

## Contents

<b>1</b>	<b>Overview</b>	<b>1</b>
<b>2</b>	<b>Message Framing Structure</b>	<b>2</b>
<b>3</b>	<b>NMEA-0183</b>	<b>2</b>
<b>4</b>	<b>Basic Formats and Payload Structure</b>	<b>3</b>
<b>5</b>	<b>GNSS Signals</b>	<b>4</b>
<b>6</b>	<b>Message Types</b>	<b>5</b>
<b>7</b>	<b>Stable Message Definitions</b>	<b>9</b>
7.1	Ext Events . . . . .	9
7.2	Imu . . . . .	10
7.3	Logging . . . . .	12
7.4	Mag . . . . .	14
7.5	Navigation . . . . .	15
7.6	Observation . . . . .	48
7.7	Settings . . . . .	83
7.8	Solution Meta . . . . .	91
7.9	System . . . . .	96
<b>8</b>	<b>Draft Message Definitions</b>	<b>109</b>
8.1	Acquisition . . . . .	109
8.2	File IO . . . . .	111
8.3	Integrity . . . . .	120
8.4	Orientation . . . . .	130
8.5	Piksi . . . . .	134
8.6	Sbas . . . . .	157
8.7	Signing . . . . .	158
8.8	Ssr . . . . .	161
8.9	Telemetry . . . . .	184
8.10	Tracking . . . . .	188
8.11	User . . . . .	192
8.12	Vehicle . . . . .	193

## 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 4.12.1-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<sup>1</sup>.

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. <sup>2</sup>
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.

<sup>1</sup>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](http://www.ross.net/crc/download/crc_v3.txt)

<sup>2</sup>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. 26), 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 L10F	GLONASS L10F	33	QZS L1CQ	QZS L1C P
4	GLO L20F	GLONASS L20F	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 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
<b>Stable</b>				
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 System	65294	MSG_SOLN_META	2N + 16	Solution Sensors Metadata
	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
<b>Draft</b>				
Acquisition	47	MSG_ACQ_RESULT	14	Satellite acquisition result
	46	MSG_ACQ_SV_PROFILE	33N	Acquisition performance 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	3076	MSG_ECDSA_CERTIFICATE	N + 6	An ECDSA certificate split over multiple messages
	3077	MSG_CERTIFICATE_CHAIN	135	The certificate chain
Ssr	3078	MSG_ECDSA_SIGNATURE	N + 71	An ECDSA signature
	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 troposphere 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
Telemetry	288	MSG_TEL_SV	12N + 8	Per-signal telemetry
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 6.0.2: SBP message types



## 7 Stable Message Definitions

### 7.1 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 7.1.1: MSG\_EXT\_EVENT 0x0101 message structure



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

Table 7.1.2: New level of pin values (flags[0])

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

Table 7.1.3: Time quality values (flags[1])

## 7.2 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		<code>tow</code>	Milliseconds since reference epoch and time status.
4	1	u8	ms / 256	<code>tow_f</code>	Milliseconds since reference epoch, fractional part
5	2	s16		<code>acc_x</code>	Acceleration in the IMU frame X axis
7	2	s16		<code>acc_y</code>	Acceleration in the IMU frame Y axis
9	2	s16		<code>acc_z</code>	Acceleration in the IMU frame Z axis
11	2	s16		<code>gyr_x</code>	Angular rate around IMU frame X axis
13	2	s16		<code>gyr_y</code>	Angular rate around IMU frame Y axis
15	2	s16		<code>gyr_z</code>	Angular rate around IMU frame Z axis
17					Total Payload Length

Table 7.2.1: MSG\_IMU\_RAW 0x0900 message structure



Field 7.2.1: 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 7.2.2: 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’.

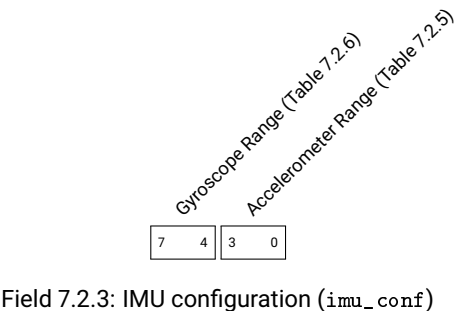
Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		imu_type	IMU type
1	2	s16		temp	Raw IMU temperature
3	1	u8		imu_conf	IMU configuration
	4				Total Payload Length

Table 7.2.3: MSG\_IMU\_AUX 0x0901 message structure



Value	Description
0	Bosch BMI160
1	ST Microelectronics ASM330LLH
4	Murata SCHA634-D03

Table 7.2.4: IMU Type values (imu\_type [0: 7])



Value	Description
0	+/- 2g
1	+/- 4g
2	+/- 8g
3	+/- 16g
4	+/- 6g

Table 7.2.5: 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
5	+/- 300 deg / s

Table 7.2.6: Gyroscope Range values (imu\_conf [4: 7])

### 7.3 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		<code>level</code>	Logging level
1	N	string		<code>text</code>	Human-readable string
	N + 1				Total Payload Length

Table 7.3.1: MSG\_LOG 0x0401 message structure



Field 7.3.1: Logging level (`level`)

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

Table 7.3.2: 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 7.3.3: MSG\_FWD 0x0402 message structure

## 7.4 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 7.4.1: MSG\_MAG\_RAW 0x0902 message structure

## 7.5 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 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 7.5.1: MSG\_GPS\_TIME 0x0102 message structure



Field 7.5.1: Status flags (reserved) (flags)

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

Table 7.5.2: 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 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	<code>wn</code>	GPS week number
2	4	u32	ms	<code>tow</code>	GPS time of week rounded to the nearest millisecond
6	4	s32	ns	<code>ns_residual</code>	Nanosecond residual of millisecond-rounded TOW (ranges from -500000 to 500000)
10	1	u8		<code>flags</code>	Status flags (reserved)
	11				Total Payload Length

Table 7.5.3: MSG\_GPS\_TIME\_GNSS 0x0104 message structure

Field 7.5.2: Status flags (reserved) (`flags`)

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

Table 7.5.4: 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

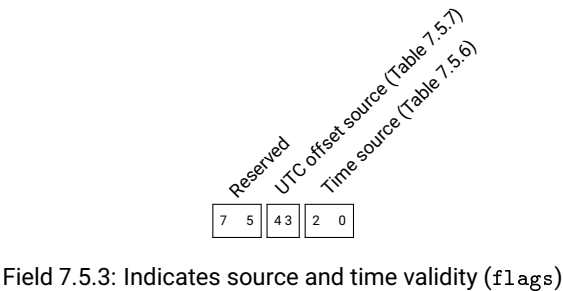
Table 7.5.5: MSG.UTC\_TIME 0x0103 message structure

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

Table 7.5.6: Time source values (flags[0:2])

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

Table 7.5.7: UTC offset source values (flags[3:4])

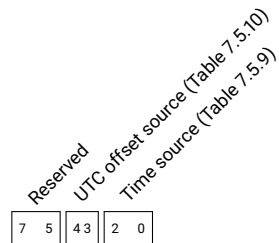


**MSG\_UTC\_TIME\_GNSS – 0x0105 – 261**

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

Table 7.5.8: MSG\_UTC\_TIME\_GNSS 0x0105 message structure

Field 7.5.4: Indicates source and time validity (**flags**)

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

Table 7.5.9: Time source values (**flags**[0:2])

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

Table 7.5.10: 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 7.5.11: MSG\_DOPS 0x0208 message structure



Field 7.5.5: 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 7.5.12: 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	<code>tow</code>	GPS Time of Week
4	8	double	m	<code>x</code>	ECEF X coordinate
12	8	double	m	<code>y</code>	ECEF Y coordinate
20	8	double	m	<code>z</code>	ECEF Z coordinate
28	2	u16	mm	<code>accuracy</code>	Position estimated standard deviation
30	1	u8		<code>n_sats</code>	Number of satellites used in solution
31	1	u8		<code>flags</code>	Status flags
	32				Total Payload Length

Table 7.5.13: MSG\_POS\_ECEF 0x0209 message structure

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

Value	Description
0	None
1	INS used

Table 7.5.15: Inertial Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

Table 7.5.16: TOW type values (`flags[5:5]`)Field 7.5.6: Status flags (`flags`)

**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	<code>tow</code>	GPS Time of Week
4	8	double	m	<code>x</code>	ECEF X coordinate
12	8	double	m	<code>y</code>	ECEF Y coordinate
20	8	double	m	<code>z</code>	ECEF Z coordinate
28	4	float	m <sup>2</sup>	<code>cov_x_x</code>	Estimated variance of x
32	4	float	m <sup>2</sup>	<code>cov_x_y</code>	Estimated covariance of x and y
36	4	float	m <sup>2</sup>	<code>cov_x_z</code>	Estimated covariance of x and z
40	4	float	m <sup>2</sup>	<code>cov_y_y</code>	Estimated variance of y
44	4	float	m <sup>2</sup>	<code>cov_y_z</code>	Estimated covariance of y and z
48	4	float	m <sup>2</sup>	<code>cov_z_z</code>	Estimated variance of z
52	1	u8		<code>n_sats</code>	Number of satellites used in solution
53	1	u8		<code>flags</code>	Status flags
54					Total Payload Length

Table 7.5.17: MSG\_POS\_ECEF\_COV 0x0214 message structure

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

Value	Description
0	None
1	INS used

Table 7.5.19: Inertial Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

Table 7.5.20: Type of reported TOW values (`flags[5:5]`)Field 7.5.7: Status flags (`flags`)

**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	<code>tow</code>	GPS Time of Week
4	8	double	deg	<code>lat</code>	Latitude
12	8	double	deg	<code>lon</code>	Longitude
20	8	double	m	<code>height</code>	Height above WGS84 ellipsoid
28	2	u16	mm	<code>h_accuracy</code>	Horizontal position estimated standard deviation
30	2	u16	mm	<code>v_accuracy</code>	Vertical position estimated standard deviation
32	1	u8		<code>n_sats</code>	Number of satellites used in solution.
33	1	u8		<code>flags</code>	Status flags
34					Total Payload Length

Table 7.5.21: MSG\_POS\_LLH 0x020A message structure

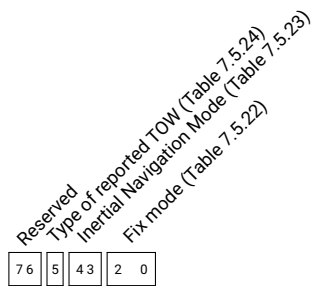
Value	Description
0	Invalid
1	Single Point Position (SPP)
2	Differential GNSS (DGNSS)
3	Float RTK
4	Fixed RTK
5	Dead Reckoning
6	SBAS Position

Table 7.5.22: Fix mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

Table 7.5.23: Inertial Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

Table 7.5.24: Type of reported TOW values (`flags[5:5]`)Field 7.5.8: Status flags (`flags`)

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 7.5.25: MSG\_POS\_LLH\_COV 0x0211 message structure

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

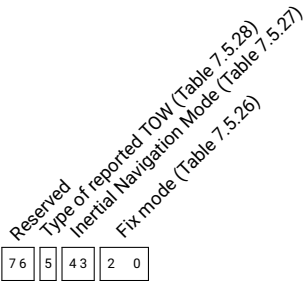
Table 7.5.26: Fix mode values (flags[0:2])

Value	Description
0	None
1	INS used

Table 7.5.27: Inertial Navigation Mode values (flags[3:4])

Value	Description
0	Time of Measurement
1	Other

Table 7.5.28: Type of reported TOW values (flags[5:5])



Field 7.5.9: Status flags (flags)

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

Table 7.5.29: MSG\_POS\_LLH\_ACC 0x0218 message structure





Field 7.5.10: 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 7.5.30: Confidence level values (`confidence_and_geoid[0:3]`)

Value	Description
0	No model
1	EGM96
2	EGM2008

Table 7.5.31: Geoid model values (`confidence_and_geoid[4:6]`)

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

Value	Description
0	None
1	INS used

Table 7.5.33: Inertial Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

Table 7.5.34: Type of reported TOW values (`flags[5:5]`)



Field 7.5.11: Status flags (`flags`)

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 7.5.35: MSG\_BASELINE\_ECEF 0x020B message structure



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

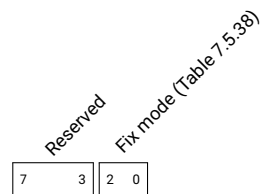
Table 7.5.36: Fix mode values (flags [0:2])

**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	<code>tow</code>	GPS Time of Week
4	4	s32	mm	<code>n</code>	Baseline North coordinate
8	4	s32	mm	<code>e</code>	Baseline East coordinate
12	4	s32	mm	<code>d</code>	Baseline Down coordinate
16	2	u16	mm	<code>h_accuracy</code>	Horizontal position estimated standard deviation
18	2	u16	mm	<code>v_accuracy</code>	Vertical position estimated standard deviation
20	1	u8		<code>n_sats</code>	Number of satellites used in solution
21	1	u8		<code>flags</code>	Status flags
22					Total Payload Length

Table 7.5.37: MSG\_BASELINE\_NED 0x020C message structure

Field 7.5.13: Status flags (`flags`)

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

Table 7.5.38: 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	<code>tow</code>	GPS Time of Week
4	4	s32	mm/s	<code>x</code>	Velocity ECEF X coordinate
8	4	s32	mm/s	<code>y</code>	Velocity ECEF Y coordinate
12	4	s32	mm/s	<code>z</code>	Velocity ECEF Z coordinate
16	2	u16	mm/s	<code>accuracy</code>	Velocity estimated standard deviation
18	1	u8		<code>n_sats</code>	Number of satellites used in solution
19	1	u8		<code>flags</code>	Status flags
20					Total Payload Length

Table 7.5.39: MSG\_VEL\_ECEF 0x020D message structure

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

Table 7.5.40: Velocity mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

Table 7.5.41: INS Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

Table 7.5.42: Type of reported TOW values (`flags[5:5]`)Field 7.5.14: Status flags (`flags`)

**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	<code>tow</code>	GPS Time of Week
4	4	s32	mm/s	<code>x</code>	Velocity ECEF X coordinate
8	4	s32	mm/s	<code>y</code>	Velocity ECEF Y coordinate
12	4	s32	mm/s	<code>z</code>	Velocity ECEF Z coordinate
16	4	float	$m^2/s^2$	<code>cov_x_x</code>	Estimated variance of x
20	4	float	$m^2/s^2$	<code>cov_x_y</code>	Estimated covariance of x and y
24	4	float	$m^2/s^2$	<code>cov_x_z</code>	Estimated covariance of x and z
28	4	float	$m^2/s^2$	<code>cov_y_y</code>	Estimated variance of y
32	4	float	$m^2/s^2$	<code>cov_y_z</code>	Estimated covariance of y and z
36	4	float	$m^2/s^2$	<code>cov_z_z</code>	Estimated variance of z
40	1	u8		<code>n_sats</code>	Number of satellites used in solution
41	1	u8		<code>flags</code>	Status flags
42					Total Payload Length

Table 7.5.43: MSG\_VEL\_ECEF\_COV 0x0215 message structure

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

Table 7.5.44: Velocity mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

Table 7.5.45: INS Navigation Mode values (`flags[3:4]`)

Value	Description
0	Time of Measurement
1	Other

Table 7.5.46: Type of reported TOW values (`flags[5:5]`)Field 7.5.15: Status flags (`flags`)

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 7.5.47: MSG\_VEL\_NED 0x020E message structure

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

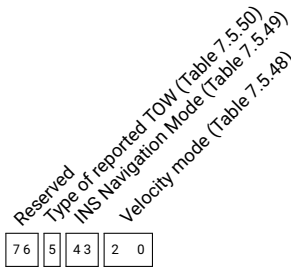
Table 7.5.48: Velocity mode values (flags[0:2])

Value	Description
0	None
1	INS used

Table 7.5.49: INS Navigation Mode values (flags[3:4])

Value	Description
0	Time of Measurement
1	Other

Table 7.5.50: Type of reported TOW values (flags[5:5])



Field 7.5.16: Status flags (flags)

**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 <sup>2</sup>	cov_n_n	Estimated variance of northward measurement
20	4	float	m <sup>2</sup>	cov_n_e	Covariance of northward and eastward measurement
24	4	float	m <sup>2</sup>	cov_n_d	Covariance of northward and downward measurement
28	4	float	m <sup>2</sup>	cov_e_e	Estimated variance of eastward measurement
32	4	float	m <sup>2</sup>	cov_e_d	Covariance of eastward and downward measurement
36	4	float	m <sup>2</sup>	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 7.5.51: MSG\_VEL\_NED\_COV 0x0212 message structure

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

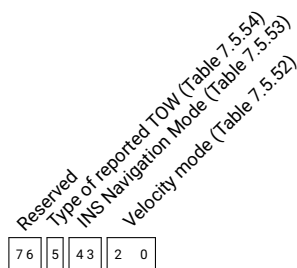
Table 7.5.52: Velocity mode values (flags[0:2])

Value	Description
0	None
1	INS used

Table 7.5.53: INS Navigation Mode values (flags[3:4])

Value	Description
0	Time of Measurement
1	Other

Table 7.5.54: Type of reported TOW values (flags[5:5])



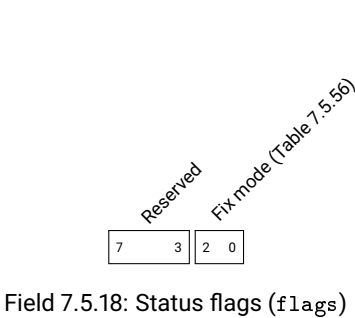
Field 7.5.17: Status flags (flags)

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 7.5.55: MSG\_POS\_ECEF\_GNSS 0x0229 message structure



Field 7.5.18: 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 7.5.56: Fix mode values (flags[0:2])

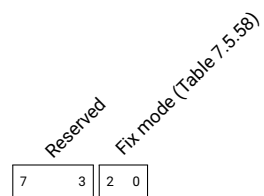


**MSG\_POS\_ECEF\_COV\_GNSS – 0x0234 – 564**

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	<code>tow</code>	GPS Time of Week
4	8	double	m	<code>x</code>	ECEF X coordinate
12	8	double	m	<code>y</code>	ECEF Y coordinate
20	8	double	m	<code>z</code>	ECEF Z coordinate
28	4	float	m <sup>2</sup>	<code>cov_x_x</code>	Estimated variance of x
32	4	float	m <sup>2</sup>	<code>cov_x_y</code>	Estimated covariance of x and y
36	4	float	m <sup>2</sup>	<code>cov_x_z</code>	Estimated covariance of x and z
40	4	float	m <sup>2</sup>	<code>cov_y_y</code>	Estimated variance of y
44	4	float	m <sup>2</sup>	<code>cov_y_z</code>	Estimated covariance of y and z
48	4	float	m <sup>2</sup>	<code>cov_z_z</code>	Estimated variance of z
52	1	u8		<code>n_sats</code>	Number of satellites used in solution
53	1	u8		<code>flags</code>	Status flags
54					Total Payload Length

Table 7.5.57: MSG\_POS\_ECEF\_COV\_GNSS 0x0234 message structure

Field 7.5.19: 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 7.5.58: 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 7.5.59: MSG\_POS\_LLH\_GNSS 0x022A message structure

7

3

2

0

Reserved

Fix mode (Table 7.5.60)

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

Field 7.5.20: Status flags (flags)

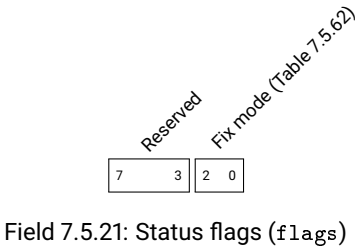
Table 7.5.60: Fix mode values (flags[0:2])

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 7.5.61: MSG\_POS\_LLH\_COV\_GNSS 0x0231 message structure



Field 7.5.21: 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

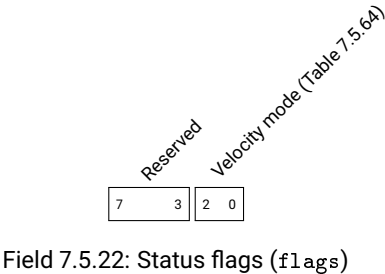
Table 7.5.62: Fix mode values (flags [0:2])

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 7.5.63: MSG\_VEL\_ECEF\_GNSS 0x022D message structure



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

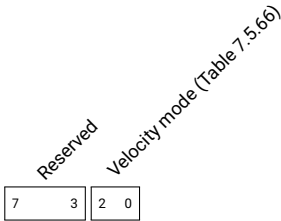
Table 7.5.64: Velocity mode values (flags[0:2])

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 <sup>2</sup> /s <sup>2</sup>	cov_x_x	Estimated variance of x
20	4	float	m <sup>2</sup> /s <sup>2</sup>	cov_x_y	Estimated covariance of x and y
24	4	float	m <sup>2</sup> /s <sup>2</sup>	cov_x_z	Estimated covariance of x and z
28	4	float	m <sup>2</sup> /s <sup>2</sup>	cov_y_y	Estimated variance of y
32	4	float	m <sup>2</sup> /s <sup>2</sup>	cov_y_z	Estimated covariance of y and z
36	4	float	m <sup>2</sup> /s <sup>2</sup>	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 7.5.65: MSG\_VEL\_ECEF\_COV\_GNSS 0x0235 message structure



Field 7.5.23: Status flags (flags)

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

Table 7.5.66: 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 7.5.67: MSG\_VEL\_NED\_GNSS 0x022E message structure



Field 7.5.24: Status flags (flags)

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

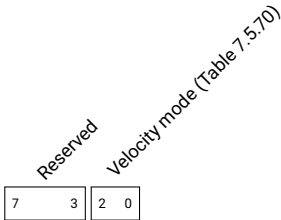
Table 7.5.68: Velocity mode values (flags[0:2])

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 7.5.69: MSG\_VEL\_NED\_COV\_GNSS 0x0232 message structure



Field 7.5.25: Status flags (flags)

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

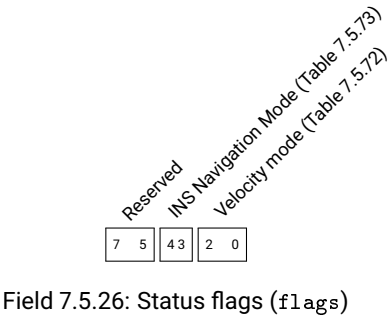
Table 7.5.70: Velocity mode values (flags[0:2])

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 7.5.71: MSG\_VEL\_BODY 0x0213 message structure



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

Table 7.5.72: Velocity mode values (flags [0:2])

Value	Description
0	None
1	INS used

Table 7.5.73: 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	<code>tow</code>	GPS Time of Week
4	4	u32	microdegrees	<code>cog</code>	Course over ground relative to north direction
8	4	u32	mm/s	<code>sog</code>	Speed over ground (based on horizontal velocity)
12	4	s32	mm/s	<code>v_up</code>	Vertical velocity component (positive up)
16	4	u32	microdegrees	<code>cog_accuracy</code>	Course over ground estimated standard deviation
20	4	u32	mm/s	<code>sog_accuracy</code>	Speed over ground estimated standard deviation
24	4	u32	mm/s	<code>v_up_accuracy</code>	Vertical velocity estimated standard deviation
28	2	u16		<code>flags</code>	Status flags
	30				Total Payload Length

Table 7.5.74: MSG\_VEL\_COG 0x021C message structure

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

Table 7.5.75: Velocity mode values (flags [0:2])

Value	Description
0	None
1	INS used

Table 7.5.76: INS Navigation Mode values (flags [3:4])

Value	Description
0	Time of Measurement
1	Other

Table 7.5.77: Type of reported TOW values (flags [5])

Value	Description
0	Invalid
1	COG valid

Table 7.5.78: COG validity values (flags [6])

Value	Description
0	Invalid
1	SOG valid

Table 7.5.79: SOG validity values (flags [7])

Value	Description
0	Invalid
1	Vertical velocity valid

Table 7.5.80: Vertical velocity validity values (flags [8])

Value	Description
0	Not frozen
1	Frozen

Table 7.5.81: 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 7.5.82: 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 7.5.83: 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 7.5.84: 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	<code>tow</code>	GPS Time of Week
4	1	u8		<code>sensor_id</code>	ID of the sensor producing this message
5	4	u32	ms	<code>timestamp_1</code>	Timestamp of first keyframe
9	4	u32	ms	<code>timestamp_2</code>	Timestamp of second keyframe
13	12	s32[3]	mm	<code>trans</code>	Relative translation [x,y,z] described in first keyframe
25	4	s32	$2^{-31}$	<code>w</code>	Real component of quaternion to describe relative rotation (second to first keyframe)
29	4	s32	$2^{-31}$	<code>x</code>	1st imaginary component of quaternion to describe relative rotation (second to first keyframe)
33	4	s32	$2^{-31}$	<code>y</code>	2nd imaginary component of quaternion to describe relative rotation (second to first keyframe)
37	4	s32	$2^{-31}$	<code>z</code>	3rd imaginary component of quaternion to describe relative rotation (second to first keyframe)
41	4	float	$m^2$	<code>cov_r_x_x</code>	Estimated variance of x (relative translation)
45	4	float	$m^2$	<code>cov_r_x_y</code>	Covariance of x and y (relative translation)
49	4	float	$m^2$	<code>cov_r_x_z</code>	Covariance of x and z (relative translation)
53	4	float	$m^2$	<code>cov_r_y_y</code>	Estimated variance of y (relative translation)
57	4	float	$m^2$	<code>cov_r_y_z</code>	Covariance of y and z (relative translation)
61	4	float	$m^2$	<code>cov_r_z_z</code>	Estimated variance of z (relative translation)
65	4	float	$rad^2$	<code>cov_c_x_x</code>	Estimated variance of x (relative rotation)
69	4	float	$rad^2$	<code>cov_c_x_y</code>	Covariance of x and y (relative rotation)
73	4	float	$rad^2$	<code>cov_c_x_z</code>	Covariance of x and z (relative rotation)
77	4	float	$rad^2$	<code>cov_c_y_y</code>	Estimated variance of y (relative rotation)
81	4	float	$rad^2$	<code>cov_c_y_z</code>	Covariance of y and z (relative rotation)
85	4	float	$rad^2$	<code>cov_c_z_z</code>	Estimated variance of z (relative rotation)
89	1	u8		<code>flags</code>	Status flags of relative translation and rotation
90					Total Payload Length

Table 7.5.85: MSG\_POSE\_RELATIVE 0x0245 message structure



Field 7.5.28: Status flags of relative translation and rotation (flags)

Value	Description
0	Invalid
1	Valid

Table 7.5.86: Relative rotation status values (flags[0:1])

Value	Description
0	Invalid
1	Valid

Table 7.5.87: Relative translation status values (flags[2:3])

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

Table 7.5.88: Time source values (flags[4:5])

## 7.6 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 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 7.6.1: MSG\_OBS 0x004A message structure





Field 7.6.1: 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 7.6.2: Pseudorange valid values (flags[0])

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

Table 7.6.3: Carrier phase valid values (flags[1])

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

Table 7.6.4: Half-cycle ambiguity values (flags[2])

Value	Description
0	Invalid doppler measurement
1	Valid doppler measurement

Table 7.6.5: Doppler valid values (flags[3])

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

Table 7.6.6: 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 7.6.7: 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

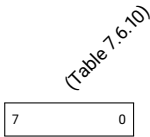
Table 7.6.8: MSG\_BASE\_POS\_ECEF 0x0048 message structure

**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	tgdl	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 7.6.9: MSG\_EPHEMERIS\_GPS\_DEP\_E 0x0081 message structure



Field 7.6.2: 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 7.6.10: 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 <sup>(1/2)</sup>	sq_rta	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 <sup>2</sup>	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 7.6.11: 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		<code>common.sid.sat</code>	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		<code>common.sid.code</code>	Signal constellation, band and code (see pg. 4)
2	4	u32	s	<code>common.toe.tow</code>	Seconds since start of GPS week
6	2	u16	week	<code>common.toe.wn</code>	GPS week number
8	4	float	m	<code>common.ura</code>	User Range Accuracy
12	4	u32	s	<code>common.fit_interval</code>	Curve fit interval
16	1	u8		<code>common.valid</code>	Status of ephemeris, 1 = valid, 0 = invalid
17	1	u8		<code>common.health_bits</code>	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	<code>tgd</code>	Group delay differential between L1 and L2
22	4	float	m	<code>c_rs</code>	Amplitude of the sine harmonic correction term to the orbit radius
26	4	float	m	<code>c_rc</code>	Amplitude of the cosine harmonic correction term to the orbit radius
30	4	float	rad	<code>c_uc</code>	Amplitude of the cosine harmonic correction term to the argument of latitude
34	4	float	rad	<code>c_us</code>	Amplitude of the sine harmonic correction term to the argument of latitude
38	4	float	rad	<code>c_ic</code>	Amplitude of the cosine harmonic correction term to the angle of inclination
42	4	float	rad	<code>c_is</code>	Amplitude of the sine harmonic correction term to the angle of inclination
46	8	double	rad/s	<code>dn</code>	Mean motion difference
54	8	double	rad	<code>m0</code>	Mean anomaly at reference time
62	8	double		<code>ecc</code>	Eccentricity of satellite orbit
70	8	double	$m^{1/2}$	<code>sqrta</code>	Square root of the semi-major axis of orbit
78	8	double	rad	<code>omega0</code>	Longitude of ascending node of orbit plane at weekly epoch
86	8	double	rad/s	<code>omegadot</code>	Rate of right ascension
94	8	double	rad	<code>w</code>	Argument of perigee
102	8	double	rad	<code>inc</code>	Inclination
110	8	double	rad/s	<code>inc_dot</code>	Inclination first derivative
118	4	float	s	<code>af0</code>	Polynomial clock correction coefficient (clock bias)
122	4	float	s/s	<code>af1</code>	Polynomial clock correction coefficient (clock drift)
126	4	float	s/s <sup>2</sup>	<code>af2</code>	Polynomial clock correction coefficient (rate of clock drift)
130	4	u32	s	<code>toc.tow</code>	Seconds since start of GPS week
134	2	u16	week	<code>toc.wn</code>	GPS week number
136	1	u8		<code>iode</code>	Issue of ephemeris data
137	2	u16		<code>iodc</code>	Issue of clock data
139					Total Payload Length

Table 7.6.12: 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		<code>common.sid.sat</code>	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		<code>common.sid.code</code>	Signal constellation, band and code (see pg. 4)
2	4	u32	s	<code>common.toe.tow</code>	Seconds since start of GPS week
6	2	u16	week	<code>common.toe.wn</code>	GPS week number
8	4	float	m	<code>common.ura</code>	User Range Accuracy
12	4	u32	s	<code>common.fit_interval</code>	Curve fit interval
16	1	u8		<code>common.valid</code>	Status of ephemeris, 1 = valid, 0 = invalid
17	1	u8		<code>common.health_bits</code>	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	<code>tgd</code>	Group delay differential between L1 and L2
22	4	float	m	<code>c_rs</code>	Amplitude of the sine harmonic correction term to the orbit radius
26	4	float	m	<code>c_rc</code>	Amplitude of the cosine harmonic correction term to the orbit radius
30	4	float	rad	<code>c_uc</code>	Amplitude of the cosine harmonic correction term to the argument of latitude
34	4	float	rad	<code>c_us</code>	Amplitude of the sine harmonic correction term to the argument of latitude
38	4	float	rad	<code>c_ic</code>	Amplitude of the cosine harmonic correction term to the angle of inclination
42	4	float	rad	<code>c_is</code>	Amplitude of the sine harmonic correction term to the angle of inclination
46	8	double	rad/s	<code>dn</code>	Mean motion difference
54	8	double	rad	<code>m0</code>	Mean anomaly at reference time
62	8	double		<code>ecc</code>	Eccentricity of satellite orbit
70	8	double	$m^{(1/2)}$	<code>sq_rta</code>	Square root of the semi-major axis of orbit
78	8	double	rad	<code>omega0</code>	Longitude of ascending node of orbit plane at weekly epoch
86	8	double	rad/s	<code>omegadot</code>	Rate of right ascension
94	8	double	rad	<code>w</code>	Argument of perigee
102	8	double	rad	<code>inc</code>	Inclination
110	8	double	rad/s	<code>inc_dot</code>	Inclination first derivative
118	4	float	s	<code>af0</code>	Polynomial clock correction coefficient (clock bias)
122	4	float	s/s	<code>af1</code>	Polynomial clock correction coefficient (clock drift)
126	4	float	$s/s^2$	<code>af2</code>	Polynomial clock correction coefficient (rate of clock drift)
130	4	u32	s	<code>toc.tow</code>	Seconds since start of GPS week
134	2	u16	week	<code>toc.wn</code>	GPS week number
136	1	u8		<code>iode</code>	Issue of ephemeris data
137	2	u16		<code>iodc</code>	Issue of clock data
139					Total Payload Length

Table 7.6.13: 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	tgdl	Group delay differential for B1
22	4	float	s	tgdl	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 <sub>oe</sub> per RTCM/CSNO recommendation: IODE = mod(t <sub>oe</sub> / 720, 240)
145	2	u16		iodc	Issue of clock data Calculated from the navigation data parameter t <sub>oe</sub> per RTCM/CSNO recommendation: IODE = mod(t <sub>oc</sub> / 720, 240)
147					Total Payload Length

Table 7.6.14: 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		<code>common.sid.sat</code>	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		<code>common.sid.code</code>	Signal constellation, band and code (see pg. 4)
2	4	u32	s	<code>common.toe.tow</code>	Seconds since start of GPS week
6	2	u16	week	<code>common.toe.wn</code>	GPS week number
8	4	float	m	<code>common.ura</code>	User Range Accuracy
12	4	u32	s	<code>common.fit_interval</code>	Curve fit interval
16	1	u8		<code>common.valid</code>	Status of ephemeris, 1 = valid, 0 = invalid
17	1	u8		<code>common.health_bits</code>	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	<code>bgd_e1e5a</code>	E1-E5a Broadcast Group Delay
22	4	float	s	<code>bgd_e1e5b</code>	E1-E5b Broadcast Group Delay
26	4	float	m	<code>c_rs</code>	Amplitude of the sine harmonic correction term to the orbit radius
30	4	float	m	<code>c_rc</code>	Amplitude of the cosine harmonic correction term to the orbit radius
34	4	float	rad	<code>c_uc</code>	Amplitude of the cosine harmonic correction term to the argument of latitude
38	4	float	rad	<code>c_us</code>	Amplitude of the sine harmonic correction term to the argument of latitude
42	4	float	rad	<code>c_ic</code>	Amplitude of the cosine harmonic correction term to the angle of inclination
46	4	float	rad	<code>c_is</code>	Amplitude of the sine harmonic correction term to the angle of inclination
50	8	double	rad/s	<code>dn</code>	Mean motion difference
58	8	double	rad	<code>m0</code>	Mean anomaly at reference time
66	8	double		<code>ecc</code>	Eccentricity of satellite orbit
74	8	double	m <sup>1/2</sup>	<code>sqrrta</code>	Square root of the semi-major axis of orbit
82	8	double	rad	<code>omega0</code>	Longitude of ascending node of orbit plane at weekly epoch
90	8	double	rad/s	<code>omegadot</code>	Rate of right ascension
98	8	double	rad	<code>w</code>	Argument of perigee
106	8	double	rad	<code>inc</code>	Inclination
114	8	double	rad/s	<code>inc_dot</code>	Inclination first derivative
122	8	double	s	<code>af0</code>	Polynomial clock correction coefficient (clock bias)
130	8	double	s/s	<code>af1</code>	Polynomial clock correction coefficient (clock drift)
138	4	float	s/s <sup>2</sup>	<code>af2</code>	Polynomial clock correction coefficient (rate of clock drift)
142	4	u32	s	<code>toc.tow</code>	Seconds since start of GPS week
146	2	u16	week	<code>toc.wn</code>	GPS week number
148	2	u16		<code>iode</code>	Issue of data (IODnav)
150	2	u16		<code>iodc</code>	Issue of data (IODnav). Always equal to iode
152					Total Payload Length

Table 7.6.15: 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 7.6.16: MSG\_EPHEMERIS\_GAL 0x008D message structure

## MSG\_EPHEMERIS\_SBAS\_DEP\_A – 0x0082 – 130

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

Table 7.6.17: MSG\_EPHEMERIS\_SBAS\_DEP\_A 0x0082 message structure

(Table 7.6.18)

7	0
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Field 7.6.3: 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 7.6.18: 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		<code>common.sid.sat</code>	Constellation-specific satellite identifier. Note: unlike GnssSignal, GPS satellites are encoded as (PRN - 1). Other constellations do not have this offset.
2	1	u8		<code>common.sid.code</code>	Signal constellation, band and code
3	1	u8		<code>common.sid.reserved</code>	Reserved
4	4	u32	ms	<code>common.toe.tow</code>	Milliseconds since start of GPS week
8	2	u16	week	<code>common.toe.wn</code>	GPS week number
10	8	double	m	<code>common.ura</code>	User Range Accuracy
18	4	u32	s	<code>common.fit_interval</code>	Curve fit interval
22	1	u8		<code>common.valid</code>	Status of ephemeris, 1 = valid, 0 = invalid
23	1	u8		<code>common.health_bits</code>	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		<code>gamma</code>	Relative deviation of predicted carrier frequency from nominal
32	8	double	s	<code>tau</code>	Correction to the SV time
40	24	double[3]	m	<code>pos</code>	Position of the SV at tb in PZ-90.02 coordinates system
64	24	double[3]	m/s	<code>vel</code>	Velocity vector of the SV at tb in PZ-90.02 coordinates system
88	24	double[3]	m/s <sup>2</sup>	<code>acc</code>	Acceleration vector of the SV at tb in PZ-90.02 coordinates sys
112					Total Payload Length

Table 7.6.19: MSG\_EPHEMERIS\_GLO\_DEP\_A 0x0083 message structure

Field 7.6.4: Signal constellation, band and code (`common.sid.code`)

(Table 7.6.20)

7	0
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Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P

Table 7.6.20: 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		<code>common.sid.sat</code>	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		<code>common.sid.code</code>	Signal constellation, band and code (see pg. 4)
2	4	u32	s	<code>common.toe.tow</code>	Seconds since start of GPS week
6	2	u16	week	<code>common.toe.wn</code>	GPS week number
8	8	double	m	<code>common.ura</code>	User Range Accuracy
16	4	u32	s	<code>common.fit_interval</code>	Curve fit interval
20	1	u8		<code>common.valid</code>	Status of ephemeris, 1 = valid, 0 = invalid
21	1	u8		<code>common.health_bits</code>	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	<code>pos</code>	Position of the GEO at time toe
46	24	double[3]	m/s	<code>vel</code>	Velocity of the GEO at time toe
70	24	double[3]	m/s <sup>2</sup>	<code>acc</code>	Acceleration of the GEO at time toe
94	8	double	s	<code>a_gf0</code>	Time offset of the GEO clock w.r.t. SBAS Network Time
102	8	double	s/s	<code>a_gf1</code>	Drift of the GEO clock w.r.t. SBAS Network Time
110					Total Payload Length

Table 7.6.21: MSG\_EPHEMERIS\_SBAS\_DEP\_B 0x0084 message structure

## MSG\_EPHEMERIS\_SBAS – 0x008C – 140

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		<code>common.sid.sat</code>	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		<code>common.sid.code</code>	Signal constellation, band and code (see pg. 4)
2	4	u32	s	<code>common.toe.tow</code>	Seconds since start of GPS week
6	2	u16	week	<code>common.toe.wn</code>	GPS week number
8	4	float	m	<code>common.ura</code>	User Range Accuracy
12	4	u32	s	<code>common.fit_interval</code>	Curve fit interval
16	1	u8		<code>common.valid</code>	Status of ephemeris, 1 = valid, 0 = invalid
17	1	u8		<code>common.health_bits</code>	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	<code>pos</code>	Position of the GEO at time toe
42	12	float[3]	m/s	<code>vel</code>	Velocity of the GEO at time toe
54	12	float[3]	m/s <sup>2</sup>	<code>acc</code>	Acceleration of the GEO at time toe
66	4	float	s	<code>a_gf0</code>	Time offset of the GEO clock w.r.t. SBAS Network Time
70	4	float	s/s	<code>a_gf1</code>	Drift of the GEO clock w.r.t. SBAS Network Time
74					Total Payload Length

Table 7.6.22: 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		<code>common.sid.sat</code>	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		<code>common.sid.code</code>	Signal constellation, band and code (see pg. 4)
2	4	u32	s	<code>common.toe.tow</code>	Seconds since start of GPS week
6	2	u16	week	<code>common.toe.wn</code>	GPS week number
8	8	double	m	<code>common.ura</code>	User Range Accuracy
16	4	u32	s	<code>common.fit_interval</code>	Curve fit interval
20	1	u8		<code>common.valid</code>	Status of ephemeris, 1 = valid, 0 = invalid
21	1	u8		<code>common.health_bits</code>	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 Others: 0 = valid, non-zero = invalid
22	8	double		<code>gamma</code>	Relative deviation of predicted carrier frequency from nominal
30	8	double	s	<code>tau</code>	Correction to the SV time
38	24	double[3]	m	<code>pos</code>	Position of the SV at tb in PZ-90.02 coordinates system
62	24	double[3]	m/s	<code>vel</code>	Velocity vector of the SV at tb in PZ-90.02 coordinates system
86	24	double[3]	m/s <sup>2</sup>	<code>acc</code>	Acceleration vector of the SV at tb in PZ-90.02 coordinates sys
110					Total Payload Length

Table 7.6.23: 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		<code>common.sid.sat</code>	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		<code>common.sid.code</code>	Signal constellation, band and code (see pg. 4)
2	4	u32	s	<code>common.toe.tow</code>	Seconds since start of GPS week
6	2	u16	week	<code>common.toe.wn</code>	GPS week number
8	8	double	m	<code>common.ura</code>	User Range Accuracy
16	4	u32	s	<code>common.fit_interval</code>	Curve fit interval
20	1	u8		<code>common.valid</code>	Status of ephemeris, 1 = valid, 0 = invalid
21	1	u8		<code>common.health_bits</code>	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 Others: 0 = valid, non-zero = invalid
22	8	double		<code>gamma</code>	Relative deviation of predicted carrier frequency from nominal
30	8	double	s	<code>tau</code>	Correction to the SV time
38	8	double	s	<code>d_tau</code>	Equipment delay between L1 and L2
46	24	double[3]	m	<code>pos</code>	Position of the SV at tb in PZ-90.02 coordinates system
70	24	double[3]	m/s	<code>vel</code>	Velocity vector of the SV at tb in PZ-90.02 coordinates system
94	24	double[3]	m/s <sup>2</sup>	<code>acc</code>	Acceleration vector of the SV at tb in PZ-90.02 coordinates sys
118	1	u8		<code>fcn</code>	Frequency slot. FCN+8 (that is [1..14]). 0 or 0xFF for invalid
119					Total Payload Length

Table 7.6.24: 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		<code>common.sid.sat</code>	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		<code>common.sid.code</code>	Signal constellation, band and code (see pg. 4)
2	4	u32	s	<code>common.toe.tow</code>	Seconds since start of GPS week
6	2	u16	week	<code>common.toe.wn</code>	GPS week number
8	8	double	m	<code>common.ura</code>	User Range Accuracy
16	4	u32	s	<code>common.fit_interval</code>	Curve fit interval
20	1	u8		<code>common.valid</code>	Status of ephemeris, 1 = valid, 0 = invalid
21	1	u8		<code>common.health_bits</code>	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 Others: 0 = valid, non-zero = invalid
22	8	double		<code>gamma</code>	Relative deviation of predicted carrier frequency from nominal
30	8	double	s	<code>tau</code>	Correction to the SV time
38	8	double	s	<code>d_tau</code>	Equipment delay between L1 and L2
46	24	double[3]	m	<code>pos</code>	Position of the SV at <code>tb</code> in PZ-90.02 coordinates system
70	24	double[3]	m/s	<code>vel</code>	Velocity vector of the SV at <code>tb</code> in PZ-90.02 coordinates system
94	24	double[3]	m/s <sup>2</sup>	<code>acc</code>	Acceleration vector of the SV at <code>tb</code> in PZ-90.02 coordinates sys
118	1	u8		<code>fcn</code>	Frequency slot. FCN+8 (that is [1..14]). 0 or 0xFF for invalid
119	1	u8		<code>iod</code>	Issue of data. Equal to the 7 bits of the immediate data word <code>t_b</code>
120					Total Payload Length

Table 7.6.25: 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		<code>common.sid.sat</code>	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		<code>common.sid.code</code>	Signal constellation, band and code (see pg. 4)
2	4	u32	s	<code>common.toe.tow</code>	Seconds since start of GPS week
6	2	u16	week	<code>common.toe.wn</code>	GPS week number
8	4	float	m	<code>common.ura</code>	User Range Accuracy
12	4	u32	s	<code>common.fit_interval</code>	Curve fit interval
16	1	u8		<code>common.valid</code>	Status of ephemeris, 1 = valid, 0 = invalid
17	1	u8		<code>common.health_bits</code>	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		<code>gamma</code>	Relative deviation of predicted carrier frequency from nominal
22	4	float	s	<code>tau</code>	Correction to the SV time
26	4	float	s	<code>d_tau</code>	Equipment delay between L1 and L2
30	24	double[3]	m	<code>pos</code>	Position of the SV at <code>tb</code> in PZ-90.02 coordinates system
54	24	double[3]	m/s	<code>vel</code>	Velocity vector of the SV at <code>tb</code> in PZ-90.02 coordinates system
78	12	float[3]	m/s <sup>2</sup>	<code>acc</code>	Acceleration vector of the SV at <code>tb</code> in PZ-90.02 coordinates sys
90	1	u8		<code>fcn</code>	Frequency slot. FCN+8 (that is [1..14]). 0 or 0xFF for invalid
91	1	u8		<code>iod</code>	Issue of data. Equal to the 7 bits of the immediate data word <code>t_b</code>
92					Total Payload Length

Table 7.6.26: 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	<code>t_nmct.tow</code>	Seconds since start of GPS week
4	2	u16	week	<code>t_nmct.wn</code>	GPS week number
6	8	double	s	<code>a0</code>	
14	8	double	s/semi-circle	<code>a1</code>	
22	8	double	s/(semi-circle) <sup>2</sup>	<code>a2</code>	
30	8	double	s/(semi-circle) <sup>3</sup>	<code>a3</code>	
38	8	double	s	<code>b0</code>	
46	8	double	s/semi-circle	<code>b1</code>	
54	8	double	s/(semi-circle) <sup>2</sup>	<code>b2</code>	
62	8	double	s/(semi-circle) <sup>3</sup>	<code>b3</code>	
70					Total Payload Length

Table 7.6.27: 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	<code>t_nmct.tow</code>	Seconds since start of GPS week
4	2	u16	week	<code>t_nmct.wn</code>	GPS week number
6	4	u32		<code>l2c_mask</code>	L2C capability mask, SV32 bit being MSB, SV1 bit being LSB
10					Total Payload Length

Table 7.6.28: 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, <a href="https://www.caat.or.th/wp-content/uploads/2018/03/SL-2018.18.E-1.pdf">https://www.caat.or.th/wp-content/uploads/2018/03/SL-2018.18.E-1.pdf</a> )
50	8	u64		gc.sbas_l5	SBAS L5 active mask (PRNs 120..158, AN 7/62.2.2-18/18 Table B-23, <a href="https://www.caat.or.th/wp-content/uploads/2018/03/SL-2018.18.E-1.pdf">https://www.caat.or.th/wp-content/uploads/2018/03/SL-2018.18.E-1.pdf</a> )
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 7.6.29: 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	$s * 2^{-35}$	tgd	
10	2	s16	$s * 2^{-35}$	isc_l1ca	
12	2	s16	$s * 2^{-35}$	isc_l2c	
14					Total Payload Length

Table 7.6.30: 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 7.6.31: MSG\_GROUP\_DELAY\_DEP\_B 0x0093 message structure



Field 7.6.5: 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 7.6.32: 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 tgdc validity etc. 1 = value is valid, 0 = value is not valid.
9	2	s16	$s * 2^{-35}$	tgdc	
11	2	s16	$s * 2^{-35}$	isc_l1ca	
13	2	s16	$s * 2^{-35}$	isc_l2c	
15					Total Payload Length

Table 7.6.33: 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		<code>common.sid.sat</code>	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		<code>common.sid.code</code>	Signal constellation, band and code (see pg. 4)
2	4	u32	s	<code>common.toa.tow</code>	Seconds since start of GPS week
6	2	u16	week	<code>common.toa.wn</code>	GPS week number
8	8	double	m	<code>common.ura</code>	User Range Accuracy
16	4	u32	s	<code>common.fit_interval</code>	Curve fit interval
20	1	u8		<code>common.valid</code>	Status of almanac, 1 = valid, 0 = invalid
21	1	u8		<code>common.health_bits</code>	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	<code>m0</code>	Mean anomaly at reference time
30	8	double		<code>ecc</code>	Eccentricity of satellite orbit
38	8	double	$m^{1/2}$	<code>sq_rta</code>	Square root of the semi-major axis of orbit
46	8	double	rad	<code>omega0</code>	Longitude of ascending node of orbit plane at weekly epoch
54	8	double	rad/s	<code>omegado_t</code>	Rate of right ascension
62	8	double	rad	<code>w</code>	Argument of perigee
70	8	double	rad	<code>inc</code>	Inclination
78	8	double	s	<code>af0</code>	Polynomial clock correction coefficient (clock bias)
86	8	double	s/s	<code>af1</code>	Polynomial clock correction coefficient (clock drift)
94					Total Payload Length

Table 7.6.34: 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 <sup>2</sup> )	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 7.6.35: 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 7.6.36: 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		<code>azel[N].sid.sat</code>	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		<code>azel[N].sid.code</code>	Signal constellation, band and code (see pg. 4)
$4N + 2$	1	u8	deg * 2	<code>azel[N].az</code>	Azimuth angle (range 0..179)
$4N + 3$	1	s8	deg	<code>azel[N].el</code>	Elevation angle (range -90..90)
$4N$					Total Payload Length

Table 7.6.37: 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 7.6.38: MSG\_OSR 0x0640 message structure

Value	Description
0	Do not use signal
1	Valid signal

Table 7.6.39: Correction validity values (`flags[0]`)

Value	Description
0	Partial fixing unavailable
1	Partial fixing available

Table 7.6.40: Partial fixing flag values (`flags[1]`)

Value	Description
0	Full fixing unavailable
1	Full fixing available

Table 7.6.41: Full fixing flag values (`flags[2]`)

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

Table 7.6.42: Invalid code corrections values (`flags[3]`)

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

Table 7.6.43: Invalid phase corrections values (`flags[4]`)



Field 7.6.6: Correction flags. (`flags`)

## 7.7 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 7.7.1: 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 7.7.2: 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\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	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 7.7.3: MSG\_SETTINGS\_WRITE\_RESP 0x00AF message structure



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 7.7.4: 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 7.7.5: 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 7.7.6: 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\_BY\_INDEX\_RESP".

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

Table 7.7.7: 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\0FORMAT\_TYPE\0" 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 7.7.8: 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 7.7.9: MSG\_SETTINGS\_READ\_BY\_INDEX\_DONE 0x00A6 message structure

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

Table 7.8.1: MSG\_SOLN\_META 0xFF0E message structure



Field 7.8.1: 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 7.8.2: Time status values (`age_gnss[30:31]`)



Field 7.8.2: 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 7.8.3: Sensor Type values (`sol_in[N].sensor_type[0:2]`)

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

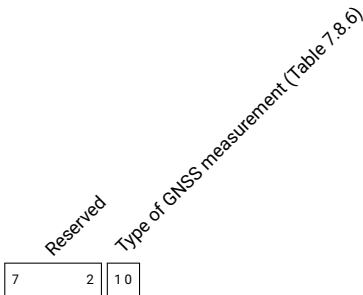
Table 7.8.4: Sensor Usage values (`sol_in[N].sensor_type[3:4]`)

GNSSInputType

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

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

Table 7.8.5: GNSSInputType message structure



Field 7.8.3: 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 7.8.6: Type of GNSS measurement values (`flags[0:1]`)

## IMUInputType

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

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

Table 7.8.7: IMUInputType message structure

Value	Description
0	6-axis MEMS
1	Other type

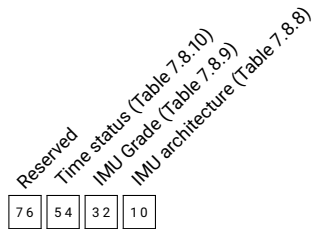
Table 7.8.8: IMU architecture values (`flags[0:1]`)

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

Table 7.8.9: 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 7.8.10: Time status values (`flags[4:5]`)



Field 7.8.4: Instrument time, grade, and architecture for a sensor. (`flags`)

OdolInputType

Metadata around the Odometry sensors involved in the fused 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 7.8.11: OdolInputType message structure

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

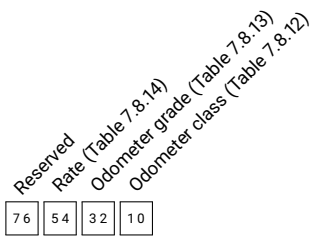
Table 7.8.12: Odometer class values (flags[0:1])

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

Table 7.8.13: Odometer grade values (flags[2:3])

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

Table 7.8.14: Rate values (flags[4:5])



Field 7.8.5: Instrument ODO rate, grade, and quality. (flags)

## 7.9 System

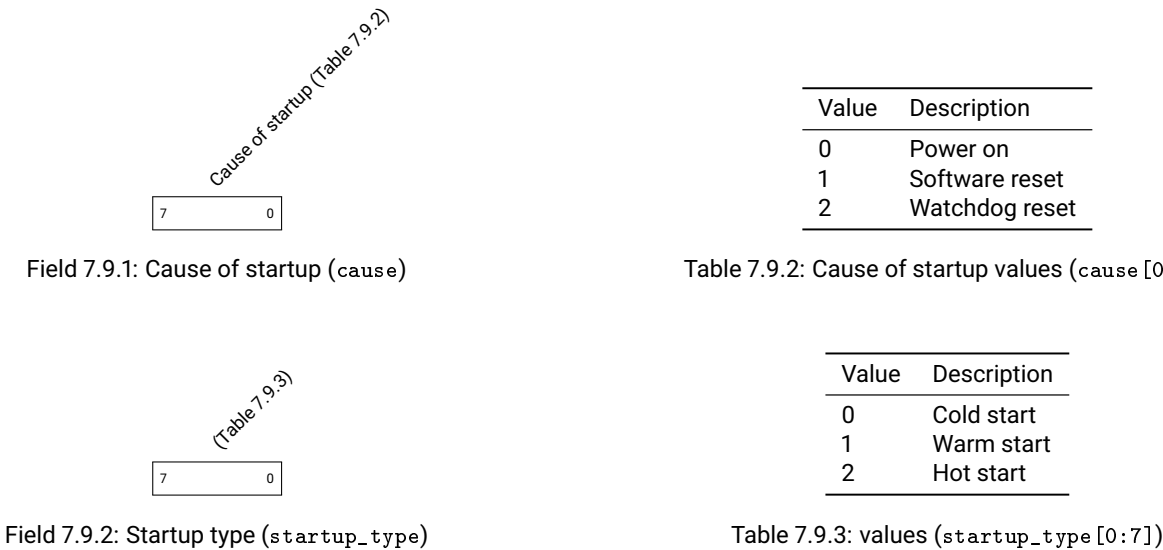
Standardized system messages from Swift Navigation devices.

### 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
					Total Payload Length
					4

Table 7.9.1: MSG\_STARTUP 0xFF00 message structure



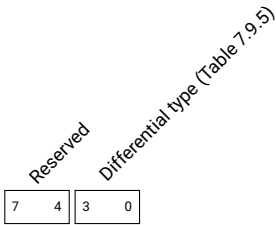


MSG\_DGNSS\_STATUS – 0xFF02 – 65282

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 7.9.4: MSG\_DGNSS\_STATUS 0xFF02 message structure



Field 7.9.3: Status flags (flags)

Value	Description
0	Invalid
1	Code Difference
2	RTK

Table 7.9.5: 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 7.9.6: MSG\_HEARTBEAT 0xFFFF message structure

Value	Description
0	System Healthy
1	An error has occurred

Table 7.9.7: System Error Flag values (flags[0])

Value	Description
0	System Healthy
1	An IO error has occurred

Table 7.9.8: IO Error values (flags[1])

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

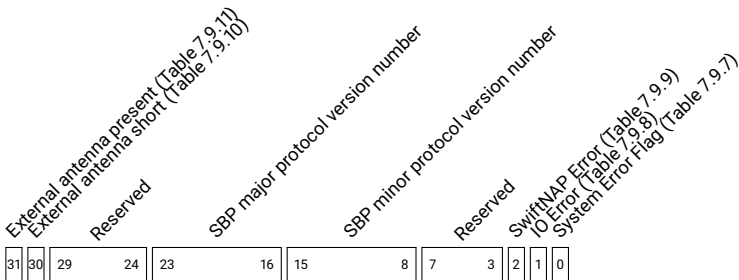
Table 7.9.9: SwiftNAP Error values (flags[2])

Value	Description
0	No short detected
1	Short detected

Table 7.9.10: External antenna short values (flags[30])

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

Table 7.9.11: External antenna present values (flags[31])



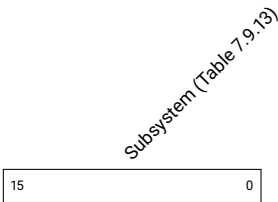
Field 7.9.4: Status flags (flags)

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

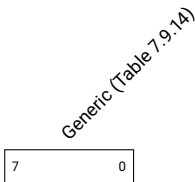
Table 7.9.12: SubSystemReport message structure



Field 7.9.5: 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 7.9.13: Subsystem values (component [0:15])



Field 7.9.6: Generic form status report (generic)

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

Table 7.9.14: Generic values (generic[0:7])

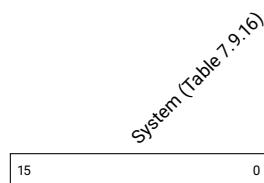
**MSG\_STATUS\_REPORT – 0xFFFE – 65534**

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

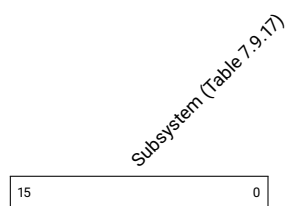
Table 7.9.15: MSG\_STATUS\_REPORT 0xFFFE message structure



Field 7.9.7: Identity of reporting system (reporting\_system)

Value	Description
0	Starling
1	Precision GNSS Module (PGM)

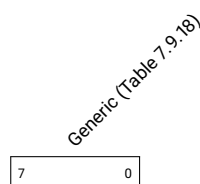
Table 7.9.16: System values (reporting\_system[0:15])



Field 7.9.8: 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 7.9.17: Subsystem values (component [0:15])



Field 7.9.9: Generic form status report (generic)

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

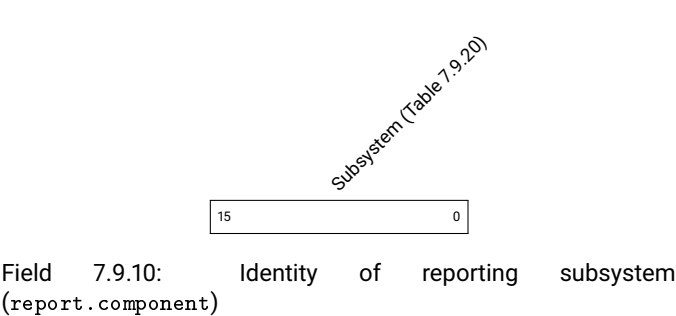
Table 7.9.18: Generic values (generic[0:7])

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.

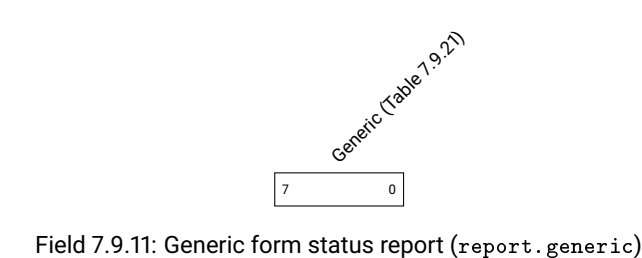
Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		uptime	Milliseconds since system startup
4	2	u16		report.component	Identity of reporting subsystem
6	1	u8		report.generic	Generic form status report
7	1	u8		report.specific	Subsystem specific status code
	8				Total Payload Length

Table 7.9.19: StatusJournalItem message structure



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 7.9.20: Subsystem values (report.component[0:15])



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

Table 7.9.21: 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 7.9.22: MSG\_STATUS\_JOURNAL 0xFFFD message structure



Field 7.9.12: Identity of reporting system (reporting\_system)

Value	Description
0	Starling
1	Precision GNSS Module (PGM)

Table 7.9.23: System values (reporting\_system[0:15])



Field 7.9.13: 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 7.9.24: Subsystem values (report.component[0:15])



Field 7.9.14: Generic form status report (report.generic)

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

Table 7.9.25: 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		<code>flags</code>	Status flags
	4				Total Payload Length

Table 7.9.26: MSG\_INS\_STATUS 0xFF03 message structure



Field 7.9.15: 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 7.9.27: Mode values (flags [0:2])

Value	Description
0	No GNSS fix available
1	GNSS fix

Table 7.9.28: GNSS Fix values (flags [3])

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

Table 7.9.29: 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 7.9.30: Odometry status values (flags [8:9])

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

Table 7.9.31: Odometry Synch values (flags [10])

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

Table 7.9.32: Motion State values (flags [11:13])

Value	Description
0	Smoothpose Loosely Coupled
1	Starling

Table 7.9.33: 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 7.9.34: MSG\_GNSS\_TIME\_OFFSET 0xFF07 message structure

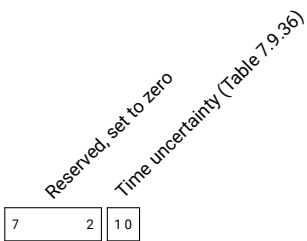
MSG\_PPS\_TIME – 0xFF08 – 65288

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 synchronisation 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 7.9.35: MSG\_PPS\_TIME 0xFF08 message structure



Field 7.9.16: Status flags (flags)

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

Table 7.9.36: 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 7.9.37: MSG\_SENSOR\_AID\_EVENT 0xFF09 message structure



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

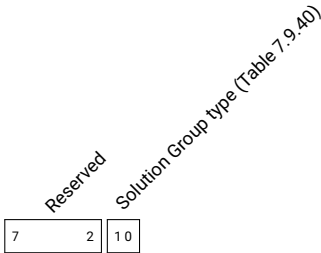
Table 7.9.38: Type identifier values (`sensor_type` [0:7])

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 7.9.39: MSG\_GROUP\_META 0xFF0A message structure



Field 7.9.18: Status flags (reserved) (flags)

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

Table 7.9.40: Solution Group type values (flags [0:1])

8 Draft Message Definitions

8.1 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 8.1.1: MSG\_ACQ\_RESULT 0x002F message structure

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 8.1.2: values (sid.code[0:7])

(Table 8.1.2)

7

0

Field 8.1.1: Signal constellation, band and code (sid.code)

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 8.1.3: MSG\_ACQ\_SV\_PROFILE 0x002E message structure

(Table 8.1.4)

7

0

Field 8.1.2: 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 8.1.4: values (acq\_sv\_profile[N].sid.code[0:7])

## 8.2 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		<code>sequence</code>	Read sequence number
4	4	u32	bytes	<code>offset</code>	File offset
8	1	u8	bytes	<code>chunk_size</code>	Chunk size to read
9	N	string		<code>filename</code>	Name of the file to read from
	N + 9				Total Payload Length

Table 8.2.1: 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		<code>sequence</code>	Read sequence number
4	N	u8[N]		<code>contents</code>	Contents of read file
	N + 4				Total Payload Length

Table 8.2.2: 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 <i>n</i> elements of the file list
8	N	string		dirname	Name of the directory to list
	N + 8				Total Payload Length

Table 8.2.3: 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 a 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		<code>sequence</code>	Read sequence number
4	N	u8[N]		<code>contents</code>	Contents of read directory
	N + 4				Total Payload Length

Table 8.2.4: 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 8.2.5: 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		<code>sequence</code>	Write sequence number
4	4	u32	bytes	<code>offset</code>	Offset into the file at which to start writing in bytes
8	N	string		<code>filename</code>	Name of the file to write to
9	N	u8[N]		<code>data</code>	Variable-length array of data to write
	N + 9				Total Payload Length

Table 8.2.6: 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		<code>sequence</code>	Write sequence number
	4				Total Payload Length

Table 8.2.7: 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 8.2.8: 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		<code>sequence</code>	Advice sequence number
4	4	u32		<code>window_size</code>	The number of SBP packets in the data in-flight window
8	4	u32		<code>batch_size</code>	The number of SBP packets sent in one PDU
12	4	u32		<code>fileio_version</code>	The version of FileIO that is supported
	16				Total Payload Length

Table 8.2.9: MSG\_FILEIO\_CONFIG\_RESP 0x1002 message structure

### 8.3 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 8.3.1: MSG\_SSR\_FLAG\_HIGH\_LEVEL 0x0BB9 message structure

Use GPS satellites. (Table 8.3.2)

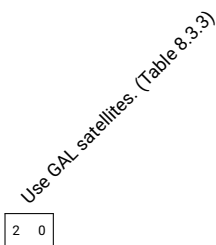
2 0

Field 8.3.1: Use GPS satellites. (use\_gps\_sat)

Value	Description
0	Nominal
1	Warning
2	Alert
3	Not monitored

Table 8.3.2: Use GPS satellites. values (use\_gps\_sat[0:2])

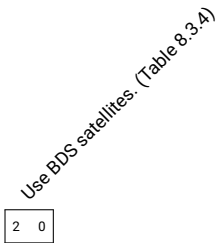




Field 8.3.2: Use GAL satellites. (use\_gal\_sat)

Value	Description
0	Nominal
1	Warning
2	Alert
3	Not monitored

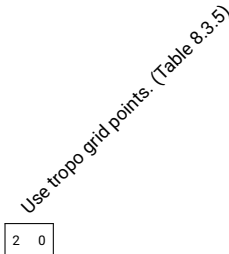
Table 8.3.3: Use GAL satellites. values (use\_gal\_sat [0:2])



Field 8.3.3: Use BDS satellites. (use\_bds\_sat)

Value	Description
0	Nominal
1	Warning
2	Alert
3	Not monitored

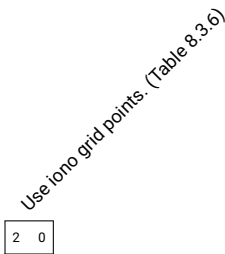
Table 8.3.4: Use BDS satellites. values (use\_bds\_sat [0:2])



Field 8.3.4: Use tropo grid points. (use\_tropo\_grid\_points)

Value	Description
0	Nominal
1	Warning
2	Alert
3	Not monitored

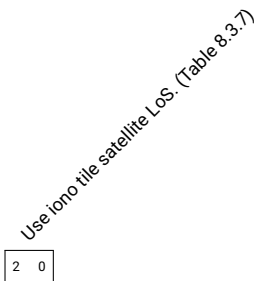
Table 8.3.5: Use tropo grid points. values (use\_tropo\_grid\_points [0:2])



Field 8.3.5: Use iono grid points. (use\_iono\_grid\_points)

Value	Description
0	Nominal
1	Warning
2	Alert
3	Not monitored

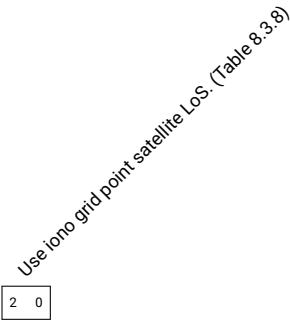
Table 8.3.6: Use iono grid points. values (use\_iono\_grid\_points [0:2])



Field 8.3.6: Use iono tile satellite LoS. (use\_iono\_tile\_sat\_los)

Value	Description
0	Nominal
1	Warning
2	Alert
3	Not monitored

Table 8.3.7: Use iono tile satellite LoS. values (use\_iono\_tile\_sat\_los [0:2])



Field 8.3.7: Use iono grid point satellite LoS. (use\_iono\_grid\_point\_sat\_los)

Value	Description
0	Nominal
1	Warning
2	Alert
3	Not monitored

Table 8.3.8: 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 8.3.9: 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 8.3.10: 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 8.3.11: 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 8.3.12: MSG\_SSR\_FLAG\_IONO\_TILE\_SAT\_LOS 0x0BCD message structure

(Table 8.3.13)

7

0

Field 8.3.8: Constellation ID to which the SV belongs (faulty\_los[N].constellation)

Table 8.3.13: values (faulty\_los[N].constellation[0:7])

Value	Description
0	GPS
3	BDS
5	GAL

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 8.3.14: MSG\_SSR\_FLAG\_IONO\_GRID\_POINT\_SAT\_LOS 0x0BD1 message structure

(Table 8.3.15)

7

0

Value	Description
0	GPS
3	BDS
5	GAL

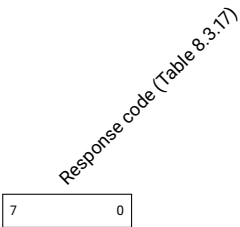
Field 8.3.9: Constellation ID to which the SV belongs  
(faulty\_los[N].constellation)

Table 8.3.15: 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 8.3.16: MSG\_ACKNOWLEDGE 0x0BD2 message structure



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

Field 8.3.10: Reported status of the request. (response\_code)

Table 8.3.17: Response code values (response\_code[0:7])



Value	Description
0	Not requested
1	Requested

Table 8.3.18: Integrity values (`correction_mask_on_demand[8]`)

Value	Description
0	Not requested
1	Requested

Table 8.3.19: Atmospheric values (`correction_mask_on_demand[7]`)

Value	Description
0	Not requested
1	Requested

Table 8.3.20: Satellite phase bias values (`correction_mask_on_demand[6]`)

Value	Description
0	Not requested
1	Requested

Table 8.3.21: Satellite code bias values (`correction_mask_on_demand[5]`)

Value	Description
0	Not requested
1	Requested

Table 8.3.22: Satellite orbit values (`correction_mask_on_demand[4]`)

Value	Description
0	Not requested
1	Requested

Table 8.3.23: Satellite clock values (`correction_mask_on_demand[3]`)

Value	Description
0	Not requested
1	Requested

Table 8.3.24: Ephemeris values (`correction_mask_on_demand[2]`)

Value	Description
0	Not requested
1	Requested

Table 8.3.25: Low rate messages values (`correction_mask_on_demand[1]`)



Field 8.3.11: 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`)

## 8.4 Orientation

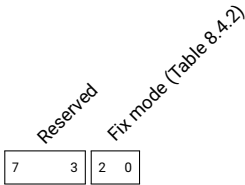
### Orientation Messages

#### 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 8.4.1: MSG\_BASELINE\_HEADING 0x020F message structure



Field 8.4.1: Status flags (flags)

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

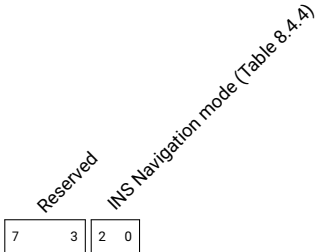
Table 8.4.2: Fix mode values (flags[0:2])

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 8.4.3: MSG\_ORIENT\_QUAT 0x0220 message structure



Field 8.4.2: Status flags (flags)

Value	Description
0	Invalid
1	Valid

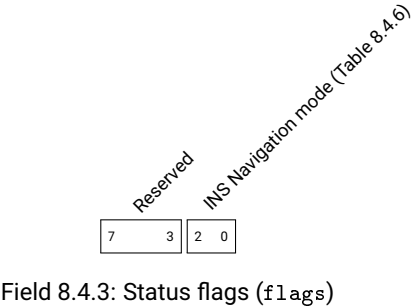
Table 8.4.4: INS Navigation mode values (flags [0:2])

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 8.4.5: MSG\_ORIENT\_EULER 0x0221 message structure



Value	Description
0	Invalid
1	Valid

Table 8.4.6: 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 8.4.7: MSG\_ANGULAR\_RATE 0x0222 message structure



Field 8.4.4: Status flags (flags)

Value	Description
0	Invalid
1	Valid

Table 8.4.8: INS Navigation mode values (flags [0:2])

## 8.5 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 almanac onto the Piksi's flash memory from the host.

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

Table 8.5.1: 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 8.5.2: 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 8.5.3: MSG\_RESET 0x00B6 message structure



Field 8.5.1: Reset flags (flags)

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

Table 8.5.4: 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 8.5.5: 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 8.5.6: 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 8.5.7: 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		<code>filter</code>	Filter flags
	1				Total Payload Length

Table 8.5.8: MSG\_RESET\_FILTERS 0x0022 message structure



Field 8.5.2: Filter flags (`filter`)

Value	Description
0	DGNSS filter
1	IAR process
2	Inertial filter

Table 8.5.9: 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 8.5.10: 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		<code>name</code>	Thread name (NULL terminated)
20	2	u16		<code>cpu</code>	Percentage cpu use for this thread. Values range from 0 - 1000 and needs to be renormalized to 100
22	4	u32	bytes	<code>stack_free</code>	Free stack space for this thread
	26				Total Payload Length

Table 8.5.11: 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 8.5.12: 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 8.5.13: 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 8.5.14: 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 8.5.15: MSG\_MASK\_SATELLITE 0x002B message structure

Reserved

Tracking channels (Table 8.5.17)

Acquisition channel (Table 8.5.16)

7

2

1

0

Field 8.5.3: Mask of systems that should ignore this satellite. (mask)

Value	Description
0	Enabled
1	Skip this satellite on future acquisitions

Table 8.5.16: Acquisition channel values (mask [0])

Value	Description
0	Enabled
1	Drop this PRN if currently tracking

Table 8.5.17: Tracking channels values (mask [1])

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 8.5.18: values (sid.code [0:7])

(Table 8.5.18)

7

0

Field 8.5.4: Signal constellation, band and code (sid.code)

**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 8.5.19: 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 8.5.20: 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 8.5.21: 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 8.5.22: 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 8.5.23: 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 8.5.24: 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	<code>interfaces[N].duration</code>	Duration over which the measurement was collected
$40N + 8$	8	u64		<code>interfaces[N].total_bytes</code>	Number of bytes handled in total within period
$40N + 16$	4	u32		<code>interfaces[N].rx_bytes</code>	Number of bytes transmitted within period
$40N + 20$	4	u32		<code>interfaces[N].tx_bytes</code>	Number of bytes received within period
$40N + 24$	16	string		<code>interfaces[N].interface_name</code>	Interface Name
40N					Total Payload Length

Table 8.5.25: 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 8.5.26: 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 8.5.27: 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 8.5.28: MSG\_FRONT\_END\_GAIN 0x00BF message structure

8.6 Sbas

SBAS data

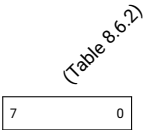
MSG SBAS RAW – 0x7777 – 30583

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 8.6.1: MSG\_SBAS\_RAW 0x7777 message structure

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



Field 8.6.1: Signal constellation, band and code (sid.code)

Table 8.6.2: values (sid.code [0:7])

8.7 Signing

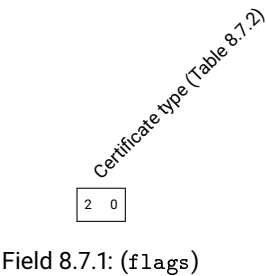
Messages relating to signatures

MSG ECDSA CERTIFICATE – 0x0C04 – 3076

A DER encoded x.509 ECDSA-256 certificate (using curve secp256r1).

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		n_msg	Total number messages that make up the certificate. The first nibble (mask 0xF0 or left shifted by 4 bits) is the size of the sequence (n), second nibble (mask 0x0F) is the zero-indexed counter (ith packet of n).
1	4	u8[4]		certificate_id	The last 4 bytes of the certificate's SHA-1 fingerprint
5	1	u8		flags	
6	N	u8[N]		certificate_bytes	DER encoded x.509 ECDSA certificate bytes
N + 6					Total Payload Length

Table 8.7.1: MSG\_ECDSA\_CERTIFICATE 0x0C04 message structure



Value	Description
0	Corrections certificate
1	Root certificate
2	Intermediate certificate

Table 8.7.2: Certificate type values (flags [0:2])

**MSG CERTIFICATE CHAIN — 0x0C05 — 3077**

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	20	u8[20]		root_certificate	SHA-1 fingerprint of the root certificate
20	20	u8[20]		intermediate_certificate	SHA-1 fingerprint of the intermediate certificate
40	20	u8[20]		corrections_certificate	SHA-1 fingerprint of the corrections certificate
60	2	u16	year	expiration.year	Year
62	1	u8	months	expiration.month	Month (range 1..12)
63	1	u8	day	expiration.day	days in the month (range 1-31)
64	1	u8	hours	expiration.hours	hours of day (range 0-23)
65	1	u8	minutes	expiration.minutes	minutes of hour (range 0-59)
66	1	u8	seconds	expiration.seconds	seconds of minute (range 0-60) rounded down
67	4	u32	nanoseconds	expiration.ns	nanoseconds of second (range 0-999999999)
71	64	u8[64]		signature	An ECDSA signature (created by the root certificate) over the concatenation of the SBP payload bytes preceding this field (that is: the concatenation of 'root_certificate', 'intermediate_certificate', and 'corrections_certificate'). This certificate chain "allow list" can also be validated by fetching it from <http(s)://certs.swiftnav.com/chain>.
135					Total Payload Length

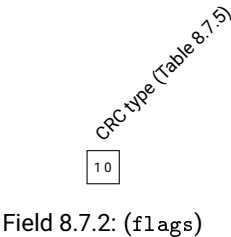
Table 8.7.3: MSG\_CERTIFICATE\_CHAIN 0x0C05 message structure

MSG ECDSA SIGNATURE – 0x0C06 – 3078

An ECDSA-256 signature using SHA-256 as the message digest algorithm.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		flags	
1	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.
2	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.
3	4	u8[4]		certificate_id	The last 4 bytes of the certificate's SHA-1 fingerprint
7	64	u8[64]		signature	ECDSA signature for the messages using SHA-256 as the digest algorithm.
71	N	u8[N]		signed_messages	CRCs of the messages covered by this signature. For Skylark, which delivers SBP messages wrapped in Swift's proprietary RTCM message framing, these are the 24-bit CRCs from the RTCM message framing. For SBP only streams, this will be 16-bit CRCs from the SBP framing. See the 'flags' field to determine the type of CRCs covered.
N + 71					Total Payload Length

Table 8.7.4: MSG\_ECDSA\_SIGNATURE 0x0C06 message structure



Value	Description
0	24-bit CRCs from RTCM framing
1	16-bit CRCs from SBP framing

Table 8.7.5: CRC type values (flags [0:1])



## 8.8 Ssr

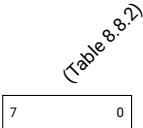
### Precise State Space Representation (SSR) corrections format

#### 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 <sup>-2</sup>	c2	C2 polynomial coefficient for correction of broadcast satellite clock
50					Total Payload Length

Table 8.8.1: MSG\_SSR\_ORBIT\_CLOCK 0x05DD message structure



Field 8.8.1: 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 8.8.2: 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 RTCM specifications (DF380, DF381, DF382 and DF467).
3N + 11	2	s16	0.01 m	biases[N].value	Code bias value
3N + 10				Total Payload Length	

Table 8.8.3: MSG\_SSR\_CODE\_BIASES 0x05E1 message structure

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 8.8.4: values (sid.code [0:7])

(Table 8.8.4)

7

0

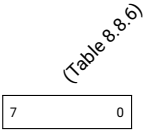
Field 8.8.2: Signal constellation, band and code (sid.code)

**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-Wubben 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 RTCM specifications (DF380, DF381, DF382 and DF467)
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 8.8.5: MSG\_SSR\_PHASE\_BIASES 0x05E6 message structure



Field 8.8.3: 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 8.8.6: 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/deg^2
11N + 14					Total Payload Length

Table 8.8.7: MSG\_SSR\_STEC\_CORRECTION\_DEP 0x05FB message structure

(Table 8.8.8)

7

0

Field 8.8.4: Constellation ID to which the SV belongs (stec\_sat\_list[N].sv\_id.constellation)

Value	Description
0	GPS
3	BDS
5	GAL

Table 8.8.8: 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/deg^2
11N + 16				Total Payload Length	

Table 8.8.9: MSG\_SSR\_STEC\_CORRECTION 0x05FD message structure

(Table 8.8.10)

7

0

Field 8.8.5: Constellation ID to which the SV belongs (stec\_sat\_list[N].sv\_id.constellation)

Value	Description
0	GPS
3	BDS
5	GAL

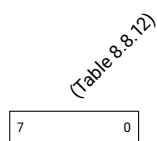
Table 8.8.10: values (stec\_sat\_list[N].sv\_id.constellation[0:7])

**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.stdev	Modified DF389. class 3 MSB, value 5 LSB. stddev = $(3^{\text{class}} * (1 + \text{value}/16) - 1)$
5N + 23	1	u8		stec_residuals[N].sv_id.sat Id	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 = $(3^{\text{class}} * (1 + \text{value}/16) - 1) * 10$
5N + 23					Total Payload Length

Table 8.8.11: MSG\_SSR\_GRIDDED\_CORRECTION 0x05FC message structure



Field 8.8.6: Constellation ID to which the SV belongs  
(stec\_residuals[N].sv\_id.constellation)

Value	Description
0	GPS
3	BDS
5	GAL

Table 8.8.12: values (stec\_residuals[N].sv\_id.constellation[0:7])



**MSG SSR GRIDDED CORRECTION BOUNDS – 0x05FE – 1534**

Note 1: Range: 0-17.5 m.  $i \leq 200$ , mean = 0.01i;  $200 < i \leq 230$ , 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 = $(3^{\text{class}} * (1 + \text{value}/16) - 1)$
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 = $(3^{\text{class}} * (1 + \text{value}/16) - 1) * 10$
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 8.8.13: MSG\_SSR\_GRIDDED\_CORRECTION\_BOUNDS 0x05FE message structure



Field 8.8.7: 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 8.8.14: values(`stec_sat_list[N].stec_residual.sv_id.constellation`)

**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: $N = \text{floor}((X / 90) * 2^{14})$ 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: $N = \text{floor}((X / 180) * 2^{15})$ 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 than 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 8.8.15: 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: $N = \text{floor}((X / 90) * 2^{14})$ 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: $N = \text{floor}((X / 180) * 2^{15})$ 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 than 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 8.8.16: 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: $N = \text{floor}((X / 90) * 2^{14})$ 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: $N = \text{floor}((X / 180) * 2^{15})$ 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 8.8.17: MSG\_SSR\_TILE\_DEFINITION 0x05F8 message structure

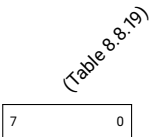


MSG SSR SATELLITE APC DEP – 0x0604 – 1540

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

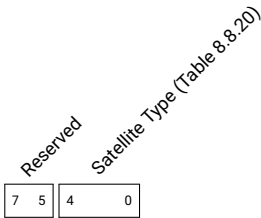
Table 8.8.18: MSG\_SSR\_SATELLITE\_APC\_DEP 0x0604 message structure

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



Field 8.8.8: Signal constellation, band and code (sid.code)

Table 8.8.19: values (sid.code[0:7])



Field 8.8.9: 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

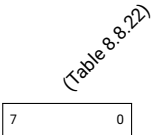
Table 8.8.20: Satellite Type values (`sat_info[0:4]`)

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	

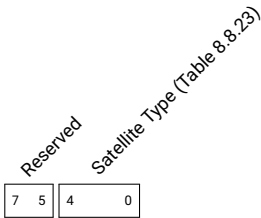
Table 8.8.21: MSG\_SSR\_SATELLITE\_APC 0x0605 message structure

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



Field 8.8.10: Signal constellation, band and code (sid.code)

Table 8.8.22: values (sid.code[0:7])



Field 8.8.11: 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 8.8.23: Satellite Type values (`sat_info[0:4]`)

**MSG SSR ORBIT CLOCK BOUNDS – 0x05DE – 1502**

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

Note 2: Range: 0-17.5 m.  $i \leq 200$ ,  $\text{std} = 0.01i$ ;  $200 < i \leq 230$ ,  $\text{std} = 2 + 0.1(i - 200)$ ;  $i > 230$ ,  $\text{std} = 5 + 0.5(i - 230)$ .

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 8.8.24: 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 and Tracking Mode Identifier. Similar to either RTCM DF380 (GPS), DF382 (Galileo) or DF467 (BDS) depending on the constellation.
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 8.8.25: 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 8.8.26: MSG\_SSR\_ORBIT\_CLOCK\_BOUNDS\_DEGRADATION 0x05DF message structure

## 8.9 Telemetry

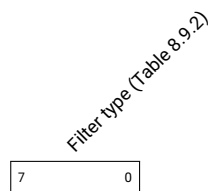
Telemetry messages reported by Starling engine. The messages include various byproducts of state estimation and other logic across Starling and are aimed at efficient issue diagnostics.

### MSG TEL SV – 0x0120 – 288

This message includes telemetry pertinent to satellite signals available to Starling.

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
6	1	u8		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)
7	1	u8		origin_flags	Flags to identify the filter type from which the telemetry is reported from
12N + 8	1	u8	deg * 2	sv_tel[N].az	Azimuth angle (range 0..179)
12N + 9	1	s8	deg	sv_tel[N].el	Elevation angle (range -90..90)
12N + 10	1	u8		sv_tel[N].availability_flag	Observation availability at filter update
12N + 11	2	s16	1 dm	sv_tel[N].pseudorange_residual	Pseudorange observation residual
12N + 13	2	s16	5 mm	sv_tel[N].phase_residual	Carrier-phase or carrier-phase-derived observation residual
12N + 15	1	u8		sv_tel[N].outlier_flags	Reports if observation is marked as an outlier and is excluded from the update
12N + 16	1	u8		sv_tel[N].ephemeris_flags	Ephemeris metadata
12N + 17	1	u8		sv_tel[N].correction_flags	Reserved
12N + 18	1	u8		sv_tel[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].
12N + 19	1	u8		sv_tel[N].sid.code	Signal constellation, band and code
12N + 8					Total Payload Length

Table 8.9.1: MSG\_TEL\_SV 0x0120 message structure



Value	Description
0	Standalone
1	Differential

Field 8.9.1: Flags to identify the filter type from which the telemetry is reported from (origin\_flags)

Table 8.9.2: Filter type values (origin\_flags[0:7])





Field 8.9.2: Observation availability at filter update  
(sv\_tel[N].availability\_flags)

Value	Description
0	Pseudorange unavailable
1	Pseudorange available

Table 8.9.3: Pseudorange availability values  
(sv\_tel[N].availability\_flags[0])

Value	Description
0	Carrier-phase unavailable
1	Carrier-phase available

Table 8.9.4: Carrier-phase availability values  
(sv\_tel[N].availability\_flags[1])

Value	Description
0	Computed-Doppler unavailable
1	Computed-Doppler available

Table 8.9.5: Computed-Doppler availability values  
(sv\_tel[N].availability\_flags[2])

Value	Description
0	Measured-Doppler unavailable
1	Measured-Doppler available

Table 8.9.6: Measured-Doppler availability values  
(sv\_tel[N].availability\_flags[3])



Field 8.9.3: Reports if observation is marked as an outlier and is excluded from the update (`sv_tel[N].outlier_flags`)

Value	Description
0	Pseudorange accepted
1	Pseudorange marked as outlier
2	Pseudorange marked as major outlier

Table 8.9.7: Pseudorange outlier values (`sv_tel[N].outlier_flags[0:1]`)

Value	Description
0	Carrier-phase accepted
1	Carrier-phase marked as outlier

Table 8.9.8: Carrier-phase outlier values (`sv_tel[N].outlier_flags[2]`)

Value	Description
0	Computed-Doppler accepted
1	Computed-Doppler marked as outlier

Table 8.9.9: Computed-Doppler outlier values (`sv_tel[N].outlier_flags[3]`)

Value	Description
0	Measured-Doppler accepted
1	Measured-Doppler marked as outlier

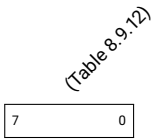
Table 8.9.10: Measured-Doppler outlier values (`sv_tel[N].outlier_flags[4]`)



Field 8.9.4: Ephemeris metadata (`sv_tel[N].ephemeris_flags`)

Value	Description
0	Valid ephemeris available
1	No valid ephemeris available (general status)

Table 8.9.11: Ephemeris available values (`sv_tel[N].ephemeris_flags[0]`)



Field 8.9.5: Signal constellation, band and code  
(`sv_tel[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 8.9.12: values (`sv_tel[N].sid.code[0:7]`)

8.10 Tracking

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

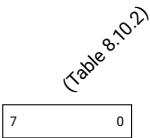
MSG TRACKING STATE – 0x0041 – 65

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 8.10.1: MSG\_TRACKING\_STATE 0x0041 message structure

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



Field 8.10.1: Signal constellation, band and code (sid.code)

Table 8.10.2: 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 8.10.3: MSG\_MEASUREMENT\_STATE 0x0061 message structure

(Table 8.10.4)

7

0

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

Field 8.10.2: Signal constellation, band and code (mesid.code)

Table 8.10.4: 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 8.10.5: MSG\_TRACKING\_IQ 0x002D message structure

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



Field 8.10.3: Signal constellation, band and code (sid.code)

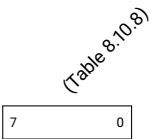
Table 8.10.6: values (sid.code[0:7])

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 8.10.7: MSG\_TRACKING\_IQ\_DEP\_B 0x002C message structure



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

Field 8.10.4: Signal constellation, band and code (sid.code)

Table 8.10.8: values (sid.code[0:7])

## 8.11 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]		<code>contents</code>	User data payload
	N				Total Payload Length

Table 8.11.1: MSG\_USER\_DATA 0x0800 message structure



8.12 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
					Total Payload Length
					9

Table 8.12.1: MSG\_ODOMETRY 0x0903 message structure

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

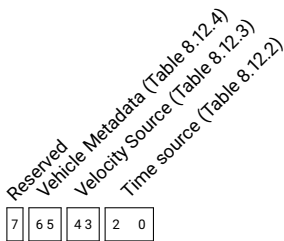
Table 8.12.2: Time source values (flags[0:2])

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

Table 8.12.3: Velocity Source values (flags[3:4])

Value	Description
0	Unavailable
1	Forward
2	Reverse
3	Park

Table 8.12.4: Vehicle Metadata values (flags[5:6])



Field 8.12.1: Status flags (flags)

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 8.12.5: MSG\_WHEELTICK 0x0904 message structure

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

Table 8.12.6: Synchronization type values (flags [0:1])

Value	Description
0	Unavailable
1	Forward
2	Reverse
3	Park

Table 8.12.7: Vehicle Metadata values (flags [2:3])

Reserved

Vehicle Metadata (Table 8.12.7)

Synchronization type (Table 8.12.6)

7

4

32

10

Field 8.12.2: Field indicating the type of timestamp contained in the time field. (flags)