppler
2	GNSS Velocity Displacement

Table 8.8.6: Type of GNSS measurement values (`flags[0:1]`)

IMUInputType

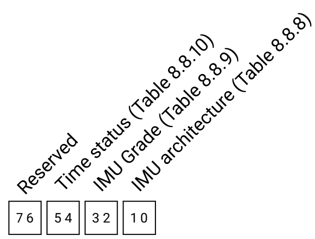
Metadata around the IMU sensors involved in the fuzed solution. Accessible through sol_in[N].flags in a MSG_SOLN_META.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`flags`	Instrument time, grade, and architecture for a sensor.
	1				Total Payload Length

Table 8.8.7: IMUInputType message structure

Value	Description
0	6-axis MEMS
1	Other type

Table 8.8.8: IMU architecture values (`flags[0:1]`)



Field 8.8.4: Instrument time, grade, and architecture for a sensor. (`flags`)

Value	Description
0	Consumer Grade
1	Tactical grade
2	Intermediate Grade
3	Superior (Marine / Aviation) Grade

Table 8.8.9: IMU Grade values (`flags[2:3]`)

Value	Description
0	Reference epoch is start of current GPS week
1	Reference epoch is time of system startup
2	Reference epoch is unknown
3	Reference epoch is last PPS

Table 8.8.10: Time status values (`flags[4:5]`)

OdoInputType

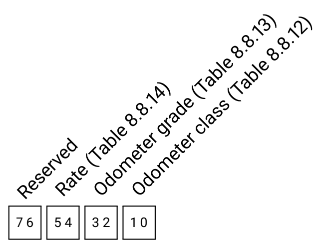
Metadata around the Odometry sensors involved in the fuzed solution. Accessible through sol_in[N].flags in a MSG_SOLN_META.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`flags`	Instrument ODO rate, grade, and quality.
	1				Total Payload Length

Table 8.8.11: OdoInputType message structure

Value	Description
0	Single or averaged ticks
1	Single or averaged speed
2	Multi-dimensional ticks
3	Multi-dimensional speed

Table 8.8.12: Odometer class values (`flags[0:1]`)



Field 8.8.5: Instrument ODO rate, grade, and quality. (`flags`)

Value	Description
0	Low Grade (e.g. quantized CAN)
1	Medium Grade
2	Superior Grade
3	Reserved

Table 8.8.13: Odometer grade values (`flags[2:3]`)

Value	Description
0	Fixed incoming rate
1	Triggered by minimum distance or speed
2	Reserved
3	Reserved

Table 8.8.14: Rate values (`flags[4:5]`)

8.9 System

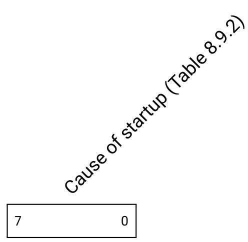
Standardized system messages from Swift Navigation devices.

MSG_STARTUP — 0xFF00 — 65280

The system start-up message is sent once on system start-up. It notifies the host or other attached devices that the system has started and is now ready to respond to commands or configuration requests.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`cause`	Cause of startup
1	1	u8		`startup_type`	Startup type
2	2	u16		`reserved`	Reserved
	4				Total Payload Length

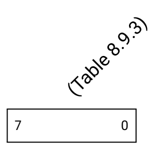
Table 8.9.1: MSG_STARTUP 0xFF00 message structure



Field 8.9.1: Cause of startup (`cause`)

Value	Description
0	Power on
1	Software reset
2	Watchdog reset

Table 8.9.2: Cause of startup values (`cause[0:7]`)



Field 8.9.2: Startup type (`startup_type`)

Value	Description
0	Cold start
1	Warm start
2	Hot start

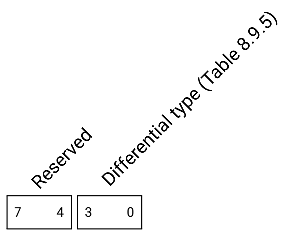
Table 8.9.3: values (`startup_type[0:7]`)

MSG_DGNSS_STATUS — 0xFF02 — 65282

This message provides information about the receipt of Differential corrections. It is expected to be sent with each receipt of a complete corrections packet.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`flags`	Status flags
1	2	u16	deci-seconds	`latency`	Latency of observation receipt
3	1	u8		`num_signals`	Number of signals from base station
4	N	string		`source`	Corrections source string
	N + 4				Total Payload Length

Table 8.9.4: MSG_DGNSS_STATUS 0xFF02 message structure



Field 8.9.3: Status flags (`flags`)

Value	Description
0	Invalid
1	Code Difference
2	RTK

Table 8.9.5: Differential type values (`flags[0:3]`)

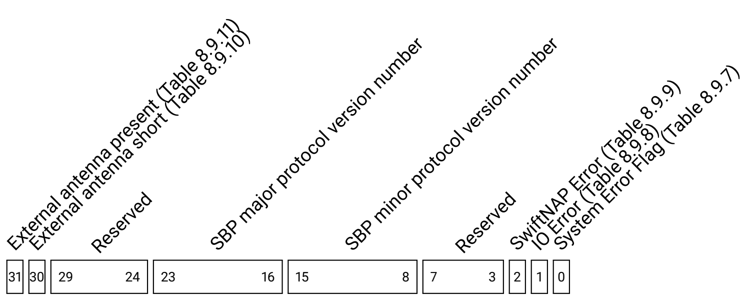
MSG_HEARTBEAT — 0xFFFF — 65535

The heartbeat message is sent periodically to inform the host or other attached devices that the system is running. It is used to monitor system malfunctions. It also contains status flags that indicate to the host the status of the system and whether it is operating correctly. Currently, the expected heartbeat interval is 1 sec.

The system error flag is used to indicate that an error has occurred in the system. To determine the source of the error, the remaining error flags should be inspected.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		`flags`	Status flags
	4				Total Payload Length

Table 8.9.6: MSG_HEARTBEAT 0xFFFF message structure



Field 8.9.4: Status flags (`flags`)

Value	Description
0	System Healthy
1	An error has occurred

Table 8.9.7: System Error Flag values (`flags[0]`)

Value	Description
0	System Healthy
1	An IO error has occurred

Table 8.9.8: IO Error values (`flags[1]`)

Value	Description
0	System Healthy
1	An error has occurred in the SwiftNAP

Table 8.9.9: SwiftNAP Error values (`flags[2]`)

Value	Description
0	No short detected
1	Short detected

Table 8.9.10: External antenna short values (`flags[30]`)

Value	Description
0	No external antenna detected
1	External antenna is present

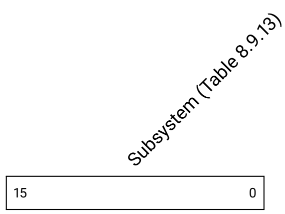
Table 8.9.11: External antenna present values (`flags[31]`)

SubSystemReport

Report the general and specific state of a subsystem. If the generic state is reported as initializing, the specific state should be ignored.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16		`component`	Identity of reporting subsystem
2	1	u8		`generic`	Generic form status report
3	1	u8		`specific`	Subsystem specific status code
	4				Total Payload Length

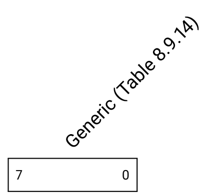
Table 8.9.12: SubSystemReport message structure



Field 8.9.5: Identity of reporting subsystem (`component`)

Value	Description
0	Primary GNSS Antenna
1	Measurement Engine
2	Corrections Client
3	Differential GNSS Engine
4	CAN
5	Wheel Odometry
6	Sensor Fusion Engine

Table 8.9.13: Subsystem values (`component[0:15]`)



Field 8.9.6: Generic form status report (`generic`)

Value	Description
0	OK/Nominal
1	Initializing
2	Unknown
3	Degraded
4	Unusable

Table 8.9.14: Generic values (`generic[0:7]`)

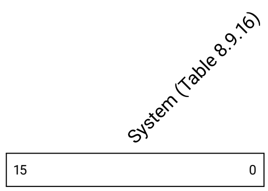
MSG_STATUS_REPORT — 0xFFFE — 65534

The status report is sent periodically to inform the host or other attached devices that the system is running. It is used to monitor system malfunctions. It contains status reports that indicate to the host the status of each subsystem and whether it is operating correctly.

Interpretation of the subsystem specific status code is product dependent, but if the generic status code is initializing, it should be ignored. Refer to product documentation for details.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16		`reporting_system`	Identity of reporting system
2	2	u16		`sbp_version`	SBP protocol version
4	4	u32		`sequence`	Increments on each status report sent
8	4	u32		`uptime`	Number of seconds since system start-up
4N + 12	2	u16		`status[N].component`	Identity of reporting subsystem
4N + 14	1	u8		`status[N].generic`	Generic form status report
4N + 15	1	u8		`status[N].specific`	Subsystem specific status code
	4N + 12				Total Payload Length

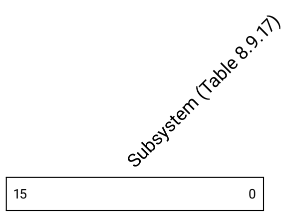
Table 8.9.15: MSG_STATUS_REPORT 0xFFFE message structure



Field 8.9.7: Identity of reporting system (`reporting_system`)

Value	Description
0	Starling
1	Precision GNSS Module (PGM)

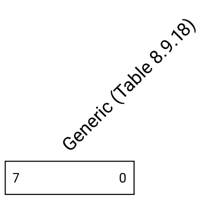
Table 8.9.16: System values (`reporting_system[0:15]`)



Field 8.9.8: Identity of reporting subsystem (`component`)

Value	Description
0	Primary GNSS Antenna
1	Measurement Engine
2	Corrections Client
3	Differential GNSS Engine
4	CAN
5	Wheel Odometry
6	Sensor Fusion Engine

Table 8.9.17: Subsystem values (`component[0:15]`)



Field 8.9.9: Generic form status report (`generic`)

Value	Description
0	OK/Nominal
1	Initializing
2	Unknown
3	Degraded
4	Unusable

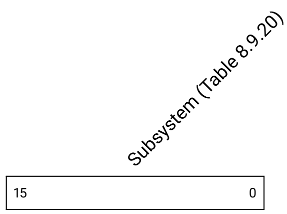
Table 8.9.18: Generic values (`generic[0:7]`)

StatusJournalItem

Reports the uptime and the state of a subsystem via generic and specific status codes. If the generic state is reported as initializing, the specific state should be ignored.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		`uptime`	Milliseconds since system startup
4	2	u16		`report.component`	Identity of reporting subsystem
6	1	u8		`report.generic`	Generic form status report
7	1	u8		`report.specific`	Subsystem specific status code
	8				Total Payload Length

Table 8.9.19: StatusJournalItem message structure



Field 8.9.10: Identity of reporting subsystem (`report.component`)

Value	Description
0	Primary GNSS Antenna
1	Measurement Engine
2	Corrections Client
3	Differential GNSS Engine
4	CAN
5	Wheel Odometry
6	Sensor Fusion Engine

Table 8.9.20: Subsystem values (`report.component[0:15]`)

Field 8.9.11: Generic form status report (`report.generic`)

Value	Description
0	OK/Nominal
1	Initializing
2	Unknown
3	Degraded
4	Unusable

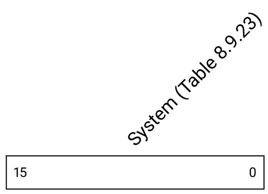
Table 8.9.21: Generic values (`report.generic[0:7]`)

MSG_STATUS_JOURNAL — 0xFFFD — 65533

The status journal message contains past status reports (see MSG_STATUS_REPORT) and functions as a error/event storage for telemetry purposes.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16		`reporting_system`	Identity of reporting system
2	2	u16		`sbp_version`	SBP protocol version
4	4	u32		`total_status_reports`	Total number of status reports sent since system startup
8	1	u8		`sequence_descriptor`	Index and number of messages in this sequence. First nibble is the size of the sequence (n), second nibble is the zero-indexed counter (ith packet of n)
$8N + 9$	4	u32		`journal[N].uptime`	Milliseconds since system startup
$8N + 13$	2	u16		`journal[N].report.component`	Identity of reporting subsystem
$8N + 15$	1	u8		`journal[N].report.generic`	Generic form status report
$8N + 16$	1	u8		`journal[N].report.specific`	Subsystem specific status code
	$8N + 9$				Total Payload Length

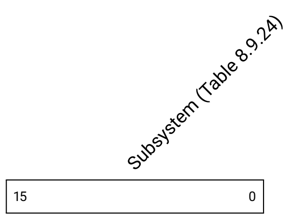
Table 8.9.22: MSG_STATUS_JOURNAL 0xFFFD message structure



Field 8.9.12: Identity of reporting system (`reporting_system`)

Value	Description
0	Starling
1	Precision GNSS Module (PGM)

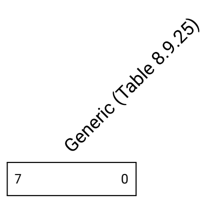
Table 8.9.23: System values (`reporting_system[0:15]`)



Field 8.9.13: Identity of reporting subsystem (`report.component`)

Value	Description
0	Primary GNSS Antenna
1	Measurement Engine
2	Corrections Client
3	Differential GNSS Engine
4	CAN
5	Wheel Odometry
6	Sensor Fusion Engine

Table 8.9.24: Subsystem values (`report.component[0:15]`)



Field 8.9.14: Generic form status report (`report.generic`)

Value	Description
0	OK/Nominal
1	Initializing
2	Unknown
3	Degraded
4	Unusable

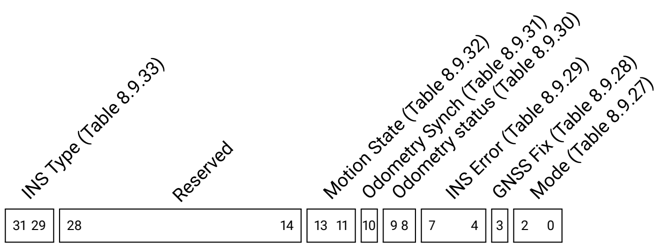
Table 8.9.25: Generic values (`report.generic[0:7]`)

MSG_INS_STATUS — 0xFF03 — 65283

The INS status message describes the state of the operation and initialization of the inertial navigation system.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		flags	Status flags
	4				Total Payload Length

Table 8.9.26: MSG_INS_STATUS 0xFF03 message structure



Field 8.9.15: Status flags (`flags`)

Value	Description
0	Awaiting initialization
1	Dynamically aligning
2	Ready
3	GNSS Outage exceeds max duration
4	FastStart seeding
5	FastStart validating
6	Validating unsafe fast start seed

Table 8.9.27: Mode values (`flags[0:2]`)

Value	Description
0	No GNSS fix available
1	GNSS fix

Table 8.9.28: GNSS Fix values (`flags[3]`)

Value	Description
0	Reserved
1	IMU Data Error
2	INS License Error
3	IMU Calibration Data Error

Table 8.9.29: INS Error values (`flags[4:7]`)

Value	Description
0	No Odometry
1	Odometry received within last second
2	Odometry not received within last second

Table 8.9.30: Odometry status values (`flags[8:9]`)

Value	Description
0	Odometry timestamp nominal
1	Odometry timestamp out of bounds

Table 8.9.31: Odometry Synch values (`flags[10]`)

Value	Description
0	Unknown or Init
1	Arbitrary Motion
2	Straight Motion
3	Stationary

Table 8.9.32: Motion State values (`flags[11:13]`)

Value	Description
0	Smoothpose Loosely Coupled
1	Starling

Table 8.9.33: INS Type values (`flags[29:31]`)

MSG_GNSS_TIME_OFFSET — 0xFF07 — 65287

The GNSS time offset message contains the information that is needed to translate messages tagged with a local timestamp (e.g. IMU or wheeltick messages) to GNSS time for the sender producing this message.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	s16	weeks	`weeks`	Weeks portion of the time offset
2	4	s32	ms	`milliseconds`	Milliseconds portion of the time offset
6	2	s16	microseconds	`microseconds`	Microseconds portion of the time offset
8	1	u8		`flags`	Status flags (reserved)
	9				Total Payload Length

Table 8.9.34: MSG_GNSS_TIME_OFFSET 0xFF07 message structure

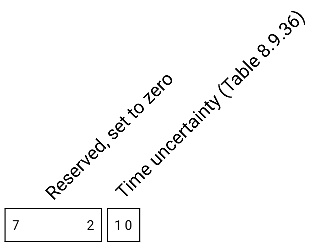
MSG_PPS_TIME — 0xFF08 — 65288

The PPS time message contains the value of the sender's local time in microseconds at the moment a pulse is detected on the PPS input. This is to be used for syncronisation of sensor data sampled with a local timestamp (e.g. IMU or wheeltick messages) where GNSS time is unknown to the sender.

The local time used to timestamp the PPS pulse must be generated by the same clock which is used to timestamp the IMU/wheel sensor data and should follow the same roll-over rules. A separate MSG_PPS_TIME message should be sent for each source of sensor data which uses PPS-relative timestamping. The sender ID for each of these MSG_PPS_TIME messages should match the sender ID of the respective sensor data.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	8	u64	microseconds	`time`	Local time in microseconds
8	1	u8		`flags`	Status flags
	9				Total Payload Length

Table 8.9.35: MSG_PPS_TIME 0xFF08 message structure



Field 8.9.16: Status flags (`flags`)

Value	Description
0	Unknown
1	+/- 10 milliseconds
2	+/- 10 microseconds
3	< 1 microseconds

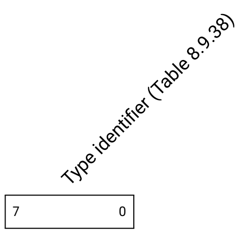
Table 8.9.36: Time uncertainty values (`flags[0:1]`)

MSG_SENSOR_AID_EVENT — 0xFF09 — 65289

This diagnostic message contains state and update status information for all sensors that are being used by the fusion engine. This message will be generated asynchronously to the solution messages and will be emitted anytime a sensor update is being processed.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	milliseconds	time	Update timestamp in milliseconds.
4	1	u8		sensor_type	Sensor type
5	2	u16		sensor_id	Sensor identifier
7	1	u8		sensor_state	Reserved for future use
8	1	u8		n_available_meas	Number of available measurements in this epoch
9	1	u8		n_attempted_meas	Number of attempted measurements in this epoch
10	1	u8		n_accepted_meas	Number of accepted measurements in this epoch
11	4	u32		flags	Reserved for future use
	15				Total Payload Length

Table 8.9.37: MSG_SENSOR_AID_EVENT 0xFF09 message structure



Field 8.9.17: Sensor type (sensor_type)

Value	Description
0	GNSS position
1	GNSS average velocity
2	GNSS instantaneous velocity
3	Wheel ticks
4	Wheel speed
5	IMU
6	Time differences of carrier phase

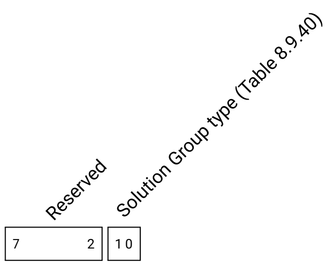
Table 8.9.38: Type identifier values (sensor_type[0:7])

MSG_GROUP_META — 0xFF0A — 65290

This leading message lists the time metadata of the Solution Group. It also lists the atomic contents (i.e. types of messages included) of the Solution Group.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`group_id`	Id of the Msgs Group, 0 is Unknown, 1 is Bestpos, 2 is Gnss
1	1	u8		`flags`	Status flags (reserved)
2	1	u8		`n_group_msgs`	Size of list group_msgs
3	N	u16[N]		`group_msgs`	An in-order list of message types included in the Solution Group, including GROUP_META itself
	$2N + 3$				Total Payload Length

Table 8.9.39: MSG_GROUP_META 0xFF0A message structure



Field 8.9.18: Status flags (reserved) (`flags`)

Value	Description
0	None (invalid)
1	GNSS only
2	GNSS+INS (Fuzed)
3	Reserved

Table 8.9.40: Solution Group type values (`flags[0:1]`)

9 Draft Message Definitions

9.1 Acquisition

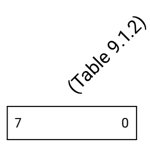
Satellite acquisition messages from the device.

MSG ACQ RESULT — 0x002F — 47

This message describes the results from an attempted GPS signal acquisition search for a satellite PRN over a code phase/carrier frequency range. It contains the parameters of the point in the acquisition search space with the best carrier-to-noise (CN/0) ratio.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	float	dB Hz	`cn0`	CN/0 of best point
4	4	float	chips	`cp`	Code phase of best point
8	4	float	hz	`cf`	Carrier frequency of best point
12	1	u8		`sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
13	1	u8		`sid.code`	Signal constellation, band and code
	14				Total Payload Length

Table 9.1.1: MSG_ACQ_RESULT 0x002F message structure



Field 9.1.1: Signal constellation, band and code (`sid.code`)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P
12	BDS2 B1
13	BDS2 B2
14	GAL E1B
20	GAL E7I
47	BDS3 B2a

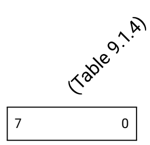
Table 9.1.2: values (`sid.code[0:7]`)

MSG ACQ SV PROFILE — 0x002E — 46

The message describes all SV profiles during acquisition time. The message is used to debug and measure the performance.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
33N + 0	1	u8		acq_sv_profile[N].job_type	SV search job type (deep, fallback, etc)
33N + 1	1	u8		acq_sv_profile[N].status	Acquisition status 1 is Success, 0 is Failure
33N + 2	2	u16	dB-Hz*10	acq_sv_profile[N].cn0	CN0 value. Only valid if status is '1'
33N + 4	1	u8	ms	acq_sv_profile[N].int_time	Acquisition integration time
33N + 5	1	u8		acq_sv_profile[N].sid.sat	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
33N + 6	1	u8		acq_sv_profile[N].sid.code	Signal constellation, band and code
33N + 7	2	u16	Hz	acq_sv_profile[N].bin_width	Acq frequency bin width
33N + 9	4	u32	ms	acq_sv_profile[N].timestamp	Timestamp of the job complete event
33N + 13	4	u32	us	acq_sv_profile[N].time_spent	Time spent to search for sid.code
33N + 17	4	s32	Hz	acq_sv_profile[N].cf_min	Doppler range lowest frequency
33N + 21	4	s32	Hz	acq_sv_profile[N].cf_max	Doppler range highest frequency
33N + 25	4	s32	Hz	acq_sv_profile[N].cf	Doppler value of detected peak. Only valid if status is '1'
33N + 29	4	u32	chips*10	acq_sv_profile[N].cp	Codephase of detected peak. Only valid if status is '1'
	33N				Total Payload Length

Table 9.1.3: MSG_ACQ_SV_PROFILE 0x002E message structure



Field 9.1.2: Signal constellation, band and code (acq_sv_profile[N].sid.code)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P
12	BDS2 B1
13	BDS2 B2
14	GAL E1B
20	GAL E7I
47	BDS3 B2a

Table 9.1.4: values (acq_sv_profile[N].sid.code[0:7])

9.2 File IO

Messages for using device's onboard flash filesystem functionality. This allows data to be stored persistently in the device's program flash with wear-levelling using a simple filesystem interface. The file system interface (CFS) defines an abstract API for reading directories and for reading and writing files.

Note that some of these messages share the same message type ID for both the host request and the device response.

MSG FILEIO READ REQ — 0x00A8 — 168

The file read message reads a certain length (up to 255 bytes) from a given offset into a file, and returns the data in a MSG_FILEIO_READ_RESP message where the message length field indicates how many bytes were successfully read. The sequence number in the request will be returned in the response. If the message is invalid, a followup MSG_PRINT message will print "Invalid fileio read message". A device will only respond to this message when it is received from sender ID 0x42.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		`sequence`	Read sequence number
4	4	u32	bytes	`offset`	File offset
8	1	u8	bytes	`chunk_size`	Chunk size to read
9	N	string		`filename`	Name of the file to read from
	N + 9				Total Payload Length

Table 9.2.1: MSG_FILEIO_READ_REQ 0x00A8 message structure

MSG FILEIO READ RESP — 0x00A3 — 163

The file read message reads a certain length (up to 255 bytes) from a given offset into a file, and returns the data in a message where the message length field indicates how many bytes were successfully read. The sequence number in the response is preserved from the request.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		`sequence`	Read sequence number
4	N	u8[N]		`contents`	Contents of read file
	N + 4				Total Payload Length

Table 9.2.2: MSG_FILEIO_READ_RESP 0x00A3 message structure

MSG FILEIO READ DIR REQ — 0x00A9 — 169

The read directory message lists the files in a directory on the device's onboard flash file system. The offset parameter can be used to skip the first n elements of the file list. Returns a MSG_FILEIO_READ_DIR_RESP message containing the directory listings as a NULL delimited list. The listing is chunked over multiple SBP packets. The sequence number in the request will be returned in the response. If message is invalid, a followup MSG_PRINT message will print "Invalid fileio read message". A device will only respond to this message when it is received from sender ID 0x42.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		sequence	Read sequence number
4	4	u32		offset	The offset to skip the first n elements of the file list
8	N	string		dirname	Name of the directory to list
	$N + 8$				Total Payload Length

Table 9.2.3: MSG_FILEIO_READ_DIR_REQ 0x00A9 message structure

MSG FILEIO READ DIR RESP — 0x00AA — 170

The read directory message lists the files in a directory on the device's onboard flash file system. Message contains the directory listings as a NULL delimited list. The listing is chunked over multiple SBP packets and the end of the list is identified by an packet with no entries. The sequence number in the response is preserved from the request.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		`sequence`	Read sequence number
4	N	u8[N]		`contents`	Contents of read directory
	N + 4				Total Payload Length

Table 9.2.4: MSG_FILEIO_READ_DIR_RESP 0x00AA message structure

MSG FILEIO REMOVE — 0x00AC — 172

The file remove message deletes a file from the file system. If the message is invalid, a followup MSG_PRINT message will print ”Invalid fileio remove message”. A device will only process this message when it is received from sender ID 0x42.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	N	string		`filename`	Name of the file to delete
	N				Total Payload Length

Table 9.2.5: MSG_FILEIO_REMOVE 0x00AC message structure

MSG FILEIO WRITE REQ — 0x00AD — 173

The file write message writes a certain length (up to 255 bytes) of data to a file at a given offset. Returns a copy of the original MSG_FILEIO_WRITE_RESP message to check integrity of the write. The sequence number in the request will be returned in the response. If message is invalid, a followup MSG_PRINT message will print ”Invalid fileio write message”. A device will only process this message when it is received from sender ID 0x42.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		`sequence`	Write sequence number
4	4	u32	bytes	`offset`	Offset into the file at which to start writing in bytes
8	N	string		`filename`	Name of the file to write to
9	N	u8[N]		`data`	Variable-length array of data to write
	N + 9				Total Payload Length

Table 9.2.6: MSG_FILEIO_WRITE_REQ 0x00AD message structure

MSG FILEIO WRITE RESP — 0x00AB — 171

The file write message writes a certain length (up to 255 bytes) of data to a file at a given offset. The message is a copy of the original MSG_FILEIO_WRITE_REQ message to check integrity of the write. The sequence number in the response is preserved from the request.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		`sequence`	Write sequence number
	4				Total Payload Length

Table 9.2.7: MSG_FILEIO_WRITE_RESP 0x00AB message structure

MSG FILEIO CONFIG REQ — 0x1001 — 4097

Requests advice on the optimal configuration for a FileIO transfer. Newer version of FileIO can support greater throughput by supporting a large window of FileIO data that can be in-flight during read or write operations.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		`sequence`	Advice sequence number
	4				Total Payload Length

Table 9.2.8: MSG_FILEIO_CONFIG_REQ 0x1001 message structure

MSG FILEIO CONFIG RESP — 0x1002 — 4098

The advice on the optimal configuration for a FileIO transfer. Newer version of FileIO can support greater throughput by supporting a large window of FileIO data that can be in-flight during read or write operations.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		sequence	Advice sequence number
4	4	u32		window_size	The number of SBP packets in the data in-flight window
8	4	u32		batch_size	The number of SBP packets sent in one PDU
12	4	u32		fileio_version	The version of FileIO that is supported
	16				Total Payload Length

Table 9.2.9: MSG_FILEIO_CONFIG_RESP 0x1002 message structure

9.3 Integrity

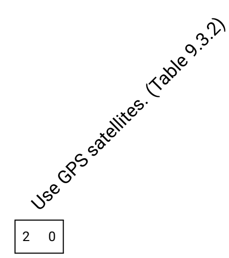
Integrity flag messages

MSG SSR FLAG HIGH LEVEL — 0x0BB9 — 3001

Integrity monitoring flags for multiple aggregated elements. An element could be a satellite, SSR grid point, or SSR tile. A group of aggregated elements being monitored for integrity could refer to:
- Satellites in a particular {GPS, GAL, BDS} constellation.
- Satellites in the line-of-sight of a particular SSR tile.
- Satellites in the line-of-sight of a particular SSR grid point.
The integrity usage for a group of aggregated elements varies according to the integrity flag of the satellites comprising that group.
SSR_INTEGRITY_USAGE_NOMINAL: All satellites received passed the integrity check and have flag INTEGRITY_FLAG_OK.
SSR_INTEGRITY_USAGE_WARNING: A limited number of elements in the group failed the integrity check. Refer to more granular integrity messages for details on the specific failing elements.
SSR_INTEGRITY_USAGE_ALERT: Most elements in the group failed the integrity check, do not use for positioning.
SSR_INTEGRITY_USAGE_NOT_MONITORED: Unable to verify the integrity flag of elements in the group.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	`obs_time.tow`	Seconds since start of GPS week
4	2	u16	week	`obs_time.wn`	GPS week number
6	4	u32	s	`corr_time.tow`	Seconds since start of GPS week
10	2	u16	week	`corr_time.wn`	GPS week number
12	1	u8		`ssr_sol_id`	SSR Solution ID.
13	2	u16		`tile_set_id`	Unique identifier of the set this tile belongs to.
15	2	u16		`tile_id`	Unique identifier of this tile in the tile set.
17	1	u8		`chain_id`	Chain and type of flag.
18	1	u8		`use_gps_sat`	Use GPS satellites.
19	1	u8		`use_gal_sat`	Use GAL satellites.
20	1	u8		`use_bds_sat`	Use BDS satellites.
21	6	u8[6]		`reserved`	Reserved
27	1	u8		`use_tropo_grid_points`	Use tropo grid points.
28	1	u8		`use_iono_grid_points`	Use iono grid points.
29	1	u8		`use_iono_tile_sat_los`	Use iono tile satellite LoS.
30	1	u8		`use_iono_grid_point_sat_los`	Use iono grid point satellite LoS.
	31				Total Payload Length

Table 9.3.1: MSG_SSR_FLAG_HIGH_LEVEL 0x0BB9 message structure



Field 9.3.1: Use GPS satellites. (`use_gps_sat`)

Value	Description
0	Nominal
1	Warning
2	Alert
3	Not monitored

Table 9.3.2: Use GPS satellites. values (`use_gps_sat[0:2]`)

Use GAL satellites. (Table 9.3.3)

2	0

Field 9.3.2: Use GAL satellites. (`use_gal_sat`)

Value	Description
0	Nominal
1	Warning
2	Alert
3	Not monitored

Table 9.3.3: Use GAL satellites. values (`use_gal_sat[0:2]`)

Use BDS satellites. (Table 9.3.4)

2	0

Field 9.3.3: Use BDS satellites. (`use_bds_sat`)

Value	Description
0	Nominal
1	Warning
2	Alert
3	Not monitored

Table 9.3.4: Use BDS satellites. values (`use_bds_sat[0:2]`)

Use tropo grid points. (Table 9.3.5)

2	0

Field 9.3.4: Use tropo grid points. (`use_tropo_grid_points`)

Value	Description
0	Nominal
1	Warning
2	Alert
3	Not monitored

Table 9.3.5: Use tropo grid points. values (`use_tropo_grid_points[0:2]`)

Use iono grid points. (Table 9.3.6)

2	0

Field 9.3.5: Use iono grid points. (`use_iono_grid_points`)

Value	Description
0	Nominal
1	Warning
2	Alert
3	Not monitored

Table 9.3.6: Use iono grid points. values (`use_iono_grid_points[0:2]`)

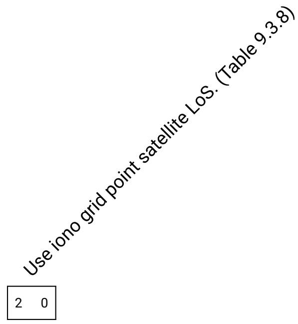
Use iono tile satellite LoS. (Table 9.3.7)

2	0

Field 9.3.6: Use iono tile satellite LoS. (`use_iono_tile_sat_los`)

Value	Description
0	Nominal
1	Warning
2	Alert
3	Not monitored

Table 9.3.7: Use iono tile satellite LoS. values (`use_iono_tile_sat_los[0:2]`)



Field 9.3.7: Use iono grid point satellite LoS. (`use_iono_grid_point_sat_los`)

Value	Description
0	Nominal
1	Warning
2	Alert
3	Not monitored

Table 9.3.8: Use iono grid point satellite LoS. values (`use_iono_grid_point_sat_los[0:2]`)

MSG SSR FLAG SATELLITES — 0x0BBD — 3005

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	obs_time.tow	Seconds since start of GPS week
4	2	u16	week	obs_time.wn	GPS week number
6	1	u8		num_msgs	Number of messages in the dataset
7	1	u8		seq_num	Position of this message in the dataset
8	1	u8		ssr_sol_id	SSR Solution ID.
9	1	u8		chain_id	Chain and type of flag.
10	1	u8		const_id	Constellation ID.
11	1	u8		n_faulty_sats	Number of faulty satellites.
12	N	u8[N]		faulty_sats	List of faulty satellites.
	N + 12				Total Payload Length

Table 9.3.9: MSG_SSR_FLAG_SATELLITES 0x0BBD message structure

MSG SSR FLAG TROPO GRID POINTS — 0x0BC3 — 3011

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	header.obs_time.tow	Seconds since start of GPS week
4	2	u16	week	header.obs_time.wn	GPS week number
6	1	u8		header.num_msgs	Number of messages in the dataset
7	1	u8		header.seq_num	Position of this message in the dataset
8	1	u8		header.ssr_sol_id	SSR Solution ID.
9	2	u16		header.tile_set_id	Unique identifier of the set this tile belongs to.
11	2	u16		header.tile_id	Unique identifier of this tile in the tile set.
13	1	u8		header.chain_id	Chain and type of flag.
14	1	u8		n_faulty_points	Number of faulty grid points.
15	N	u16[N]		faulty_points	List of faulty grid points.
	$2N + 15$				Total Payload Length

Table 9.3.10: MSG_SSR_FLAG_TROPO_GRID_POINTS 0x0BC3 message structure

MSG SSR FLAG IONO GRID POINTS — 0x0BC7 — 3015

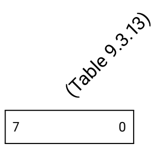
Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	header.obs_time.tow	Seconds since start of GPS week
4	2	u16	week	header.obs_time.wn	GPS week number
6	1	u8		header.num_msgs	Number of messages in the dataset
7	1	u8		header.seq_num	Position of this message in the dataset
8	1	u8		header.ssr_sol_id	SSR Solution ID.
9	2	u16		header.tile_set_id	Unique identifier of the set this tile belongs to.
11	2	u16		header.tile_id	Unique identifier of this tile in the tile set.
13	1	u8		header.chain_id	Chain and type of flag.
14	1	u8		n_faulty_points	Number of faulty grid points.
15	N	u16[N]		faulty_points	List of faulty grid points.
	$2N + 15$				Total Payload Length

Table 9.3.11: MSG_SSR_FLAG_IONO_GRID_POINTS 0x0BC7 message structure

MSG SSR FLAG IONO TILE SAT LOS — 0x0BCD — 3021

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	header.obs_time.tow	Seconds since start of GPS week
4	2	u16	week	header.obs_time.wn	GPS week number
6	1	u8		header.num_msgs	Number of messages in the dataset
7	1	u8		header.seq_num	Position of this message in the dataset
8	1	u8		header.ssr_sol_id	SSR Solution ID.
9	2	u16		header.tile_set_id	Unique identifier of the set this tile belongs to.
11	2	u16		header.tile_id	Unique identifier of this tile in the tile set.
13	1	u8		header.chain_id	Chain and type of flag.
14	1	u8		n_faulty_los	Number of faulty LOS.
$2N + 15$	1	u8		faulty_los[N].satId	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
$2N + 16$	1	u8		faulty_los[N].constellation	Constellation ID to which the SV belongs
	$2N + 15$				Total Payload Length

Table 9.3.12: MSG_SSR_FLAG_IONO_TILE_SAT_LOS 0x0BCD message structure



Field 9.3.8: Constellation ID to which the SV belongs (faulty_los[N].constellation)

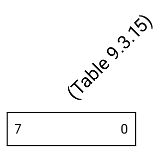
Value	Description
0	GPS
3	BDS
5	GAL

Table 9.3.13: values (faulty_los[N].constellation[0:7])

MSG SSR FLAG IONO GRID POINT SAT LOS — 0x0BD1 — 3025

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	header.obs_time.tow	Seconds since start of GPS week
4	2	u16	week	header.obs_time.wn	GPS week number
6	1	u8		header.num_msgs	Number of messages in the dataset
7	1	u8		header.seq_num	Position of this message in the dataset
8	1	u8		header.ssr_sol_id	SSR Solution ID.
9	2	u16		header.tile_set_id	Unique identifier of the set this tile belongs to.
11	2	u16		header.tile_id	Unique identifier of this tile in the tile set.
13	1	u8		header.chain_id	Chain and type of flag.
14	2	u16		grid_point_id	Index of the grid point.
16	1	u8		n_faulty_los	Number of faulty LOS.
$2N + 17$	1	u8		faulty_los[N].satId	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
$2N + 18$	1	u8		faulty_los[N].constellation	Constellation ID to which the SV belongs
	$2N + 17$				Total Payload Length

Table 9.3.14: MSG_SSR_FLAG_IONO_GRID_POINT_SAT_LOS 0x0BD1 message structure



Field 9.3.9: Constellation ID to which the SV belongs (faulty_los[N].constellation)

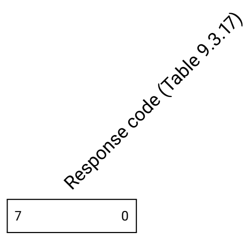
Value	Description
0	GPS
3	BDS
5	GAL

Table 9.3.15: values (faulty_los[N].constellation[0:7])

MSG ACKNOWLEDGE — 0x0BD2 — 3026

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`request_id`	Echo of the request ID field from the corresponding CRA message, or 255 if no request ID was provided.
1	4	u32		`area_id`	Echo of the Area ID field from the corresponding CRA message.
5	1	u8		`response_code`	Reported status of the request.
6	2	u16		`correction_mask_on_demand`	Contains the message group(s) that will be sent in response from the corresponding CRA correction mask. An echo of the correction mask field from the corresponding CRA message.
8	2	u16		`correction_mask_stream`	For future expansion. Always set to 0.
10	1	u8		`solution_id`	The solution ID of the instance providing the corrections.
	11				Total Payload Length

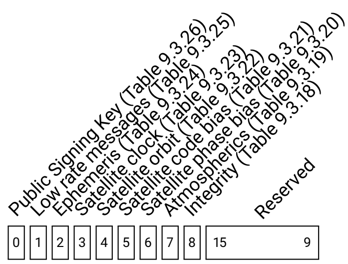
Table 9.3.16: MSG_ACKNOWLEDGE 0x0BD2 message structure



Field 9.3.10: Reported status of the request. (`response_code`)

Value	Description
0	Ok
1	Out of coverage
2	Forbidden
3	Invalid request
4	Invalid area id

Table 9.3.17: Response code values (`response_code[0:7]`)



Field 9.3.11: Contains the message group(s) that will be sent in response from the corresponding CRA correction mask. An echo of the correction mask field from the corresponding CRA message. (`correction_mask_on_demand`)

Value	Description
0	Not requested
1	Requested

Table 9.3.18: Integrity values (`correction_mask_on_demand[8]`)

Value	Description
0	Not requested
1	Requested

Table 9.3.19: Atmospherics values (`correction_mask_on_demand[7]`)

Value	Description
0	Not requested
1	Requested

Table 9.3.20: Satellite phase bias values (`correction_mask_on_demand[6]`)

Value	Description
0	Not requested
1	Requested

Table 9.3.21: Satellite code bias values (`correction_mask_on_demand[5]`)

Value	Description
0	Not requested
1	Requested

Table 9.3.22: Satellite orbit values (`correction_mask_on_demand[4]`)

Value	Description
0	Not requested
1	Requested

Table 9.3.23: Satellite clock values (`correction_mask_on_demand[3]`)

Value	Description
0	Not requested
1	Requested

Table 9.3.24: Ephemeris values (`correction_mask_on_demand[2]`)

Value	Description
0	Not requested
1	Requested

Table 9.3.25: Low rate messages values (`correction_mask_on_demand[1]`)

9.4 Orientation

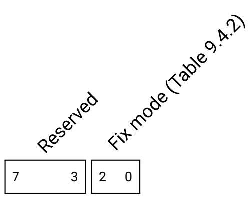
Orientation Messages

MSG BASELINE HEADING — 0x020F — 527

This message reports the baseline heading pointing from the base station to the rover relative to True North. The full GPS time is given by the preceding MSG_GPS_TIME with the matching time-of-week (tow). It is intended that time-matched RTK mode is used when the base station is moving.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	4	u32	mdeg	`heading`	Heading
8	1	u8		`n_sats`	Number of satellites used in solution
9	1	u8		`flags`	Status flags
	10				Total Payload Length

Table 9.4.1: MSG_BASELINE_HEADING 0x020F message structure



Field 9.4.1: Status flags (`flags`)

Value	Description
0	Invalid
1	Reserved
2	Differential GNSS (DGNSS)
3	Float RTK
4	Fixed RTK

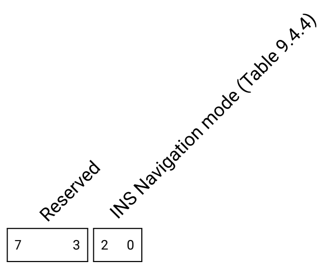
Table 9.4.2: Fix mode values (`flags[0:2]`)

MSG ORIENT QUAT — 0x0220 — 544

This message reports the quaternion vector describing the vehicle body frame's orientation with respect to a local-level NED frame. The components of the vector should sum to a unit vector assuming that the LSB of each component as a value of 2^-31. This message will only be available in future INS versions of Swift Products and is not produced by Piksi Multi or Duro.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	4	s32	2^-31	`w`	Real component
8	4	s32	2^-31	`x`	1st imaginary component
12	4	s32	2^-31	`y`	2nd imaginary component
16	4	s32	2^-31	`z`	3rd imaginary component
20	4	float	N/A	`w_accuracy`	Estimated standard deviation of w
24	4	float	N/A	`x_accuracy`	Estimated standard deviation of x
28	4	float	N/A	`y_accuracy`	Estimated standard deviation of y
32	4	float	N/A	`z_accuracy`	Estimated standard deviation of z
36	1	u8		`flags`	Status flags
	37				Total Payload Length

Table 9.4.3: MSG_ORIENT_QUAT 0x0220 message structure



Field 9.4.2: Status flags (`flags`)

Value	Description
0	Invalid
1	Valid

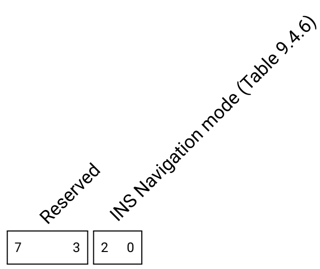
Table 9.4.4: INS Navigation mode values (`flags[0:2]`)

MSG ORIENT EULER — 0x0221 — 545

This message reports the yaw, pitch, and roll angles of the vehicle body frame. The rotations should applied intrinsically in the order yaw, pitch, and roll in order to rotate the from a frame aligned with the local-level NED frame to the vehicle body frame. This message will only be available in future INS versions of Swift Products and is not produced by Piksi Multi or Duro.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	4	s32	microdegrees	`roll`	rotation about the forward axis of the vehicle
8	4	s32	microdegrees	`pitch`	rotation about the rightward axis of the vehicle
12	4	s32	microdegrees	`yaw`	rotation about the downward axis of the vehicle
16	4	float	degrees	`roll_accuracy`	Estimated standard deviation of roll
20	4	float	degrees	`pitch_accuracy`	Estimated standard deviation of pitch
24	4	float	degrees	`yaw_accuracy`	Estimated standard deviation of yaw
28	1	u8		`flags`	Status flags
	29				Total Payload Length

Table 9.4.5: MSG_ORIENT_EULER 0x0221 message structure



Field 9.4.3: Status flags (`flags`)

Value	Description
0	Invalid
1	Valid

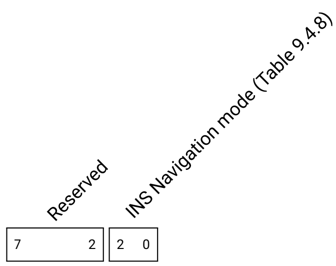
Table 9.4.6: INS Navigation mode values (`flags[0:2]`)

MSG ANGULAR RATE — 0x0222 — 546

This message reports the orientation rates in the vehicle body frame. The values represent the measurements a strapped down gyroscope would make and are not equivalent to the time derivative of the Euler angles. The orientation and origin of the user frame is specified via device settings. By convention, the vehicle x-axis is expected to be aligned with the forward direction, while the vehicle y-axis is expected to be aligned with the right direction, and the vehicle z-axis should be aligned with the down direction. This message will only be available in future INS versions of Swift Products and is not produced by Piksi Multi or Duro.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	GPS Time of Week
4	4	s32	microdegrees/	`x`	angular rate about x axis
8	4	s32	microdegrees/	`y`	angular rate about y axis
12	4	s32	microdegrees/	`z`	angular rate about z axis
16	1	u8		`flags`	Status flags
	17				Total Payload Length

Table 9.4.7: MSG_ANGULAR_RATE 0x0222 message structure



Field 9.4.4: Status flags (`flags`)

Value	Description
0	Invalid
1	Valid

Table 9.4.8: INS Navigation mode values (`flags[0:2]`)

9.5 Piksi

System health, configuration, and diagnostic messages specific to the Piksi L1 receiver, including a variety of legacy messages that may no longer be used.

MSG ALMANAC — 0x0069 — 105

This is a legacy message for sending and loading a satellite alamanac onto the Piksi's flash memory from the host.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
	0				Total Payload Length

Table 9.5.1: MSG_ALMANAC 0x0069 message structure

MSG SET TIME — 0x0068 — 104

This message sets up timing functionality using a coarse GPS time estimate sent by the host.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
	0				Total Payload Length

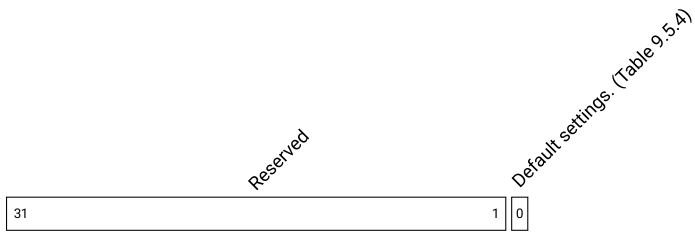
Table 9.5.2: MSG_SET_TIME 0x0068 message structure

MSG RESET — 0x00B6 — 182

This message from the host resets the Piksi back into the bootloader.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		`flags`	Reset flags
	4				Total Payload Length

Table 9.5.3: MSG_RESET 0x00B6 message structure



Field 9.5.1: Reset flags (`flags`)

Value	Description
0	Preserve existing settings.
1	Resore default settings.

Table 9.5.4: Default settings. values (`flags[0]`)

MSG RESET DEP — 0x00B2 — 178

This message from the host resets the Piksi back into the bootloader.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
	0				Total Payload Length

Table 9.5.5: MSG_RESET_DEP 0x00B2 message structure

MSG CW RESULTS — 0x00C0 — 192

This is an unused legacy message for result reporting from the CW interference channel on the SwiftNAP. This message will be removed in a future release.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
	0				Total Payload Length

Table 9.5.6: MSG_CW_RESULTS 0x00C0 message structure

MSG CW START — 0x00C1 — 193

This is an unused legacy message from the host for starting the CW interference channel on the SwiftNAP. This message will be removed in a future release.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
	0				Total Payload Length

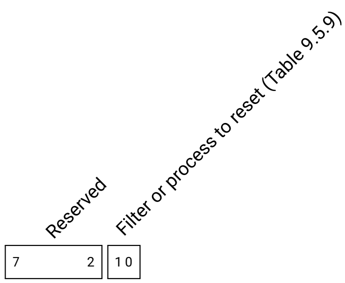
Table 9.5.7: MSG_CW_START 0x00C1 message structure

MSG RESET FILTERS — 0x0022 — 34

This message resets either the DGNSS Kalman filters or Integer Ambiguity Resolution (IAR) process.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`filter`	Filter flags
	1				Total Payload Length

Table 9.5.8: MSG_RESET_FILTERS 0x0022 message structure



Field 9.5.2: Filter flags (`filter`)

Value	Description
0	DGNSS filter
1	IAR process
2	Inertial filter

Table 9.5.9: Filter or process to reset values (`filter[0:1]`)

MSG INIT BASE DEP — 0x0023 — 35

Deprecated

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
	0				Total Payload Length

Table 9.5.10: MSG_INIT_BASE_DEP 0x0023 message structure

MSG THREAD STATE — 0x0017 — 23

The thread usage message from the device reports real-time operating system (RTOS) thread usage statistics for the named thread. The reported percentage values must be normalized.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	20	string		`name`	Thread name (NULL terminated)
20	2	u16		`cpu`	Percentage cpu use for this thread. Values range from 0 - 1000 and needs to be renormalized to 100
22	4	u32	bytes	`stack_free`	Free stack space for this thread
	26				Total Payload Length

Table 9.5.11: MSG_THREAD_STATE 0x0017 message structure

MSG UART STATE — 0x001D — 29

The UART message reports data latency and throughput of the UART channels providing SBP I/O. On the default Piksi configuration, UARTs A and B are used for telemetry radios, but can also be host access ports for embedded hosts, or other interfaces in future. The reported percentage values must be normalized. Observations latency and period can be used to assess the health of the differential corrections link. Latency provides the timeliness of received base observations while the period indicates their likelihood of transmission.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	float	kB/s	`uart_a.tx_throughput`	UART transmit throughput
4	4	float	kB/s	`uart_a.rx_throughput`	UART receive throughput
8	2	u16		`uart_a.crc_error_count`	UART CRC error count
10	2	u16		`uart_a.io_error_count`	UART IO error count
12	1	u8		`uart_a.tx_buffer_level`	UART transmit buffer percentage utilization (ranges from 0 to 255)
13	1	u8		`uart_a.rx_buffer_level`	UART receive buffer percentage utilization (ranges from 0 to 255)
14	4	float	kB/s	`uart_b.tx_throughput`	UART transmit throughput
18	4	float	kB/s	`uart_b.rx_throughput`	UART receive throughput
22	2	u16		`uart_b.crc_error_count`	UART CRC error count
24	2	u16		`uart_b.io_error_count`	UART IO error count
26	1	u8		`uart_b.tx_buffer_level`	UART transmit buffer percentage utilization (ranges from 0 to 255)
27	1	u8		`uart_b.rx_buffer_level`	UART receive buffer percentage utilization (ranges from 0 to 255)
28	4	float	kB/s	`uart_ftdi.tx_throughput`	UART transmit throughput
32	4	float	kB/s	`uart_ftdi.rx_throughput`	UART receive throughput
36	2	u16		`uart_ftdi.crc_error_count`	UART CRC error count
38	2	u16		`uart_ftdi.io_error_count`	UART IO error count
40	1	u8		`uart_ftdi.tx_buffer_level`	UART transmit buffer percentage utilization (ranges from 0 to 255)
41	1	u8		`uart_ftdi.rx_buffer_level`	UART receive buffer percentage utilization (ranges from 0 to 255)
42	4	s32	ms	`latency.avg`	Average latency
46	4	s32	ms	`latency.lmin`	Minimum latency
50	4	s32	ms	`latency.lmax`	Maximum latency
54	4	s32	ms	`latency.current`	Smoothed estimate of the current latency
58	4	s32	ms	`obs_period.avg`	Average period
62	4	s32	ms	`obs_period.pmin`	Minimum period
66	4	s32	ms	`obs_period.pmax`	Maximum period
70	4	s32	ms	`obs_period.current`	Smoothed estimate of the current period
	74				Total Payload Length

Table 9.5.12: MSG_UART_STATE 0x001D message structure

MSG UART STATE DEPA — 0x0018 — 24

Deprecated

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	float	kB/s	`uart_a.tx_throughput`	UART transmit throughput
4	4	float	kB/s	`uart_a.rx_throughput`	UART receive throughput
8	2	u16		`uart_a.crc_error_count`	UART CRC error count
10	2	u16		`uart_a.io_error_count`	UART IO error count
12	1	u8		`uart_a.tx_buffer_level`	UART transmit buffer percentage utilization (ranges from 0 to 255)
13	1	u8		`uart_a.rx_buffer_level`	UART receive buffer percentage utilization (ranges from 0 to 255)
14	4	float	kB/s	`uart_b.tx_throughput`	UART transmit throughput
18	4	float	kB/s	`uart_b.rx_throughput`	UART receive throughput
22	2	u16		`uart_b.crc_error_count`	UART CRC error count
24	2	u16		`uart_b.io_error_count`	UART IO error count
26	1	u8		`uart_b.tx_buffer_level`	UART transmit buffer percentage utilization (ranges from 0 to 255)
27	1	u8		`uart_b.rx_buffer_level`	UART receive buffer percentage utilization (ranges from 0 to 255)
28	4	float	kB/s	`uart_ftdi.tx_throughput`	UART transmit throughput
32	4	float	kB/s	`uart_ftdi.rx_throughput`	UART receive throughput
36	2	u16		`uart_ftdi.crc_error_count`	UART CRC error count
38	2	u16		`uart_ftdi.io_error_count`	UART IO error count
40	1	u8		`uart_ftdi.tx_buffer_level`	UART transmit buffer percentage utilization (ranges from 0 to 255)
41	1	u8		`uart_ftdi.rx_buffer_level`	UART receive buffer percentage utilization (ranges from 0 to 255)
42	4	s32	ms	`latency.avg`	Average latency
46	4	s32	ms	`latency.lmin`	Minimum latency
50	4	s32	ms	`latency.lmax`	Maximum latency
54	4	s32	ms	`latency.current`	Smoothed estimate of the current latency
	58				Total Payload Length

Table 9.5.13: MSG_UART_STATE_DEPA 0x0018 message structure

MSG IAR STATE — 0x0019 — 25

This message reports the state of the Integer Ambiguity Resolution (IAR) process, which resolves unknown integer ambiguities from double-differenced carrier-phase measurements from satellite observations.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		num_hyps	Number of integer ambiguity hypotheses remaining
	4				Total Payload Length

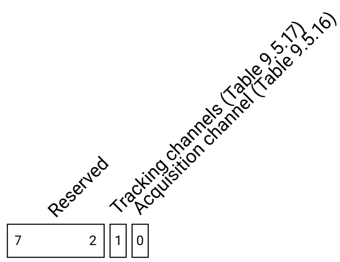
Table 9.5.14: MSG_IAR_STATE 0x0019 message structure

MSG MASK SATELLITE — 0x002B — 43

This message allows setting a mask to prevent a particular satellite from being used in various Piksi subsystems.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`mask`	Mask of systems that should ignore this satellite.
1	1	u8		`sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
2	1	u8		`sid.code`	Signal constellation, band and code
	3				Total Payload Length

Table 9.5.15: MSG_MASK_SATELLITE 0x002B message structure



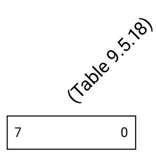
Field 9.5.3: Mask of systems that should ignore this satellite. (`mask`)

Value	Description
0	Enabled
1	Skip this satellite on future acquisitions

Table 9.5.16: Acquisition channel values (`mask[0]`)

Value	Description
0	Enabled
1	Drop this PRN if currently tracking

Table 9.5.17: Tracking channels values (`mask[1]`)



Field 9.5.4: Signal constellation, band and code (`sid.code`)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P
12	BDS2 B1
13	BDS2 B2
14	GAL E1B
20	GAL E7I
47	BDS3 B2a

Table 9.5.18: values (`sid.code[0:7]`)

MSG DEVICE MONITOR — 0x00B5 — 181

This message contains temperature and voltage level measurements from the processor's monitoring system and the RF frontend die temperature if available.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	s16	V / 1000	`dev_vin`	Device V_in
2	2	s16	V / 1000	`cpu_vint`	Processor V_int
4	2	s16	V / 1000	`cpu_vaux`	Processor V_aux
6	2	s16	degrees C / 100	`cpu_temperature`	Processor temperature
8	2	s16	degrees C / 100	`fe_temperature`	Frontend temperature (if available)
	10				Total Payload Length

Table 9.5.19: MSG_DEVICE_MONITOR 0x00B5 message structure

MSG COMMAND REQ — 0x00B8 — 184

Request the recipient to execute an command. Output will be sent in MSG_LOG messages, and the exit code will be returned with MSG_COMMAND_RESP.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		`sequence`	Sequence number
4	N	string		`command`	Command line to execute
	N + 4				Total Payload Length

Table 9.5.20: MSG_COMMAND_REQ 0x00B8 message structure

MSG COMMAND RESP — 0x00B9 — 185

The response to MSG_COMMAND_REQ with the return code of the command. A return code of zero indicates success.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		`sequence`	Sequence number
4	4	s32		`code`	Exit code
	8				Total Payload Length

Table 9.5.21: MSG_COMMAND_RESP 0x00B9 message structure

MSG COMMAND OUTPUT — 0x00BC — 188

Returns the standard output and standard error of the command requested by MSG_COMMAND_REQ. The sequence number can be used to filter for filtering the correct command.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		sequence	Sequence number
4	N	string		line	Line of standard output or standard error
	N + 4				Total Payload Length

Table 9.5.22: MSG_COMMAND_OUTPUT 0x00BC message structure

MSG NETWORK STATE REQ — 0x00BA — 186

Request state of Piksi network interfaces. Output will be sent in MSG_NETWORK_STATE_RESP messages.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
	0				Total Payload Length

Table 9.5.23: MSG_NETWORK_STATE_REQ 0x00BA message structure

MSG NETWORK STATE RESP — 0x00BB — 187

The state of a network interface on the Piksi. Data is made to reflect output of ifaddrs struct returned by getifaddrs in c.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u8[4]		`ipv4_address`	IPv4 address (all zero when unavailable)
4	1	u8		`ipv4_mask_size`	IPv4 netmask CIDR notation
5	16	u8[16]		`ipv6_address`	IPv6 address (all zero when unavailable)
21	1	u8		`ipv6_mask_size`	IPv6 netmask CIDR notation
22	4	u32		`rx_bytes`	Number of Rx bytes
26	4	u32		`tx_bytes`	Number of Tx bytes
30	16	string		`interface_name`	Interface Name
46	4	u32		`flags`	Interface flags from SIOCGIFFLAGS
	50				Total Payload Length

Table 9.5.24: MSG_NETWORK_STATE_RESP 0x00BB message structure

MSG NETWORK BANDWIDTH USAGE — 0x00BD — 189

The bandwidth usage, a list of usage by interface.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
$40N + 0$	8	u64	ms	interfaces[N].duration	Duration over which the measurement was collected
$40N + 8$	8	u64		interfaces[N].total_bytes	Number of bytes handled in total within period
$40N + 16$	4	u32		interfaces[N].rx_bytes	Number of bytes transmitted within period
$40N + 20$	4	u32		interfaces[N].tx_bytes	Number of bytes received within period
$40N + 24$	16	string		interfaces[N].interface_name	Interface Name
	40N				Total Payload Length

Table 9.5.25: MSG_NETWORK_BANDWIDTH_USAGE 0x00BD message structure

MSG CELL MODEM STATUS — 0x00BE — 190

If a cell modem is present on a piksi device, this message will be send periodically to update the host on the status of the modem and its various parameters.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	s8	dBm	signal_strength	Received cell signal strength in dBm, zero translates to unknown
1	4	float		signal_error_rate	BER as reported by the modem, zero translates to unknown
5	N	u8[N]		reserved	Unspecified data TBD for this schema
	N + 5				Total Payload Length

Table 9.5.26: MSG_CELL_MODEM_STATUS 0x00BE message structure

MSG SPECAN — 0x0051 — 81

Spectrum analyzer packet.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16		channel_tag	Channel ID
2	4	u32	ms	t.tow	Milliseconds since start of GPS week
6	4	s32	ns	t.ns_residual	Nanosecond residual of millisecond-rounded TOW (ranges from -500000 to 500000)
10	2	u16	week	t.wn	GPS week number
12	4	float	MHz	freq_ref	Reference frequency of this packet
16	4	float	MHz	freq_step	Frequency step of points in this packet
20	4	float	dB	amplitude_ref	Reference amplitude of this packet
24	4	float	dB	amplitude_unit	Amplitude unit value of points in this packet
28	N	u8[N]		amplitude_value	Amplitude values (in the above units) of points in this packet
	$N + 28$				Total Payload Length

Table 9.5.27: MSG_SPECAN 0x0051 message structure

MSG FRONT END GAIN — 0x00BF — 191

This message describes the gain of each channel in the receiver frontend. Each gain is encoded as a non-dimensional percentage relative to the maximum range possible for the gain stage of the frontend. By convention, each gain array has 8 entries and the index of the array corresponding to the index of the rf channel in the frontend. A gain of 127 percent encodes that rf channel is not present in the hardware. A negative value implies an error for the particular gain stage as reported by the frontend.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	8	s8[8]	percent	`rf_gain`	RF gain for each frontend channel
8	8	s8[8]	percent	`if_gain`	Intermediate frequency gain for each frontend channel
	16				Total Payload Length

Table 9.5.28: MSG_FRONT_END_GAIN 0x00BF message structure

9.6 Sbas

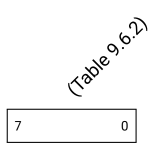
SBAS data

MSG SBAS RAW — 0x7777 — 30583

This message is sent once per second per SBAS satellite. ME checks the parity of the data block and sends only blocks that pass the check.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
1	1	u8		`sid.code`	Signal constellation, band and code
2	4	u32	ms	`tow`	GPS time-of-week at the start of the data block.
6	1	u8		`message_type`	SBAS message type (0-63)
7	27	u8[27]		`data`	Raw SBAS data field of 212 bits (last byte padded with zeros).
	34				Total Payload Length

Table 9.6.1: MSG_SBAS_RAW 0x7777 message structure



Field 9.6.1: Signal constellation, band and code (`sid.code`)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P
12	BDS2 B1
13	BDS2 B2
14	GAL E1B
20	GAL E7I
47	BDS3 B2a

Table 9.6.2: values (`sid.code[0:7]`)

9.7 Signing

Messages relating to signatures

MSG ED25519 SIGNATURE DEP — 0x0C01 — 3073

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	64	u8[64]		signature	ED25519 signature for messages.
64	20	u8[20]		fingerprint	SHA-1 fingerprint of the associated certificate.
84	N	u32[N]		signed_messages	CRCs of signed messages.
	$4N + 84$				Total Payload Length

Table 9.7.1: MSG_ED25519_SIGNATURE_DEP 0x0C01 message structure

MSG ED25519 CERTIFICATE — 0x0C02 — 3074

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		n_msg	Total number messages that make up the certificate. First nibble is the size of the sequence (n), second nibble is the zero-indexed counter (ith packet of n)
1	20	u8[20]		fingerprint	SHA-1 fingerprint of the associated certificate.
21	N	u8[N]		certificate_bytes	ED25519 certificate bytes.
	$N + 21$				Total Payload Length

Table 9.7.2: MSG_ED25519_CERTIFICATE 0x0C02 message structure

MSG ED25519 SIGNATURE — 0x0C03 — 3075

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		stream_counter	Signature message counter. Zero indexed and incremented with each signature message. The counter will not increment if this message was in response to an on demand request. The counter will roll over after 256 messages. Upon connection, the value of the counter may not initially be zero.
1	1	u8		on_demand_counter	On demand message counter. Zero indexed and incremented with each signature message sent in response to an on demand message. The counter will roll over after 256 messages. Upon connection, the value of the counter may not initially be zero.
2	64	u8[64]		signature	ED25519 signature for messages.
66	20	u8[20]		fingerprint	SHA-1 fingerprint of the associated certificate.
86	N	u32[N]		signed_messages	CRCs of signed messages.
	$4N + 86$				Total Payload Length

Table 9.7.3: MSG_ED25519_SIGNATURE 0x0C03 message structure

9.8 Ssr

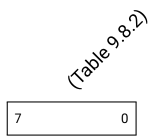
Precise State Space Representation (SSR) corrections format

MSG SSR ORBIT CLOCK — 0x05DD — 1501

The precise orbit and clock correction message is to be applied as a delta correction to broadcast ephemeris and is an equivalent to the 1060 /1066 RTCM message types.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	`time.tow`	Seconds since start of GPS week
4	2	u16	week	`time.wn`	GPS week number
6	1	u8		`sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
7	1	u8		`sid.code`	Signal constellation, band and code
8	1	u8		`update_interval`	Update interval between consecutive corrections. Encoded following RTCM DF391 specification.
9	1	u8		`iod_ssr`	IOD of the SSR correction. A change of Issue Of Data SSR is used to indicate a change in the SSR generating configuration
10	4	u32		`iod`	Issue of broadcast ephemeris data or IOD-CRC (Beidou)
14	4	s32	0.1 mm	`radial`	Orbit radial delta correction
18	4	s32	0.4 mm	`along`	Orbit along delta correction
22	4	s32	0.4 mm	`cross`	Orbit along delta correction
26	4	s32	0.001 mm/s	`dot_radial`	Velocity of orbit radial delta correction
30	4	s32	0.004 mm/s	`dot_along`	Velocity of orbit along delta correction
34	4	s32	0.004 mm/s	`dot_cross`	Velocity of orbit cross delta correction
38	4	s32	0.1 mm	`c0`	C0 polynomial coefficient for correction of broadcast satellite clock
42	4	s32	0.001 mm/s	`c1`	C1 polynomial coefficient for correction of broadcast satellite clock
46	4	s32	0.00002 mm/s^-2	`c2`	C2 polynomial coefficient for correction of broadcast satellite clock
	50				Total Payload Length

Table 9.8.1: MSG_SSR_ORBIT_CLOCK 0x05DD message structure



Field 9.8.1: Signal constellation, band and code (`sid.code`)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P
12	BDS2 B1
13	BDS2 B2
14	GAL E1B
20	GAL E7I
47	BDS3 B2a

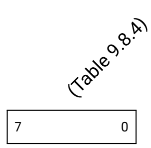
Table 9.8.2: values (`sid.code[0:7]`)

MSG SSR CODE BIASES — 0x05E1 — 1505

The precise code biases message is to be added to the pseudorange of the corresponding signal to get corrected pseudorange. It is an equivalent to the 1059 / 1065 RTCM message types.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	`time.tow`	Seconds since start of GPS week
4	2	u16	week	`time.wn`	GPS week number
6	1	u8		`sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
7	1	u8		`sid.code`	Signal constellation, band and code
8	1	u8		`update_interval`	Update interval between consecutive corrections. Encoded following RTCM DF391 specification.
9	1	u8		`iod_ssr`	IOD of the SSR correction. A change of Issue Of Data SSR is used to indicate a change in the SSR generating configuration
$3N + 10$	1	u8		`biases[N].code`	Signal encoded following Swift RTCM specifications. Table Signal and Tracking Mode Identifier.
$3N + 11$	2	s16	0.01 m	`biases[N].value`	Code bias value
	$3N + 10$				Total Payload Length

Table 9.8.3: MSG_SSR_CODE_BIASES 0x05E1 message structure



Field 9.8.2: Signal constellation, band and code (`sid.code`)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P
12	BDS2 B1
13	BDS2 B2
14	GAL E1B
20	GAL E7I
47	BDS3 B2a

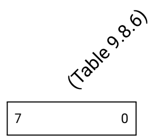
Table 9.8.4: values (`sid.code[0:7]`)

MSG SSR PHASE BIASES — 0x05E6 — 1510

The precise phase biases message contains the biases to be added to the carrier phase of the corresponding signal to get corrected carrier phase measurement, as well as the satellite yaw angle to be applied to compute the phase wind-up correction. It is typically an equivalent to the 1265 RTCM message types.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	`time.tow`	Seconds since start of GPS week
4	2	u16	week	`time.wn`	GPS week number
6	1	u8		`sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
7	1	u8		`sid.code`	Signal constellation, band and code
8	1	u8		`update_interval`	Update interval between consecutive corrections. Encoded following RTCM DF391 specification.
9	1	u8		`iod_ssr`	IOD of the SSR correction. A change of Issue Of Data SSR is used to indicate a change in the SSR generating configuration
10	1	u8		`dispersive_bias`	Indicator for the dispersive phase biases property.
11	1	u8		`mw_consistency`	Consistency indicator for Melbourne-Wubbena linear combinations
12	2	u16	1 / 256 semi-circle	`yaw`	Satellite yaw angle
14	1	s8	1 / 8192 semi-circle / s	`yaw_rate`	Satellite yaw angle rate
$8N+15$	1	u8		`biases[N].code`	Signal encoded following Swift RTCM specifications. Table Signal and Tracking Mode Identifier.
$8N+16$	1	u8		`biases[N].integer_indicator`	Indicator for integer property
$8N+17$	1	u8		`biases[N].widelane_integer_indicator`	Indicator for two groups of Wide-Lane(s) integer property
$8N+18$	1	u8		`biases[N].discontinuity_counter`	Signal phase discontinuity counter. Increased for every discontinuity in phase.
$8N+19$	4	s32	0.1 mm	`biases[N].bias`	Phase bias for specified signal
	$8N+15$				Total Payload Length

Table 9.8.5: MSG_SSR_PHASE_BIASES 0x05E6 message structure



Field 9.8.3: Signal constellation, band and code (`sid.code`)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P
12	BDS2 B1
13	BDS2 B2
14	GAL E1B
20	GAL E7I
47	BDS3 B2a

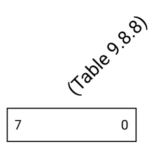
Table 9.8.6: values (`sid.code[0:7]`)

MSG SSR STEC CORRECTION DEP — 0x05FB — 1531

The Slant Total Electron Content per space vehicle, given as polynomial approximation for a given tile. This should be combined with the MSG_SSR_GRIDDED_CORRECTION message to get the state space representation of the atmospheric delay.
It is typically equivalent to the QZSS CLAS Sub Type 8 messages.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16		`header.tile_set_id`	Unique identifier of the tile set this tile belongs to.
2	2	u16		`header.tile_id`	Unique identifier of this tile in the tile set.
4	4	u32	s	`header.time.tow`	Seconds since start of GPS week
8	2	u16	week	`header.time.wn`	GPS week number
10	1	u8		`header.num_msgs`	Number of messages in the dataset
11	1	u8		`header.seq_num`	Position of this message in the dataset
12	1	u8		`header.update_interval`	Update interval between consecutive corrections. Encoded following RTCM DF391 specification.
13	1	u8		`header.iod_atmo`	IOD of the SSR atmospheric correction
$11N + 14$	1	u8		`stec_sat_list[N].sv_id.satId`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
$11N + 15$	1	u8		`stec_sat_list[N].sv_id.constellation`	Constellation ID to which the SV belongs
$11N + 16$	1	u8		`stec_sat_list[N].stec_quality_indicator`	Quality of the STEC data. Encoded following RTCM DF389 specification but in units of TECU instead of m.
$11N + 17$	8	s16[4]		`stec_sat_list[N].stec_coeff`	Coefficients of the STEC polynomial in the order of C00, C01, C10, C11. C00 = 0.05 TECU, C01/C10 = 0.02 TECU/deg, C11 0.02 TECU/degˆ2
	$11N + 14$				Total Payload Length

Table 9.8.7: MSG_SSR_STEC_CORRECTION_DEP 0x05FB message structure



Field 9.8.4: Constellation ID to which the SV belongs (`stec_sat_list[N].sv_id.constellation`)

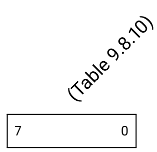
Value	Description
0	GPS
3	BDS
5	GAL

Table 9.8.8: values (`stec_sat_list[N].sv_id.constellation[0:7]`)

MSG SSR STEC CORRECTION — 0x05FD — 1533

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	`header.time.tow`	Seconds since start of GPS week
4	2	u16	week	`header.time.wn`	GPS week number
6	1	u8		`header.num_msgs`	Number of messages in the dataset
7	1	u8		`header.seq_num`	Position of this message in the dataset
8	1	u8		`header.update_interval`	Update interval between consecutive bounds. Similar to RTCM DF391.
9	1	u8		`header.sol_id`	SSR Solution ID.
10	1	u8		`ssr_iod_atmo`	IOD of the SSR atmospheric correction
11	2	u16		`tile_set_id`	Tile set ID
13	2	u16		`tile_id`	Tile ID
15	1	u8		`n_sats`	Number of satellites.
$11N + 16$	1	u8		`stec_sat_list[N].sv_id.satId`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
$11N + 17$	1	u8		`stec_sat_list[N].sv_id.constellation`	Constellation ID to which the SV belongs
$11N + 18$	1	u8		`stec_sat_list[N].stec_quality_indicator`	Quality of the STEC data. Encoded following RTCM DF389 specification but in units of TECU instead of m.
$11N + 19$	8	s16[4]		`stec_sat_list[N].stec_coeff`	Coefficients of the STEC polynomial in the order of C00, C01, C10, C11. C00 = 0.05 TECU, C01/C10 = 0.02 TECU/deg, C11 0.02 TECU/degˆ2
	$11N + 16$				Total Payload Length

Table 9.8.9: MSG_SSR_STEC_CORRECTION 0x05FD message structure



Field 9.8.5: Constellation ID to which the SV belongs (`stec_sat_list[N].sv_id.constellation`)

Value	Description
0	GPS
3	BDS
5	GAL

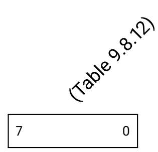
Table 9.8.10: values (`stec_sat_list[N].sv_id.constellation[0:7]`)

MSG SSR GRIDDED CORRECTION — 0x05FC — 1532

STEC residuals are per space vehicle, troposphere is not.
It is typically equivalent to the QZSS CLAS Sub Type 9 messages.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16		`header.tile_set_id`	Unique identifier of the tile set this tile belongs to.
2	2	u16		`header.tile_id`	Unique identifier of this tile in the tile set.
4	4	u32	s	`header.time.tow`	Seconds since start of GPS week
8	2	u16	week	`header.time.wn`	GPS week number
10	2	u16		`header.num_msgs`	Number of messages in the dataset
12	2	u16		`header.seq_num`	Position of this message in the dataset
14	1	u8		`header.update_interval`	Update interval between consecutive corrections. Encoded following RTCM DF391 specification.
15	1	u8		`header.iod_atmo`	IOD of the SSR atmospheric correction
16	1	u8		`header.tropo_quality_indicator`	Quality of the troposphere data. Encoded following RTCM DF389 specification in units of m.
17	2	u16		`index`	Index of the grid point.
19	2	s16	4 mm	`tropo_delay_correction.hydro`	Hydrostatic vertical delay. Add 2.3 m to get actual value.
21	1	s8	4 mm	`tropo_delay_correction.wet`	Wet vertical delay. Add 0.252 m to get actual value.
22	1	u8	mm	`tropo_delay_correction.stddev`	Modified DF389. class 3 MSB, value 5 LSB. stddev = (3^class * (1 + value/16) - 1)
5N + 23	1	u8		`stec_residuals[N].sv_id.satId`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
5N + 24	1	u8		`stec_residuals[N].sv_id.constellation`	Constellation ID to which the SV belongs
5N + 25	2	s16	0.04 TECU	`stec_residuals[N].residual`	STEC residual
5N + 27	1	u8		`stec_residuals[N].stddev`	Modified DF389. class 3 MSB, value 5 LSB. stddev = (3^class * (1 + value/16) - 1) * 10
	5N + 23				Total Payload Length

Table 9.8.11: MSG_SSR_GRIDDED_CORRECTION 0x05FC message structure



Field 9.8.6: Constellation ID to which the SV belongs (`stec_residuals[N].sv_id.constellation`)

Value	Description
0	GPS
3	BDS
5	GAL

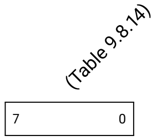
Table 9.8.12: values (`stec_residuals[N].sv_id.constellation[0:7]`)

MSG SSR GRIDDED CORRECTION BOUNDS — 0x05FE — 1534

Note 1: Range: 0-17.5 m. i<= 200, mean = 0.01i; 200<i<=230, mean=2+0.1(i-200); i>230, mean=5+0.5(i-230).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	header.time.tow	Seconds since start of GPS week
4	2	u16	week	header.time.wn	GPS week number
6	1	u8		header.num_msgs	Number of messages in the dataset
7	1	u8		header.seq_num	Position of this message in the dataset
8	1	u8		header.update_interval	Update interval between consecutive bounds. Similar to RTCM DF391.
9	1	u8		header.sol_id	SSR Solution ID.
10	1	u8		ssr_iod_atmo	IOD of the correction.
11	2	u16		tile_set_id	Set this tile belongs to.
13	2	u16		tile_id	Unique identifier of this tile in the tile set.
15	1	u8		tropo_qi	Tropo Quality Indicator. Similar to RTCM DF389.
16	2	u16		grid_point_id	Index of the Grid Point.
18	2	s16	4 mm	tropo_delay_correction.hydro	Hydrostatic vertical delay. Add 2.3 m to get actual value.
20	1	s8	4 mm	tropo_delay_correction.wet	Wet vertical delay. Add 0.252 m to get actual value.
21	1	u8	mm	tropo_delay_correction.stddev	Modified DF389. class 3 MSB, value 5 LSB. stddev = (3^class * (1 + value/16) - 1)
22	1	u8	0.005 m	tropo_v_hydro_bound_mu	Vertical Hydrostatic Error Bound Mean.
23	1	u8	0.005 m	tropo_v_hydro_bound_sig	Vertical Hydrostatic Error Bound StDev.
24	1	u8	0.005 m	tropo_v_wet_bound_mu	Vertical Wet Error Bound Mean.
25	1	u8	0.005 m	tropo_v_wet_bound_sig	Vertical Wet Error Bound StDev.
26	1	u8		n_sats	Number of satellites.
$9N + 27$	1	u8		stec_sat_list[N].stec_residual.sv_id.satId	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
$9N + 28$	1	u8		stec_sat_list[N].stec_residual.sv_id.constellation	Constellation ID to which the SV belongs
$9N + 29$	2	s16	0.04 TECU	stec_sat_list[N].stec_residual.residual	STEC residual
$9N + 31$	1	u8		stec_sat_list[N].stec_residual.stddev	Modified DF389. class 3 MSB, value 5 LSB. stddev = (3^class * (1 + value/16) - 1) * 10
$9N + 32$	1	u8	m	stec_sat_list[N].stec_bound_mu	Error Bound Mean. See Note 1.
$9N + 33$	1	u8	m	stec_sat_list[N].stec_bound_sig	Error Bound StDev. See Note 1.
$9N + 34$	1	u8	0.00005 m/s	stec_sat_list[N].stec_bound_mu_dot	Error Bound Mean First derivative.
$9N + 35$	1	u8	0.00005 m/s	stec_sat_list[N].stec_bound_sig_dot	Error Bound StDev First derivative.
	$9N + 27$				Total Payload Length

Table 9.8.13: MSG_SSR_GRIDDED_CORRECTION_BOUNDS 0x05FE message structure



Field 9.8.7: Constellation ID to which the SV belongs (`stec_sat_list[N].stec_residual.sv_id.constellation`)

Value	Description
0	GPS
3	BDS
5	GAL

Table 9.8.14: values (`stec_sat_list[N].stec_residual.sv_id.constella`

MSG SSR TILE DEFINITION DEP A — 0x05F6 — 1526

Provides the correction point coordinates for the atmospheric correction values in the MSG_SSR_STEC_CORRECTION_DEP and MSG_SSR_GRIDDED_CORRECTION messages.
Based on ETSI TS 137 355 V16.1.0 (LTE Positioning Protocol) information element GNSS-SSR-CorrectionPoints. SBP only supports gridded arrays of correction points, not lists of points.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16		tile_set_id	Unique identifier of the tile set this tile belongs to.
2	2	u16		tile_id	Unique identifier of this tile in the tile set. See GNSS-SSR-ArrayOfCorrectionPoints field correctionPointSetID.
4	2	s16	encoded degrees	corner_nw_lat	North-West corner correction point latitude. The relation between the latitude X in the range [-90, 90] and the coded number N is: N = floor((X / 90) * 2ˆ14) See GNSS-SSR-ArrayOfCorrectionPoints field referencePointLatitude.
6	2	s16	encoded degrees	corner_nw_lon	North-West corner correction point longitude. The relation between the longitude X in the range [-180, 180] and the coded number N is: N = floor((X / 180) * 2ˆ15) See GNSS-SSR-ArrayOfCorrectionPoints field referencePointLongitude.
8	2	u16	0.01 degrees	spacing_lat	Spacing of the correction points in the latitude direction. See GNSS-SSR-ArrayOfCorrectionPoints field stepOfLatitude.
10	2	u16	0.01 degrees	spacing_lon	Spacing of the correction points in the longitude direction. See GNSS-SSR-ArrayOfCorrectionPoints field stepOfLongitude.
12	2	u16		rows	Number of steps in the latitude direction. See GNSS-SSR-ArrayOfCorrectionPoints field numberOfStepsLatitude.
14	2	u16		cols	Number of steps in the longitude direction. See GNSS-SSR-ArrayOfCorrectionPoints field numberOfStepsLongitude.
16	8	u64		bitmask	Specifies the availability of correction data at the correction points in the array. If a specific bit is enabled (set to 1), the correction is not available. Only the first rows * cols bits are used, the remainder are set to 0. If there are more then 64 correction points the remaining corrections are always available. Starting with the northwest corner of the array (top left on a north oriented map) the correction points are enumerated with row precedence - first row west to east, second row west to east, until last row west to east - ending with the southeast corner of the array. See GNSS-SSR-ArrayOfCorrectionPoints field bitmaskOfGrids but note the definition of the bits is inverted.
	24				Total Payload Length

Table 9.8.15: MSG_SSR_TILE_DEFINITION_DEP_A 0x05F6 message structure

MSG SSR TILE DEFINITION DEP B — 0x05F7 — 1527

Provides the correction point coordinates for the atmospheric correction values in the MSG_SSR_STEC_CORRECTION and MSG_SSR_GRIDDED_CORRECTION messages.
Based on ETSI TS 137 355 V16.1.0 (LTE Positioning Protocol) information element GNSS-SSR-CorrectionPoints. SBP only supports gridded arrays of correction points, not lists of points.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`ssr_sol_id`	SSR Solution ID.
1	2	u16		`tile_set_id`	Unique identifier of the tile set this tile belongs to.
3	2	u16		`tile_id`	Unique identifier of this tile in the tile set. See GNSS-SSR-ArrayOfCorrectionPoints field correctionPointSetID.
5	2	s16	encoded degrees	`corner_nw_lat`	North-West corner correction point latitude. The relation between the latitude X in the range [-90, 90] and the coded number N is: N = floor((X / 90) * 2ˆ14) See GNSS-SSR-ArrayOfCorrectionPoints field referencePointLatitude.
7	2	s16	encoded degrees	`corner_nw_lon`	North-West corner correction point longitude. The relation between the longitude X in the range [-180, 180] and the coded number N is: N = floor((X / 180) * 2ˆ15) See GNSS-SSR-ArrayOfCorrectionPoints field referencePointLongitude.
9	2	u16	0.01 degrees	`spacing_lat`	Spacing of the correction points in the latitude direction. See GNSS-SSR-ArrayOfCorrectionPoints field stepOfLatitude.
11	2	u16	0.01 degrees	`spacing_lon`	Spacing of the correction points in the longitude direction. See GNSS-SSR-ArrayOfCorrectionPoints field stepOfLongitude.
13	2	u16		`rows`	Number of steps in the latitude direction. See GNSS-SSR-ArrayOfCorrectionPoints field numberOfStepsLatitude.
15	2	u16		`cols`	Number of steps in the longitude direction. See GNSS-SSR-ArrayOfCorrectionPoints field numberOfStepsLongitude.
17	8	u64		`bitmask`	Specifies the availability of correction data at the correction points in the array. If a specific bit is enabled (set to 1), the correction is not available. Only the first rows * cols bits are used, the remainder are set to 0. If there are more then 64 correction points the remaining corrections are always available. Starting with the northwest corner of the array (top left on a north oriented map) the correction points are enumerated with row precedence - first row west to east, second row west to east, until last row west to east - ending with the southeast corner of the array. See GNSS-SSR-ArrayOfCorrectionPoints field bitmaskOfGrids but note the definition of the bits is inverted.
	25				Total Payload Length

Table 9.8.16: MSG_SSR_TILE_DEFINITION_DEP_B 0x05F7 message structure

MSG SSR TILE DEFINITION — 0x05F8 — 1528

Provides the correction point coordinates for the atmospheric correction values in the MSG_SSR_STEC_CORRECTION and MSG_SSR_GRIDDED_CORRECTION messages.
Based on ETSI TS 137 355 V16.1.0 (LTE Positioning Protocol) information element GNSS-SSR-CorrectionPoints. SBP only supports gridded arrays of correction points, not lists of points.

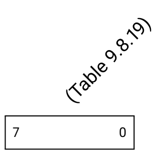
Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	`time.tow`	Seconds since start of GPS week
4	2	u16	week	`time.wn`	GPS week number
6	1	u8		`update_interval`	Update interval between consecutive corrections. Encoded following RTCM DF391 specification.
7	1	u8		`sol_id`	SSR Solution ID. Similar to RTCM DF415.
8	1	u8		`iod_atmo`	IOD of the SSR atmospheric correction.
9	2	u16		`tile_set_id`	Unique identifier of the tile set this tile belongs to.
11	2	u16		`tile_id`	Unique identifier of this tile in the tile set. See GNSS-SSR-ArrayOfCorrectionPoints field correctionPointSetID.
13	2	s16	encoded degrees	`corner_nw_lat`	North-West corner correction point latitude. The relation between the latitude X in the range [-90, 90] and the coded number N is: N = floor((X / 90) * 2^14) See GNSS-SSR-ArrayOfCorrectionPoints field referencePointLatitude.
15	2	s16	encoded degrees	`corner_nw_lon`	North-West corner correction point longitude. The relation between the longitude X in the range [-180, 180] and the coded number N is: N = floor((X / 180) * 2^15) See GNSS-SSR-ArrayOfCorrectionPoints field referencePointLongitude.
17	2	u16	0.01 degrees	`spacing_lat`	Spacing of the correction points in the latitude direction. See GNSS-SSR-ArrayOfCorrectionPoints field stepOfLatitude.
19	2	u16	0.01 degrees	`spacing_lon`	Spacing of the correction points in the longitude direction. See GNSS-SSR-ArrayOfCorrectionPoints field stepOfLongitude.
21	2	u16		`rows`	Number of steps in the latitude direction. See GNSS-SSR-ArrayOfCorrectionPoints field numberOfStepsLatitude.
23	2	u16		`cols`	Number of steps in the longitude direction. See GNSS-SSR-ArrayOfCorrectionPoints field numberOfStepsLongitude.
25	8	u64		`bitmask`	Specifies the absence of correction data at the correction points in the array (grid). Only the first rows * cols bits are used, and if a specific bit is enabled (set to 1), the correction is not available. If there are more than 64 correction points the remaining corrections are always available. The correction points are packed by rows, starting with the northwest corner of the array (top-left on a north oriented map), with each row spanning west to east, ending with the southeast corner of the array. See GNSS-SSR-ArrayOfCorrectionPoints field bitmaskOfGrids but note the definition of the bits is inverted.
	33				Total Payload Length

Table 9.8.17: MSG_SSR_TILE_DEFINITION 0x05F8 message structure

MSG SSR SATELLITE APC DEP — 0x0604 — 1540

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
$32N + 0$	1	u8		`apc[N].sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
$32N + 1$	1	u8		`apc[N].sid.code`	Signal constellation, band and code
$32N + 2$	1	u8		`apc[N].sat_info`	Additional satellite information
$32N + 3$	2	u16		`apc[N].svn`	Satellite Code, as defined by IGS. Typically the space vehicle number.
$32N + 5$	6	s16[3]	1 mm	`apc[N].pco`	Mean phase center offset, X Y and Z axes. See IGS ANTEX file format description for coordinate system definition.
$32N + 11$	21	s8[21]	1 mm	`apc[N].pcv`	Elevation dependent phase center variations. First element is 0 degrees separation from the Z axis, subsequent elements represent elevation variations in 1 degree increments.
	$32N$				Total Payload Length

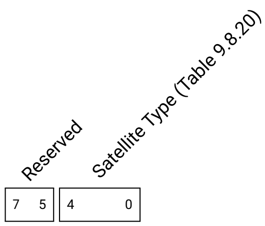
Table 9.8.18: MSG_SSR_SATELLITE_APC_DEP 0x0604 message structure



Field 9.8.8: Signal constellation, band and code (`sid.code`)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P
12	BDS2 B1
13	BDS2 B2
14	GAL E1B
20	GAL E7I
47	BDS3 B2a

Table 9.8.19: values (`sid.code[0:7]`)



Field 9.8.9: Additional satellite information (`sat_info`)

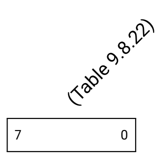
Value	Description
0	Unknown Type
1	GPS I
2	GPS II
3	GPS IIA
4	GPS IIR
5	GPS IIF
6	GPS III
7	GLONASS
8	GLONASS M
9	GLONASS K1
10	GALILEO
11	BEIDOU 2G
12	BEIDOU 2I
13	BEIDOU 2M
14	BEIDOU 3M, SECM
15	BEIDOU 3G, SECM
16	BEIDOU 3M, CAST
17	BEIDOU 3G, CAST
18	BEIDOU 3I, CAST
19	QZSS

Table 9.8.20: Satellite Type values (`sat_info[0:4]`)

MSG SSR SATELLITE APC — 0x0605 — 1541

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	time.tow	Seconds since start of GPS week
4	2	u16	week	time.wn	GPS week number
6	1	u8		update_interval	Update interval between consecutive corrections. Encoded following RTCM DF391 specification.
7	1	u8		sol_id	SSR Solution ID. Similar to RTCM DF415.
8	1	u8		iod_ssr	IOD of the SSR correction. A change of Issue Of Data SSR is used to indicate a change in the SSR generating configuration
$32N+9$	1	u8		apc[N].sid.sat	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
$32N+10$	1	u8		apc[N].sid.code	Signal constellation, band and code
$32N+11$	1	u8		apc[N].sat_info	Additional satellite information
$32N+12$	2	u16		apc[N].svn	Satellite Code, as defined by IGS. Typically the space vehicle number.
$32N+14$	6	s16[3]	1 mm	apc[N].pco	Mean phase center offset, X Y and Z axes. See IGS ANTEX file format description for coordinate system definition.
$32N+20$	21	s8[21]	1 mm	apc[N].pcv	Elevation dependent phase center variations. First element is 0 degrees separation from the Z axis, subsequent elements represent elevation variations in 1 degree increments.
	$32N+9$				Total Payload Length

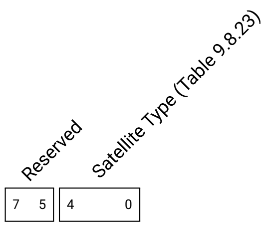
Table 9.8.21: MSG_SSR_SATELLITE_APC 0x0605 message structure



Field 9.8.10: Signal constellation, band and code (sid.code)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P
12	BDS2 B1
13	BDS2 B2
14	GAL E1B
20	GAL E7I
47	BDS3 B2a

Table 9.8.22: values (sid.code[0:7])



Field 9.8.11: Additional satellite information (`sat_info`)

Value	Description
0	Unknown Type
1	GPS I
2	GPS II
3	GPS IIA
4	GPS IIR
5	GPS IIF
6	GPS III
7	GLONASS
8	GLONASS M
9	GLONASS K1
10	GALILEO
11	BEIDOU 2G
12	BEIDOU 2I
13	BEIDOU 2M
14	BEIDOU 3M, SECM
15	BEIDOU 3G, SECM
16	BEIDOU 3M, CAST
17	BEIDOU 3G, CAST
18	BEIDOU 3I, CAST
19	QZSS

Table 9.8.23: Satellite Type values (`sat_info[0:4]`)

MSG SSR ORBIT CLOCK BOUNDS — 0x05DE — 1502

Note 1: Range: 0-17.5 m. i<=200, mean=0.01i; 200<i<=230, mean=2+0.1(i-200); i>230, mean=5+0.5(i-230).
Note 2: Range: 0-17.5 m. i<=200, std=0.01i; 200<i<=230, std=2+0.1(i-200) i>230, std=5+0.5(i-230).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	header.time.tow	Seconds since start of GPS week
4	2	u16	week	header.time.wn	GPS week number
6	1	u8		header.num_msgs	Number of messages in the dataset
7	1	u8		header.seq_num	Position of this message in the dataset
8	1	u8		header.update_interval	Update interval between consecutive bounds. Similar to RTCM DF391.
9	1	u8		header.sol_id	SSR Solution ID.
10	1	u8		ssr_iod	IOD of the SSR bound.
11	1	u8		const_id	Constellation ID to which the SVs belong.
12	1	u8		n_sats	Number of satellites.
9N + 13	1	u8		orbit_clock_bounds[N].sat_id	Satellite ID. Similar to either RTCM DF068 (GPS), DF252 (Galileo), or DF488 (BDS) depending on the constellation.
9N + 14	1	u8	m	orbit_clock_bounds[N].orb_radial_bound_mu	Mean Radial. See Note 1.
9N + 15	1	u8	m	orbit_clock_bounds[N].orb_along_bound_mu	Mean Along-Track. See Note 1.
9N + 16	1	u8	m	orbit_clock_bounds[N].orb_cross_bound_mu	Mean Cross-Track. See Note 1.
9N + 17	1	u8	m	orbit_clock_bounds[N].orb_radial_bound_sig	Standard Deviation Radial. See Note 2.
9N + 18	1	u8	m	orbit_clock_bounds[N].orb_along_bound_sig	Standard Deviation Along-Track. See Note 2.
9N + 19	1	u8	m	orbit_clock_bounds[N].orb_cross_bound_sig	Standard Deviation Cross-Track. See Note 2.
9N + 20	1	u8	m	orbit_clock_bounds[N].clock_bound_mu	Clock Bound Mean. See Note 1.
9N + 21	1	u8	m	orbit_clock_bounds[N].clock_bound_sig	Clock Bound Standard Deviation. See Note 2.
	9N + 13				Total Payload Length

Table 9.8.24: MSG_SSR_ORBIT_CLOCK_BOUNDS 0x05DE message structure

MSG SSR CODE PHASE BIASES BOUNDS — 0x05EC — 1516

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	header.time.tow	Seconds since start of GPS week
4	2	u16	week	header.time.wn	GPS week number
6	1	u8		header.num_msgs	Number of messages in the dataset
7	1	u8		header.seq_num	Position of this message in the dataset
8	1	u8		header.update_interval	Update interval between consecutive bounds. Similar to RTCM DF391.
9	1	u8		header.sol_id	SSR Solution ID.
10	1	u8		ssr_iod	IOD of the SSR bound.
11	1	u8		const_id	Constellation ID to which the SVs belong.
12	1	u8		n_sats_signals	Number of satellite-signal couples.
$6N + 13$	1	u8		satellites_signals[N].sat_id	Satellite ID. Similar to either RTCM DF068 (GPS), DF252 (Galileo), or DF488 (BDS) depending on the constellation.
$6N + 14$	1	u8		satellites_signals[N].signal_id	Signal encoded following Swift RTCM specifications. Table Signal and Tracking Mode Identifier.
$6N + 15$	1	u8	0.005 m	satellites_signals[N].code_bias_bound_mu	Code Bias Mean. Range: 0-1.275 m
$6N + 16$	1	u8	0.005 m	satellites_signals[N].code_bias_bound_sig	Code Bias Standard Deviation. Range: 0-1.275 m
$6N + 17$	1	u8	0.005 m	satellites_signals[N].phase_bias_bound_mu	Phase Bias Mean. Range: 0-1.275 m
$6N + 18$	1	u8	0.005 m	satellites_signals[N].phase_bias_bound_sig	Phase Bias Standard Deviation. Range: 0-1.275 m
	$6N + 13$				Total Payload Length

Table 9.8.25: MSG_SSR_CODE_PHASE_BIASES_BOUNDS 0x05EC message structure

MSG SSR ORBIT CLOCK BOUNDS DEGRADATION — 0x05DF — 1503

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	header.time.tow	Seconds since start of GPS week
4	2	u16	week	header.time.wn	GPS week number
6	1	u8		header.num_msgs	Number of messages in the dataset
7	1	u8		header.seq_num	Position of this message in the dataset
8	1	u8		header.update_interval	Update interval between consecutive bounds. Similar to RTCM DF391.
9	1	u8		header.sol_id	SSR Solution ID.
10	1	u8		ssr_iod	IOD of the SSR bound degradation parameter.
11	1	u8		const_id	Constellation ID to which the SVs belong.
12	8	u64		sat_bitmask	Satellite Bit Mask. Put 1 for each satellite where the following degradation parameters are applicable, 0 otherwise. Encoded following RTCM DF394 specification.
20	1	u8	0.001 m/s	orbit_clock_bounds_degradation.orb_radial_bound_mu_dot	Orbit Bound Mean Radial First derivative. Range: 0-0.255 m/s
21	1	u8	0.001 m/s	orbit_clock_bounds_degradation.orb_along_bound_mu_dot	Orbit Bound Mean Along-Track First derivative. Range: 0-0.255 m/s
22	1	u8	0.001 m/s	orbit_clock_bounds_degradation.orb_cross_bound_mu_dot	Orbit Bound Mean Cross-Track First derivative. Range: 0-0.255 m/s
23	1	u8	0.001 m/s	orbit_clock_bounds_degradation.orb_radial_bound_sig_dot	Orbit Bound Standard Deviation Radial First derivative. Range: 0-0.255 m/s
24	1	u8	0.001 m/s	orbit_clock_bounds_degradation.orb_along_bound_sig_dot	Orbit Bound Standard Deviation Along-Track First derivative. Range: 0-0.255 m/s
25	1	u8	0.001 m/s	orbit_clock_bounds_degradation.orb_cross_bound_sig_dot	Orbit Bound Standard Deviation Cross-Track First derivative. Range: 0-0.255 m/s
26	1	u8	0.001 m/s	orbit_clock_bounds_degradation.clock_bound_mu_dot	Clock Bound Mean First derivative. Range: 0-0.255 m/s
27	1	u8	0.001 m/s	orbit_clock_bounds_degradation.clock_bound_sig_dot	Clock Bound Standard Deviation First derivative. Range: 0-0.255 m/s
	28				Total Payload Length

Table 9.8.26: MSG_SSR_ORBIT_CLOCK_BOUNDS_DEGRADATION 0x05DF message structure

9.9 Tracking

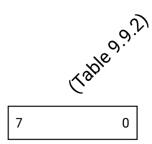
Satellite code and carrier-phase tracking messages from the device.

MSG TRACKING STATE — 0x0041 — 65

The tracking message returns a variable-length array of tracking channel states. It reports status and carrier-to-noise density measurements for all tracked satellites.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
$4N+0$	1	u8		`states[N].sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
$4N+1$	1	u8		`states[N].sid.code`	Signal constellation, band and code
$4N+2$	1	u8		`states[N].fcn`	Frequency channel number (GLONASS only)
$4N+3$	1	u8	dB Hz / 4	`states[N].cn0`	Carrier-to-Noise density. Zero implies invalid cn0.
	$4N$				Total Payload Length

Table 9.9.1: MSG_TRACKING_STATE 0x0041 message structure



Field 9.9.1: Signal constellation, band and code (`sid.code`)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P
12	BDS2 B1
13	BDS2 B2
14	GAL E1B
20	GAL E7I
47	BDS3 B2a

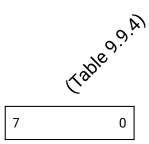
Table 9.9.2: values (`sid.code[0:7]`)

MSG MEASUREMENT STATE — 0x0061 — 97

The tracking message returns a variable-length array of tracking channel states. It reports status and carrier-to-noise density measurements for all tracked satellites.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
3N + 0	1	u8		`states[N].mesid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
3N + 1	1	u8		`states[N].mesid.code`	Signal constellation, band and code
3N + 2	1	u8	dB Hz / 4	`states[N].cn0`	Carrier-to-Noise density. Zero implies invalid cn0.
	3N				Total Payload Length

Table 9.9.3: MSG_MEASUREMENT_STATE 0x0061 message structure



Field 9.9.2: Signal constellation, band and code (`mesid.code`)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P
12	BDS2 B1
13	BDS2 B2
14	GAL E1B
20	GAL E7I
47	BDS3 B2a

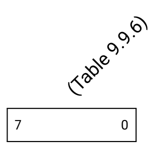
Table 9.9.4: values (`mesid.code[0:7]`)

MSG TRACKING IQ — 0x002D — 45

When enabled, a tracking channel can output the correlations at each update interval.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`channel`	Tracking channel of origin
1	1	u8		`sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
2	1	u8		`sid.code`	Signal constellation, band and code
$4N+3$	2	s16		`corrs[N].I`	In-phase correlation
$4N+5$	2	s16		`corrs[N].Q`	Quadrature correlation
	$4N+3$				Total Payload Length

Table 9.9.5: MSG_TRACKING_IQ 0x002D message structure



Field 9.9.3: Signal constellation, band and code (`sid.code`)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P
12	BDS2 B1
13	BDS2 B2
14	GAL E1B
20	GAL E7I
47	BDS3 B2a

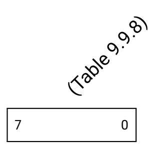
Table 9.9.6: values (`sid.code[0:7]`)

MSG TRACKING IQ DEP B — 0x002C — 44

When enabled, a tracking channel can output the correlations at each update interval.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		`channel`	Tracking channel of origin
1	1	u8		`sid.sat`	Constellation-specific satellite id. For GLO can either be (100+FCN) where FCN is in [-7,+6] or the Slot ID in [1,28].
2	1	u8		`sid.code`	Signal constellation, band and code
$8N+3$	4	s32		`corrs[N].I`	In-phase correlation
$8N+7$	4	s32		`corrs[N].Q`	Quadrature correlation
	$8N+3$				Total Payload Length

Table 9.9.7: MSG_TRACKING_IQ_DEP_B 0x002C message structure



Field 9.9.4: Signal constellation, band and code (`sid.code`)

Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P
12	BDS2 B1
13	BDS2 B2
14	GAL E1B
20	GAL E7I
47	BDS3 B2a

Table 9.9.8: values (`sid.code[0:7]`)

9.10 User

Messages reserved for use by the user.

MSG USER DATA — 0x0800 — 2048

This message can contain any application specific user data up to a maximum length of 255 bytes per message.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	N	u8[N]		contents	User data payload
	N				Total Payload Length

Table 9.10.1: MSG_USER_DATA 0x0800 message structure

9.11 Vehicle

Messages from a vehicle.

MSG ODOMETRY — 0x0903 — 2307

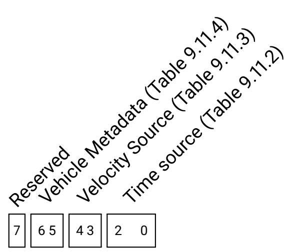
Message representing the x component of vehicle velocity in the user frame at the odometry reference point(s) specified by the user. The offset for the odometry reference point and the definition and origin of the user frame are defined through the device settings interface. There are 4 possible user-defined sources of this message which are labeled arbitrarily source 0 through 3. If using "processor time" time tags, the receiving end will expect a 'MSG_GNSS_TIME_OFFSET' when a PVT fix becomes available to synchronise odometry measurements with GNSS. Processor time shall roll over to zero after one week.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	`tow`	Time field representing either milliseconds in the GPS Week or local CPU time from the producing system in milliseconds. See the tow_source flag for the exact source of this timestamp.
4	4	s32	mm/s	`velocity`	The signed forward component of vehicle velocity.
8	1	u8		`flags`	Status flags
	9				Total Payload Length

Table 9.11.1: MSG_ODOMETRY 0x0903 message structure

Value	Description
0	None (invalid)
1	GPS Solution (ms in week)
2	Processor Time

Table 9.11.2: Time source values (`flags[0:2]`)



Field 9.11.1: Status flags (`flags`)

Value	Description
0	Source 0
1	Source 1
2	Source 2
3	Source 3

Table 9.11.3: Velocity Source values (`flags[3:4]`)

Value	Description
0	Unavailable
1	Forward
2	Reverse
3	Park

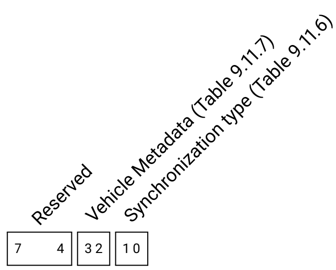
Table 9.11.4: Vehicle Metadata values (`flags[5:6]`)

MSG WHEELTICK — 0x0904 — 2308

Message containing the accumulated distance travelled by a wheel located at an odometry reference point defined by the user. The offset for the odometry reference point and the definition and origin of the user frame are defined through the device settings interface. The source of this message is identified by the source field, which is an integer ranging from 0 to 255. The timestamp associated with this message should represent the time when the accumulated tick count reached the value given by the contents of this message as accurately as possible. If using "local CPU time" time tags, the receiving end will expect a ‘MSG_GNSS_TIME_OFFSET‘ when a PVT fix becomes available to synchronise wheeltick measurements with GNSS. Local CPU time shall roll over to zero after one week.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	8	u64	us	`time`	Time field representing either microseconds since the last PPS, microseconds in the GPS Week or local CPU time from the producing system in microseconds. See the synch_type field for the exact meaning of this timestamp.
8	1	u8		`flags`	Field indicating the type of timestamp contained in the time field.
9	1	u8		`source`	ID of the sensor producing this message
10	4	s32	arbitrary distance units	`ticks`	Free-running counter of the accumulated distance for this sensor. The counter should be incrementing if travelling into one direction and decrementing when travelling in the opposite direction.
	14				Total Payload Length

Table 9.11.5: MSG_WHEELTICK 0x0904 message structure



Field 9.11.2: Field indicating the type of timestamp contained in the time field. (`flags`)

Value	Description
0	microseconds since last PPS
1	microseconds in GPS week
2	local CPU time in nominal microseconds

Table 9.11.6: Synchronization type values (`flags[0:1]`)

Value	Description
0	Unavailable
1	Forward
2	Reverse
3	Park

Table 9.11.7: Vehicle Metadata values (`flags[2:3]`)