Swift Navigation Binary Protocol

Protocol Specification 2.3.16

Contents

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 http://docs.swiftnav.com/wiki/SwiftNav_Binary_Protocol.

Message Framing Structure

SBP consists of two pieces:

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

As of Version 2.3.16, the frame consists of a 6-byte binary header section, a variable-sized payload field, and a 16-bit CRC value. All multibyte values are ordered in **little-endian** format. SBP uses the CCITT CRC16 (XMODEM implementation) for error detection[1].

Offset (bytes)	Size (bytes)	Name	Description
0	1	Preamble	Denotes the start of frame transmission. Always 0x55.
1	2	Message Type	Identifies the payload contents.
3	2	Sender	A unique identifier of the sender. On the Piksi, this 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. By default, clients of ‘libsbp‘ use a sender id value of ‘0x42‘. Sender id '0x42' is used to represent device controllers such as the Piksi Console.
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.

NMEA-0183

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

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

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

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 02 02 cc 04 14 70 3d d0 18 cf ef ff ff ef e8 ff ff f0 18 00 00 00 00 05 00 43 94`

This byte array decodes into a `MSG_BASELINE_ECEF` (see pg. 16), 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`	`02 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	`43 94`

Table 4.0.2: SBP breakdown for `MSG_BASELINE_ECEF`

Message Types

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

Package	Msg ID	Name	Size (bytes)	Description
Stable				
Ext Events	0x0101	MSG_EXT_EVENT	12	Reports timestamped external pin event
Imu	0x0900	MSG_IMU_RAW	17	Raw IMU data
	0x0901	MSG_IMU_AUX	4	Auxiliary IMU data
Logging	0x0401	MSG_LOG	$N + 1$	Plaintext logging messages with levels
	0x0402	MSG_FWD	$N + 2$	Wrapper for FWD a separate stream of information over SBP
Mag	0x0902	MSG_MAG_RAW	11	Raw magnetometer data
Navigation	0x0102	MSG_GPS_TIME	11	GPS Time
	0x0103	MSG_UTC_TIME	16	UTC Time
	0x0208	MSG_DOPS	15	Dilution of Precision
	0x0209	MSG_POS_ECEF	32	Single-point position in ECEF
	0x0214	MSG_POS_ECEF_COV	54	Single-point position in ECEF
	0x020A	MSG_POS_LLH	34	Geodetic Position
	0x0211	MSG_POS_LLH_COV	54	Geodetic Position
	0x020B	MSG_BASELINE_ECEF	20	Baseline Position in ECEF
	0x020C	MSG_BASELINE_NED	22	Baseline in NED
	0x020D	MSG_VEL_ECEF	20	Velocity in ECEF
	0x0215	MSG_VEL_ECEF_COV	42	Velocity in ECEF
	0x020E	MSG_VEL_NED	22	Velocity in NED
	0x0212	MSG_VEL_NED_COV	42	Velocity in NED
	0x0213	MSG_VEL_BODY	42	Velocity in User Frame
	0x0210	MSG_AGE_CORRECTIONS	6	Age of corrections
Observation	0x004A	MSG_OBS	$17N + 11$	GPS satellite observations
	0x0044	MSG_BASE_POS_LLH	24	Base station position
	0x0048	MSG_BASE_POS_ECEF	24	Base station position in ECEF
	0x0081	MSG_EPHEMERIS_GPS_DEP_E	185	Satellite broadcast ephemeris for GPS
	0x0086	MSG_EPHEMERIS_GPS	183	Satellite broadcast ephemeris for GPS
	0x0089	MSG_EPHEMERIS_BDS	143	Satellite broadcast ephemeris for BDS
	0x0095	MSG_EPHEMERIS_GAL	144	Satellite broadcast ephemeris for Galileo
	0x0082	MSG_EPHEMERIS_SBAS_DEP_A	112	Satellite broadcast ephemeris for SBAS
	0x0083	MSG_EPHEMERIS_GLO_DEP_A	112	Satellite broadcast ephemeris for GLO
	0x0084	MSG_EPHEMERIS_SBAS	110	Satellite broadcast ephemeris for SBAS
	0x0085	MSG_EPHEMERIS_GLO_DEP_B	110	Satellite broadcast ephemeris for GLO
	0x0087	MSG_EPHEMERIS_GLO_DEP_C	119	Satellite broadcast ephemeris for GLO
	0x0088	MSG_EPHEMERIS_GLO	120	Satellite broadcast ephemeris for GLO
	0x0090	MSG_IONO	70	Iono corrections
	0x0091	MSG_SV_CONFIGURATION_GPS	10	L2C capability mask
	0x0092	MSG_GROUP_DELAY_DEP_A	14	Group Delay
	0x0093	MSG_GROUP_DELAY_DEP_B	17	Group Delay
	0x0094	MSG_GROUP_DELAY	15	Group Delay
	0x0072	MSG_ALMANAC_GPS	94	Satellite broadcast ephemeris for GPS
	0x0073	MSG_ALMANAC_GLO	78	Satellite broadcast ephemeris for GLO

	0x0075	MSG_GLO_BIASES	9	GLONASS L1/L2 Code-Phase biases
Settings	0x00A1	MSG_SETTINGS_SAVE	0	Save settings to flash
	0x00A0	MSG_SETTINGS_WRITE	N	Write device configuration settings
	0x00AF	MSG_SETTINGS_WRITE_RESP	$N+1$	Acknowledgement with status of MSG_SETTINGS_WRITE
	0x00A4	MSG_SETTINGS_READ_REQ	N	Read device configuration settings
	0x00A5	MSG_SETTINGS_READ_RESP	N	Read device configuration settings
	0x00A2	MSG_SETTINGS_READ_BY_INDEX_REQ	2	Read setting by direct index
	0x00A7	MSG_SETTINGS_READ_BY_INDEX_RESP	$N+2$	Read setting by direct index
	0x00A6	MSG_SETTINGS_READ_BY_INDEX_DONE	0	Finished reading settings
System	0xFF00	MSG_STARTUP	4	System start-up message
	0xFF02	MSG_DGNSS_STATUS	$N+4$	Status of received corrections
	0xFFFF	MSG_HEARTBEAT	4	System heartbeat message
	0xFF03	MSG_INS_STATUS	4	Inertial Navigation System status message
Draft				
Acquisition	0x002F	MSG_ACQ_RESULT	14	Satellite acquisition result
	0x002E	MSG_ACQ_SV_PROFILE	$33N$	Acquisition perfomance measurement and debug
File IO	0x00A8	MSG_FILEIO_READ_REQ	$N+9$	Read file from the file system
	0x00A3	MSG_FILEIO_READ_RESP	$N+4$	File read from the file system
	0x00A9	MSG_FILEIO_READ_DIR_REQ	$N+8$	List files in a directory
	0x00AA	MSG_FILEIO_READ_DIR_RESP	$N+4$	Files listed in a directory
	0x00AC	MSG_FILEIO_REMOVE	N	Delete a file from the file system
	0x00AD	MSG_FILEIO_WRITE_REQ	$N+9$	Write to file
	0x00AB	MSG_FILEIO_WRITE_RESP	4	File written to
Orientation	0x020F	MSG_BASELINE_HEADING	10	Heading relative to True North
	0x0220	MSG_ORIENT_QUAT	37	Quaternion 4 component vector
	0x0221	MSG_ORIENT_EULER	29	Euler angles
	0x0222	MSG_ANGULAR_RATE	17	Vehicle Body Frame instantaneous angular rates
Piksi	0x0069	MSG_ALMANAC	0	Legacy message to load satellite almanac
	0x0068	MSG_SET_TIME	0	Send GPS time from host
	0x00B6	MSG_RESET	4	Reset the device
	0x00B2	MSG_RESET_DEP	0	Reset the device
	0x00C0	MSG_CW_RESULTS	0	Legacy message for CW interference channel (Piksi =¿ host)
	0x00C1	MSG_CW_START	0	Legacy message for CW interference channel
	0x0022	MSG_RESET_FILTERS	1	Reset IAR filters
	0x0023	MSG_INIT_BASE	0	Initialize IAR from known baseline
	0x0017	MSG_THREAD_STATE	26	State of an RTOS thread
	0x001D	MSG_UART_STATE	74	State of the UART channels
	0x0018	MSG_UART_STATE_DEPA	58	Deprecated
	0x0019	MSG_IAR_STATE	4	State of the Integer Ambiguity Resolution (IAR) process
	0x002B	MSG_MASK_SATELLITE	3	Mask a satellite from use in Piksi subsystems
	0x00B5	MSG_DEVICE_MONITOR	10	Device temperature and voltage levels
	0x00B8	MSG_COMMAND_REQ	$N+4$	Execute a command
	0x00B9	MSG_COMMAND_RESP	8	Exit code from executed command (device =¿ host)
	0x00BC	MSG_COMMAND_OUTPUT	$N+4$	Command output
	0x00BA	MSG_NETWORK_STATE_REQ	0	Request state of Piksi network interfaces
	0x00BB	MSG_NETWORK_STATE_RESP	50	State of network interface
	0x00BD	MSG_NETWORK_BANDWIDTH_USAGE	$40N$	Bandwidth usage reporting message

	0x00BE	MSG_CELL_MODEM_STATUS	$N + 5$	Cell modem information update message
	0x0051	MSG_SPECAN	$N + 28$	Spectrum analyzer
Sbas	0x7777	MSG_SBAS_RAW	34	Raw SBAS data
Ssr	0x05DC	MSG_SSR_ORBIT_CLOCK	47	Precise orbit and clock correction
	0x05E1	MSG_SSR_CODE_BIASES	$3N + 10$	Precise code biases correction
	0x05E6	MSG_SSR_PHASE_BIASES	$8N + 15$	Precise phase biases correction
Tracking	0x0041	MSG_TRACKING_STATE	$4N$	Signal tracking channel states
	0x0061	MSG_MEASUREMENT_STATE	$3N$	Measurement Engine signal tracking channel states
	0x002C	MSG_TRACKING_IQ	$8N + 3$	Tracking channel correlations
User	0x0800	MSG_USER_DATA	N	User data
Vehicle	0x0903	MSG_ODOMETRY	9	Vehicle forward (x-axis) velocity

Table 5.0.2: SBP message types

Stable Message Definitions

Ext Events

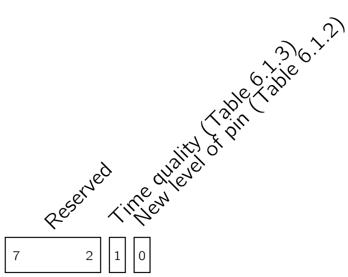
Messages reporting accurately-timestamped external events, e.g. camera shutter time.

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 6.1.1: MSG_EXT_EVENT 0x0101 message structure



Field 6.1.1: Flags (`flags`)

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

Table 6.1.2: New level of pin values (`flags[0]`)

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

Table 6.1.3: Time quality values (`flags[1]`)

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.

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		`acc_x`	Acceleration in the IMU frame X axis
7	2	s16		`acc_y`	Acceleration in the IMU frame Y axis
9	2	s16		`acc_z`	Acceleration in the IMU frame Z axis
11	2	s16		`gyr_x`	Angular rate around IMU frame X axis
13	2	s16		`gyr_y`	Angular rate around IMU frame Y axis
15	2	s16		`gyr_z`	Angular rate around IMU frame Z axis
	17				Total Payload Length

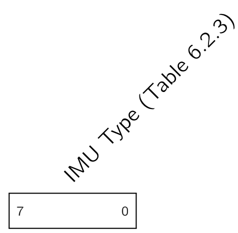
Table 6.2.1: MSG_IMU_RAW 0x0900 message structure

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 6.2.2: MSG_IMU_AUX 0x0901 message structure



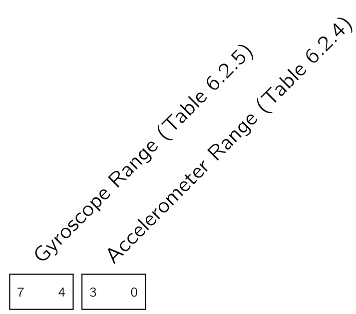
Field 6.2.1: IMU type (`imu_type`)

Value	Description
0	Bosch BMI160

Table 6.2.3: IMU Type values (`imu_type[0:7]`)

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

Table 6.2.4: Accelerometer Range values (`imu_conf[0:3]`)



Field 6.2.2: IMU configuration (`imu_conf`)

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

Table 6.2.5: Gyroscope Range values (`imu_conf[4:7]`)

Logging

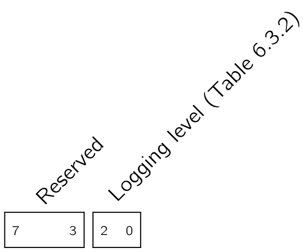
Logging and debugging messages from the device.

MSG_LOG — 0x0401 — 1025

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

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

Table 6.3.1: MSG_LOG 0x0401 message structure



Field 6.3.1: Logging level (`level`)

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

Table 6.3.2: 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	string		`fwd_payload`	variable length wrapped binary message
	$N+2$				Total Payload Length

Table 6.3.3: MSG_FWD 0x0402 message structure

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		`mag_x`	Magnetic field in the body frame X axis
7	2	s16		`mag_y`	Magnetic field in the body frame Y axis
9	2	s16		`mag_z`	Magnetic field in the body frame Z axis
	11				Total Payload Length

Table 6.4.1: MSG_MAG_RAW 0x0902 message structure

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.

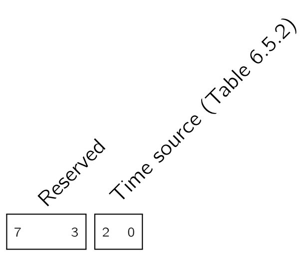
MSG_GPS_TIME — 0x0102 — 258

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

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

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

Table 6.5.1: MSG_GPS_TIME 0x0102 message structure



Field 6.5.1: Status flags (reserved) (`flags`)

Value	Description
0	None (invalid)
1	GNSS Solution

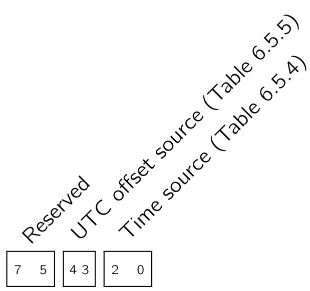
Table 6.5.2: Time source values (`flags[0:2]`)

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 6.5.3: MSG_UTC_TIME 0x0103 message structure



Field 6.5.2: Indicates source and time validity (`flags`)

Value	Description
0	None (invalid)
1	GNSS Solution

Table 6.5.4: Time source values (`flags[0:2]`)

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

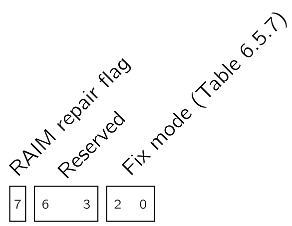
Table 6.5.5: UTC offset source values (`flags[3:4]`)

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 6.5.6: MSG_DOPS 0x0208 message structure



Field 6.5.3: 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

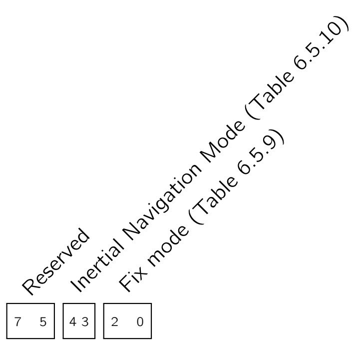
Table 6.5.7: Fix mode values (`flags[0:2]`)

MSG_POS_ECEF — 0x0209 — 521

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

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

Table 6.5.8: MSG_POS_ECEF 0x0209 message structure



Field 6.5.4: 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 6.5.9: Fix mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

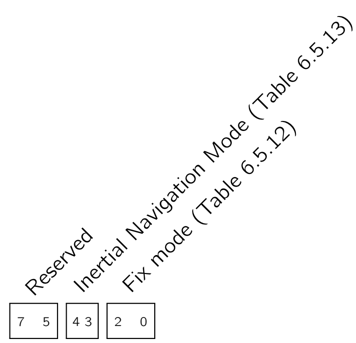
Table 6.5.10: Inertial Navigation Mode values (`flags[3:4]`)

MSG_POS_ECEF_COV — 0x0214 — 532

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

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

Table 6.5.11: MSG_POS_ECEF_COV 0x0214 message structure



Field 6.5.5: 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 6.5.12: Fix mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

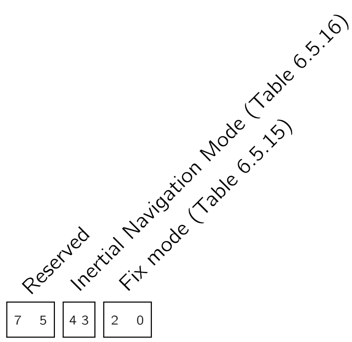
Table 6.5.13: Inertial Navigation Mode values (`flags[3:4]`)

MSG_POS_LLH — 0x020A — 522

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

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

Table 6.5.14: MSG_POS_LLH 0x020A message structure



Field 6.5.6: Status flags (`flags`)

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

Table 6.5.15: Fix mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

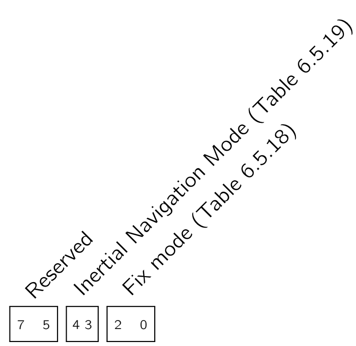
Table 6.5.16: Inertial Navigation Mode values (`flags[3:4]`)

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 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 6.5.17: MSG_POS_LLH_COV 0x0211 message structure



Field 6.5.7: Status flags (`flags`)

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

Table 6.5.18: Fix mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

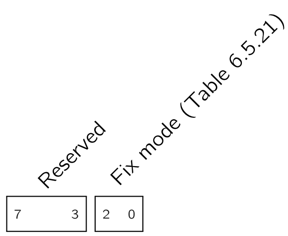
Table 6.5.19: Inertial Navigation Mode values (`flags[3:4]`)

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 6.5.20: MSG_BASELINE_ECEF 0x020B message structure



Field 6.5.8: Status flags (`flags`)

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

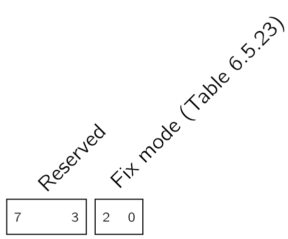
Table 6.5.21: Fix mode values (`flags[0:2]`)

MSG_BASELINE_NED — 0x020C — 524

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

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

Table 6.5.22: MSG_BASELINE_NED 0x020C message structure



Field 6.5.9: Status flags (`flags`)

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

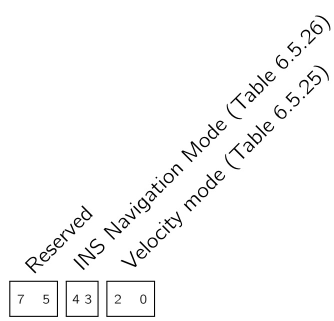
Table 6.5.23: Fix mode values (`flags[0:2]`)

MSG_VEL_ECEF — 0x020D — 525

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

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

Table 6.5.24: MSG_VEL_ECEF 0x020D message structure



Field 6.5.10: Status flags (`flags`)

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

Table 6.5.25: Velocity mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

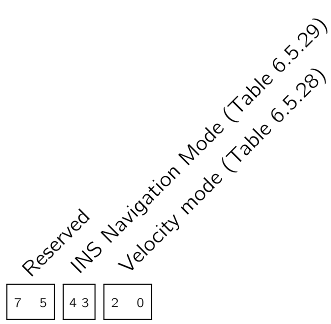
Table 6.5.26: INS Navigation Mode values (`flags[3:4]`)

MSG_VEL_ECEF_COV — 0x0215 — 533

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

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

Table 6.5.27: MSG_VEL_ECEF_COV 0x0215 message structure



Field 6.5.11: Status flags (`flags`)

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

Table 6.5.28: Velocity mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

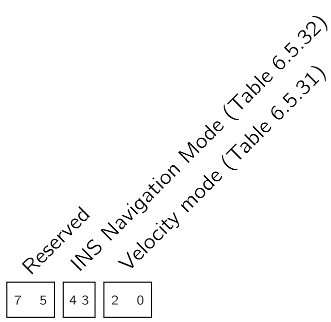
Table 6.5.29: INS Navigation Mode values (`flags[3:4]`)

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 6.5.30: MSG_VEL_NED 0x020E message structure



Field 6.5.12: Status flags (`flags`)

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

Table 6.5.31: Velocity mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

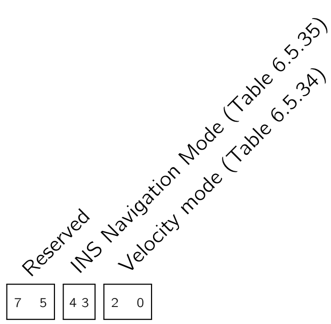
Table 6.5.32: INS Navigation Mode values (`flags[3:4]`)

MSG_VEL_NED_COV — 0x0212 — 530

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

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

Table 6.5.33: MSG_VEL_NED_COV 0x0212 message structure



Field 6.5.13: Status flags (`flags`)

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

Table 6.5.34: Velocity mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

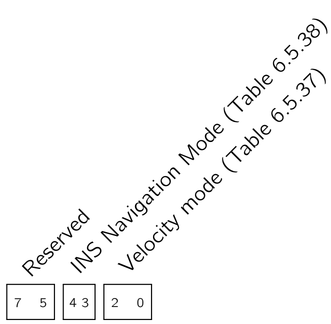
Table 6.5.35: INS Navigation Mode values (`flags[3:4]`)

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).

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 6.5.36: MSG_VEL_BODY 0x0213 message structure



Field 6.5.14: Status flags (`flags`)

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

Table 6.5.37: Velocity mode values (`flags[0:2]`)

Value	Description
0	None
1	INS used

Table 6.5.38: INS Navigation Mode values (`flags[3:4]`)

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 6.5.39: MSG_AGE_CORRECTIONS 0x0210 message structure

Observation

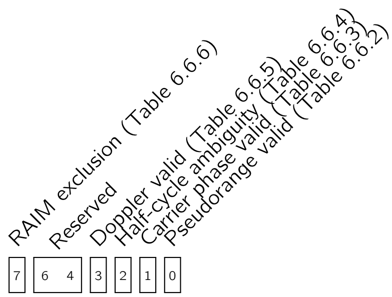
Satellite observation messages from the device.

MSG_OBS — 0x004A — 74

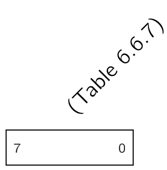
The GPS observations message reports all the raw pseudorange and carrier phase observations for the satellites being tracked by the device. Carrier phase observation here is represented as a 40-bit fixed point number with Q32.8 layout (i.e. 32-bits of whole cycles and 8-bits of fractional cycles). The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

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

Table 6.6.1: MSG_OBS 0x004A message structure



Field 6.6.1: 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`)



Field 6.6.2: Signal constellation, band and code (`sid.code`)

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

Table 6.6.2: Pseudorange valid values (`flags[0]`)

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

Table 6.6.3: Carrier phase valid values (`flags[1]`)

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

Table 6.6.4: Half-cycle ambiguity values (`flags[2]`)

Value	Description
0	Invalid doppler measurement
1	Valid doppler measurement

Table 6.6.5: Doppler valid values (`flags[3]`)

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

Table 6.6.6: RAIM exclusion values (`flags[7]`)

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

Table 6.6.7: values (`sid.code[0:7]`)

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 6.6.8: 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 coodinate
8	8	double	m	y	ECEF Y coordinate
16	8	double	m	z	ECEF Z coordinate
	24				Total Payload Length

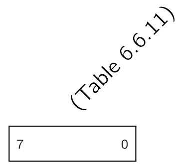
Table 6.6.9: MSG_BASE_POS_ECEF 0x0048 message structure

MSG_EPHEMERIS_GPS_DEP_E — 0x0081 — 129

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

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

Table 6.6.10: MSG_EPHEMERIS_GPS_DEP_E 0x0081 message structure



Field 6.6.3: 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

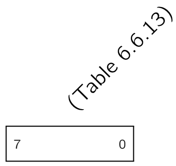
Table 6.6.11: values (`common.sid.code[0:7]`)

MSG_EPHEMERIS_GPS — 0x0086 — 134

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

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

Table 6.6.12: MSG_EPHEMERIS_GPS 0x0086 message structure



Field 6.6.4: Signal constellation, band and code (`common.sid.code`)

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

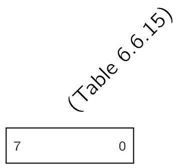
Table 6.6.13: values (`common.sid.code[0:7]`)

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 identifier. This field for Glonass 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
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	4	float	s	tgd1	Group delay differential for B1
26	4	float	s	tgd2	Group delay differential for B2
30	4	float	m	c_rs	Amplitude of the sine harmonic correction term to the orbit radius
34	4	float	m	c_rc	Amplitude of the cosine harmonic correction term to the orbit radius
38	4	float	rad	c_uc	Amplitude of the cosine harmonic correction term to the argument of latitude
42	4	float	rad	c_us	Amplitude of the sine harmonic correction term to the argument of latitude
46	4	float	rad	c_ic	Amplitude of the cosine harmonic correction term to the angle of inclination
50	4	float	rad	c_is	Amplitude of the sine harmonic correction term to the angle of inclination
54	4	float	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	4	float	rad/s	inc_dot	Inclination first derivative
118	8	double	s	af0	Polynomial clock correction coefficient (clock bias)
126	4	float	s/s	af1	Polynomial clock correction coefficient (clock drift)
130	4	float	s/s^2	af2	Polynomial clock correction coefficient (rate of clock drift)
134	4	u32	s	toc.tow	Seconds since start of GPS week
138	2	u16	week	toc.wn	GPS week number
140	1	u8		iode	Issue of ephemeris data
141	2	u16		iodc	Issue of clock data
	143				Total Payload Length

Table 6.6.14: MSG_EPHEMERIS_BDS 0x0089 message structure



Field 6.6.5: 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

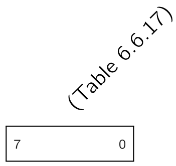
Table 6.6.15: values (`common.sid.code[0:7]`)

MSG_EPHEMERIS_GAL — 0x0095 — 149

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 identifier. This field for Glonass 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
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	4	float	s	`bgd_e1e5a`	E1-E5a Broadcast Group Delay
26	4	float	s	`bgd_e1e5b`	E1-E5b Broadcast Group Delay
30	4	float	m	`c_rs`	Amplitude of the sine harmonic correction term to the orbit radius
34	4	float	m	`c_rc`	Amplitude of the cosine harmonic correction term to the orbit radius
38	4	float	rad	`c_uc`	Amplitude of the cosine harmonic correction term to the argument of latitude
42	4	float	rad	`c_us`	Amplitude of the sine harmonic correction term to the argument of latitude
46	4	float	rad	`c_ic`	Amplitude of the cosine harmonic correction term to the angle of inclination
50	4	float	rad	`c_is`	Amplitude of the sine harmonic correction term to the angle of inclination
54	4	float	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	4	float	rad/s	`inc_dot`	Inclination first derivative
118	8	double	s	`af0`	Polynomial clock correction coefficient (clock bias)
126	4	float	s/s	`af1`	Polynomial clock correction coefficient (clock drift)
130	4	float	s/s^2	`af2`	Polynomial clock correction coefficient (rate of clock drift)
134	4	u32	s	`toc.tow`	Seconds since start of GPS week
138	2	u16	week	`toc.wn`	GPS week number
140	2	u16		`iode`	Issue of ephemeris data
142	2	u16		`iodc`	Issue of clock data
	144				Total Payload Length

Table 6.6.16: MSG_EPHEMERIS_GAL 0x0095 message structure



Field 6.6.6: Signal constellation, band and code (`common.sid.code`)

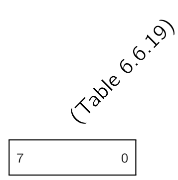
Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P

Table 6.6.17: values (`common.sid.code[0:7]`)

MSG_EPHEMERIS_SBAS_DEP_A — 0x0082 — 130

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

Table 6.6.18: MSG_EPHEMERIS_SBAS_DEP_A 0x0082 message structure



Field 6.6.7: 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

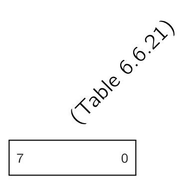
Table 6.6.19: values (`common.sid.code[0:7]`)

MSG_EPHEMERIS_GLO_DEP_A — 0x0083 — 131

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

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

Table 6.6.20: MSG_EPHEMERIS_GLO_DEP_A 0x0083 message structure



Field 6.6.8: Signal constellation, band and code (`common.sid.code`)

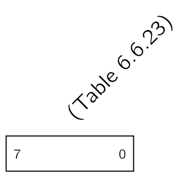
Value	Description
0	GPS L1CA
1	GPS L2CM
2	SBAS L1CA
3	GLO L1CA
4	GLO L2CA
5	GPS L1P
6	GPS L2P

Table 6.6.21: values (`common.sid.code[0:7]`)

MSG_EPHEMERIS_SBAS — 0x0084 — 132

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		common.sid.sat	Constellation-specific satellite identifier. This field for Glonass 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
2	4	u32	s	common.toe.tow	Seconds since start of GPS week
6	2	u16	week	common.toe.wn	GPS week number
8	8	double	m	common.ura	User Range Accuracy
16	4	u32	s	common.fit_interval	Curve fit interval
20	1	u8		common.valid	Status of ephemeris, 1 = valid, 0 = invalid
21	1	u8		common.health_bits	Satellite health status. GPS: ICD-GPS-200, chapter 20.3.3.3.1.4 Others: 0 = valid, non-zero = invalid
22	24	double[3]	m	pos	Position of the GEO at time toe
46	24	double[3]	m/s	vel	Velocity of the GEO at time toe
70	24	double[3]	m/s^2	acc	Acceleration of the GEO at time toe
94	8	double	s	a_gf0	Time offset of the GEO clock w.r.t. SBAS Network Time
102	8	double	s/s	a_gf1	Drift of the GEO clock w.r.t. SBAS Network Time
	110				Total Payload Length

Table 6.6.22: MSG_EPHEMERIS_SBAS 0x0084 message structure



Field 6.6.9: 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

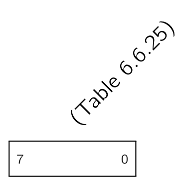
Table 6.6.23: values (common.sid.code[0:7])

MSG_EPHEMERIS_GLO_DEP_B — 0x0085 — 133

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

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

Table 6.6.24: MSG_EPHEMERIS_GLO_DEP_B 0x0085 message structure



Field 6.6.10: 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

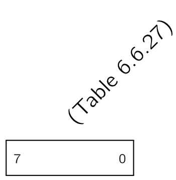
Table 6.6.25: values (`common.sid.code[0:7]`)

MSG_EPHEMERIS_GLO_DEP_C — 0x0087 — 135

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

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

Table 6.6.26: MSG_EPHEMERIS_GLO_DEP_C 0x0087 message structure



Field 6.6.11: 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

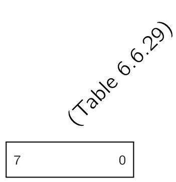
Table 6.6.27: values (common.sid.code[0:7])

MSG_EPHEMERIS_GLO — 0x0088 — 136

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

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

Table 6.6.28: MSG_EPHEMERIS_GLO 0x0088 message structure



Field 6.6.12: 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 6.6.29: values (`common.sid.code[0:7]`)

MSG_IONO — 0x0090 — 144

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

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	s	t_nmct.tow	Seconds since start of GPS week
4	2	u16	week	t_nmct.wn	GPS week number
6	8	double	s	a0	
14	8	double	s/semi-circle	a1	
22	8	double	s/(semi-circle)^2	a2	
30	8	double	s/(semi-circle)^3	a3	
38	8	double	s	b0	
46	8	double	s/semi-circle	b1	
54	8	double	s/(semi-circle)^2	b2	
62	8	double	s/(semi-circle)^3	b3	
	70				Total Payload Length

Table 6.6.30: MSG_IONO 0x0090 message structure

MSG_SV_CONFIGURATION_GPS — 0x0091 — 145

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

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

Table 6.6.31: MSG_SV_CONFIGURATION_GPS 0x0091 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

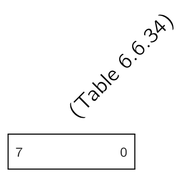
Table 6.6.32: MSG_GROUP_DELAY_DEP_A 0x0092 message structure

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 6.6.33: MSG_GROUP_DELAY_DEP_B 0x0093 message structure



Field 6.6.13: 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

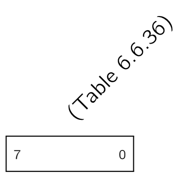
Table 6.6.34: values (`sid.code[0:7]`)

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 identifier. This field for Glonass 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		`valid`	bit-field indicating validity of the values, LSB indicating tgd validity etc. 1 = value is valid, 0 = value is not valid.
9	2	s16	s * 2^-35	`tgd`	
11	2	s16	s * 2^-35	`isc_l1ca`	
13	2	s16	s * 2^-35	`isc_l2c`	
	15				Total Payload Length

Table 6.6.35: MSG_GROUP_DELAY 0x0094 message structure



Field 6.6.14: 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

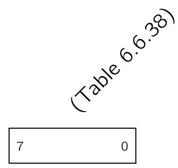
Table 6.6.36: values (`sid.code[0:7]`)

MSG_ALMANAC_GPS — 0x0072 — 114

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

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

Table 6.6.37: MSG_ALMANAC_GPS 0x0072 message structure



Field 6.6.15: 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

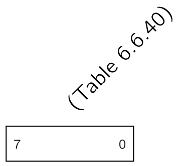
Table 6.6.38: values (`common.sid.code[0:7]`)

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 identifier. This field for Glonass 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
2	4	u32	s	common.toa.tow	Seconds since start of GPS week
6	2	u16	week	common.toa.wn	GPS week number
8	8	double	m	common.ura	User Range Accuracy
16	4	u32	s	common.fit_interval	Curve fit interval
20	1	u8		common.valid	Status of almanac, 1 = valid, 0 = invalid
21	1	u8		common.health_bits	Satellite health status for GPS: - bits 5-7: NAV data health status. See IS-GPS-200H Table 20-VII: NAV Data Health Indications. - bits 0-4: Signal health status. See IS-GPS-200H Table 20-VIII. Codes for Health of SV Signal Components. Satellite health status for GLO: See GLO ICD 5.1 table 5.1 for details - bit 0: C(n), "unhealthy" flag that is transmitted within non-immediate data and indicates overall constellation status at the moment of almanac uploading. '0' indicates malfunction of n-satellite. '1' indicates that n-satellite is operational. - bit 1: Bn(ln), '0' indicates the satellite is operational and suitable for navigation.
22	8	double	rad	lambda_na	Longitude of the first ascending node of the orbit in PZ-90.02 coordinate system
30	8	double	s	t_lambda_na	Time of the first ascending node passage
38	8	double	rad	i	Value of inclination at instant of t_lambda
46	8	double	s/orbital period	t	Value of Draconian period at instant of t_lambda
54	8	double	s/(orbital period^2)	t_dot	Rate of change of the Draconian period
62	8	double		epsilon	Eccentricity at instant of t_lambda
70	8	double	rad	omega	Argument of perigee at instant of t_lambda
	78				Total Payload Length

Table 6.6.39: MSG_ALMANAC_GLO 0x0073 message structure



Field 6.6.16: 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 6.6.40: values (`common.sid.code[0:7]`)

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 6.6.41: MSG_GLO_BIASES 0x0075 message structure

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 6.7.1: 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

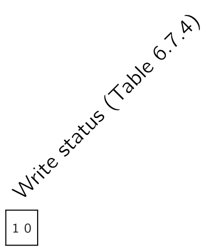
Table 6.7.2: MSG_SETTINGS_WRITE 0x00A0 message structure

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 6.7.3: MSG_SETTINGS_WRITE_RESP 0x00AF message structure



Field 6.7.1: Write status (`status`)

Value	Description
0	Accepted; value updated
1	Value rejected; unparsable or out-of-range
2	Setting rejected; the requested setting does not exist

Table 6.7.4: 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 6.7.5: MSG_SETTINGS_READ_REQ 0x00A4 message structure

MSG_SETTINGS_READ_RESP — 0x00A5 — 165

The setting message wich 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\0SET
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 6.7.6: 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		`index`	An index into the device settings, with values ranging from 0 to length(settings)
	2				Total Payload Length

Table 6.7.7: 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\0SETT 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_TY
	$N+2$				Total Payload Length

Table 6.7.8: 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 6.7.9: MSG_SETTINGS_READ_BY_INDEX_DONE 0x00A6 message structure

System

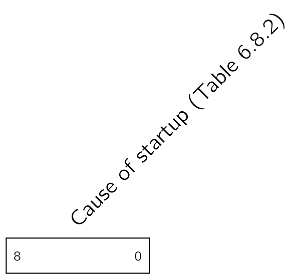
Standardized system messages from Swift Navigation devices.

MSG_STARTUP — 0xFF00 — 65280

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

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

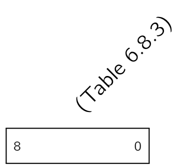
Table 6.8.1: MSG_STARTUP 0xFF00 message structure



Field 6.8.1: Cause of startup (`cause`)

Value	Description
0	Power on
1	Software reset
2	Watchdog reset

Table 6.8.2: Cause of startup values (`cause[0:8]`)



Field 6.8.2: Startup type (`startup_type`)

Value	Description
0	Cold start
1	Warm start
2	Hot start

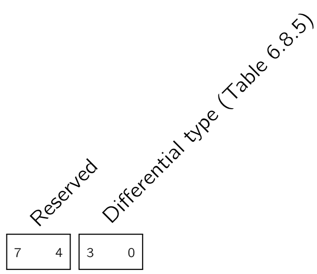
Table 6.8.3: values (`startup_type[0:8]`)

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 6.8.4: MSG_DGNSS_STATUS 0xFF02 message structure



Field 6.8.3: Status flags (`flags`)

Value	Description
0	Invalid
1	Code Difference
2	RTK

Table 6.8.5: Differential type values (`flags[0:3]`)

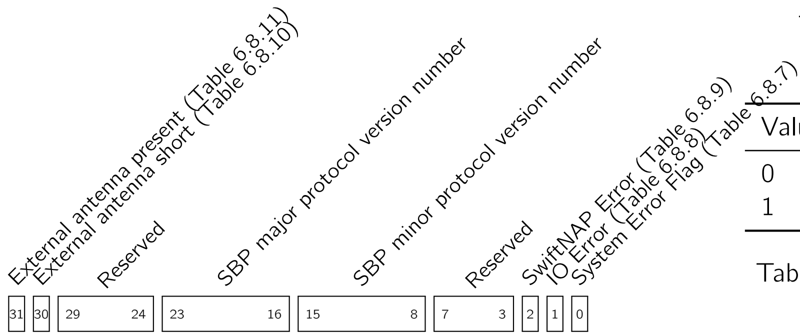
MSG_HEARTBEAT — 0xFFFF — 65535

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 6.8.6: MSG_HEARTBEAT 0xFFFF message structure



Field 6.8.4: Status flags (`flags`)

Value	Description
0	System Healthy
1	An error has occurred

Table 6.8.7: System Error Flag values (`flags[0]`)

Value	Description
0	System Healthy
1	An IO error has occurred

Table 6.8.8: IO Error values (`flags[1]`)

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

Table 6.8.9: SwiftNAP Error values (`flags[2]`)

Value	Description
0	No short detected
1	Short detected

Table 6.8.10: External antenna short values (`flags[30]`)

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

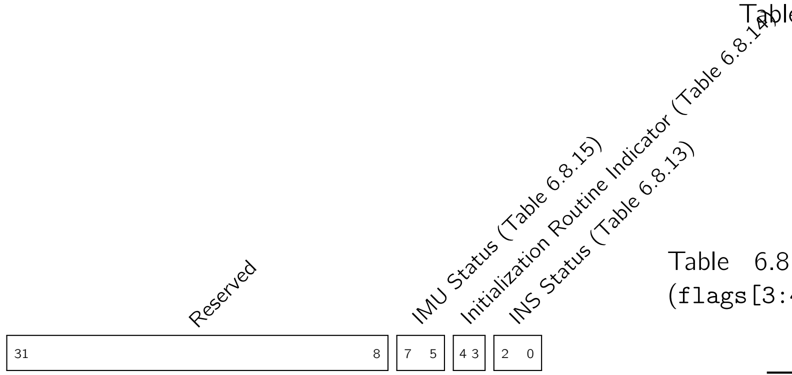
Table 6.8.11: External antenna present values (`flags[31]`)

MSG_INS_STATUS — 0xFF03 — 65283

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

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

Table 6.8.12: MSG_INS_STATUS 0xFF03 message structure



Field 6.8.5: Status flags (`flags`)

Value	Description
0	INS ready
1	INS initializing
2	INS error

Table 6.8.13: INS Status values (`flags[0:2]`)

Value	Description
0	None
1	Initial startup

Table 6.8.14: Initialization Routine Indicator values (`flags[3:4]`)

Value	Description
0	IMU Ready
1	No raw IMU data
2	No raw IMU timestamp
3	Unrecommended raw IMU rate

Table 6.8.15: IMU Status values (`flags[5:7]`)

Draft Message Definitions

Acquisition

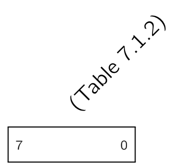
Satellite acquisition messages from the device.

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 identifier. This field for Glonass 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 7.1.1: MSG_ACQ_RESULT 0x002F message structure



Field 7.1.1: Signal constellation, band and code (`sid.code`)

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

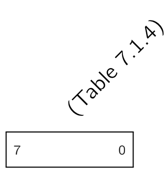
Table 7.1.2: values (`sid.code[0:7]`)

MSG ACQ SV PROFILE — 0x002E — 46

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

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
$33N+0$	1	u8		`acq_sv_profile[N].job_type`	SV search job type (deep, fallback, etc)
$33N+1$	1	u8		`acq_sv_profile[N].status`	Acquisition status 1 is Success, 0 is Failure
$33N+2$	2	u16	dB-Hz*10	`acq_sv_profile[N].cn0`	CN0 value. Only valid if status is '1'
$33N+4$	1	u8	ms	`acq_sv_profile[N].int_time`	Acquisition integration time
$33N+5$	1	u8		`acq_sv_profile[N].sid.sat`	Constellation-specific satellite identifier. This field for Glonass 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 7.1.3: MSG_ACQ_SV_PROFILE 0x002E message structure



Field 7.1.2: 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

Table 7.1.4: values (`acq_sv_profile[N].sid.code[0:7]`)

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 succesfully read.The sequence number in the request will be returned in the response. If the message is invalid, a followup MSG_PRINT message will print "Invalid fileio read message". A device will only respond to this message when it is received from sender ID 0x42.

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

Table 7.2.1: 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 succesfully read. The sequence number in the response is preserved from the request.

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

Table 7.2.2: MSG_FILEIO_READ_RESP 0x00A3 message structure

MSG FILEIO READ DIR REQ — 0x00A9 — 169

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

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

Table 7.2.3: MSG_FILEIO_READ_DIR_REQ 0x00A9 message structure

MSG FILEIO READ DIR RESP — 0x00AA — 170

The read directory message lists the files in a directory on the device's onboard flash file system. Message contains the directory listings as a NULL delimited list. The listing is chunked over multiple SBP packets and the end of the list is identified by an entry containing just the character 0xFF. The sequence number in the response is preserved from the request.

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

Table 7.2.4: 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 7.2.5: MSG_FILEIO_REMOVE 0x00AC message structure

MSG FILEIO WRITE REQ — 0x00AD — 173

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

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

Table 7.2.6: MSG_FILEIO_WRITE_REQ 0x00AD message structure

MSG FILEIO WRITE RESP — 0x00AB — 171

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

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

Table 7.2.7: MSG_FILEIO_WRITE_RESP 0x00AB message structure

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 7.3.1: MSG_BASELINE_HEADING 0x020F message structure

Field 7.3.1: Status flags (`flags`)

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

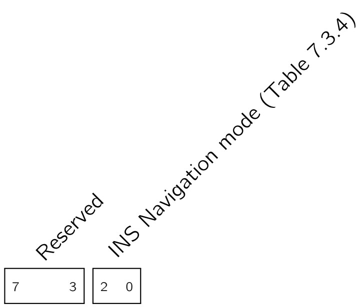
Table 7.3.2: Fix mode values (`flags[0:2]`)

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.

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 7.3.3: MSG_ORIENT_QUAT 0x0220 message structure



Field 7.3.2: Status flags (`flags`)

Value	Description
0	Invalid
1	Valid

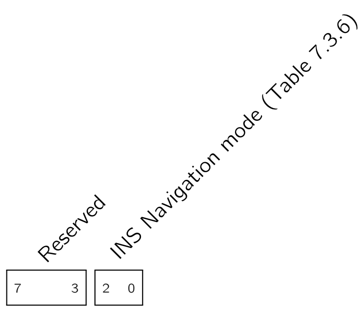
Table 7.3.4: INS Navigation mode values (`flags[0:2]`)

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.

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 7.3.5: MSG_ORIENT_EULER 0x0221 message structure



Field 7.3.3: Status flags (`flags`)

Value	Description
0	Invalid
1	Valid

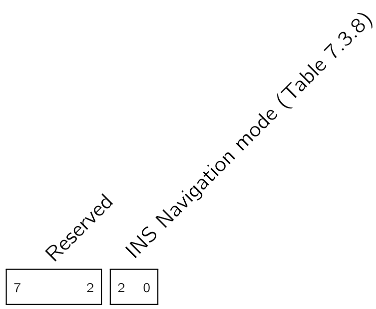
Table 7.3.6: INS Navigation mode values (`flags[0:2]`)

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.

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

Table 7.3.7: MSG_ANGULAR_RATE 0x0222 message structure



Field 7.3.4: Status flags (`flags`)

Value	Description
0	Invalid
1	Valid

Table 7.3.8: INS Navigation mode values (`flags[0:2]`)

Piksi

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

MSG ALMANAC — 0x0069 — 105

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

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

Table 7.4.1: 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

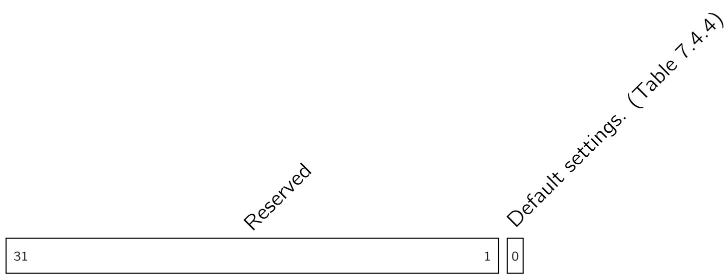
Table 7.4.2: MSG_SET_TIME 0x0068 message structure

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 7.4.3: MSG_RESET 0x00B6 message structure



Field 7.4.1: Reset flags (`flags`)

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

Table 7.4.4: 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 7.4.5: 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 7.4.6: 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

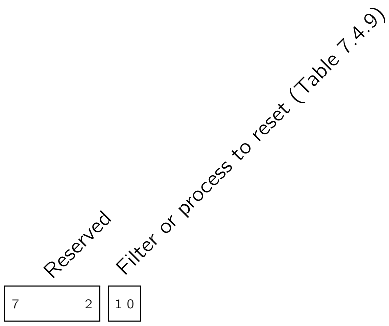
Table 7.4.7: MSG_CW_START 0x00C1 message structure

MSG RESET FILTERS — 0x0022 — 34

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

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

Table 7.4.8: MSG_RESET_FILTERS 0x0022 message structure



Field 7.4.2: Filter flags (`filter`)

Value	Description
0	DGNSS filter
1	IAR process
2	Inertial filter

Table 7.4.9: Filter or process to reset values (`filter[0:1]`)

MSG INIT BASE — 0x0023 — 35

This message initializes the integer ambiguity resolution (IAR) process on the Piksi to use an assumed baseline position between the base station and rover receivers. Warns via MSG_PRINT if there aren't a shared minimum number (4) of satellite observations between the two.

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

Table 7.4.10: MSG_INIT_BASE 0x0023 message structure

MSG THREAD STATE — 0x0017 — 23

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

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

Table 7.4.11: 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 7.4.12: 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 7.4.13: 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

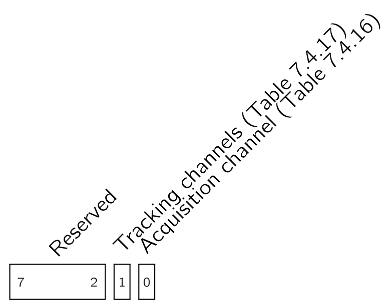
Table 7.4.14: MSG_IAR_STATE 0x0019 message structure

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 identifier. This field for Glonass 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 7.4.15: MSG_MASK_SATELLITE 0x002B message structure



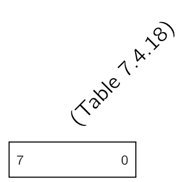
Field 7.4.3: Mask of systems that should ignore this satellite. (`mask`)

Value	Description
0	Enabled
1	Skip this satellite on future acquisitions

Table 7.4.16: Acquisition channel values (`mask[0]`)

Value	Description
0	Enabled
1	Drop this PRN if currently tracking

Table 7.4.17: Tracking channels values (`mask[1]`)



Field 7.4.4: Signal constellation, band and code (`sid.code`)

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

Table 7.4.18: values (`sid.code[0:7]`)

MSG DEVICE MONITOR — 0x00B5 — 181

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

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

Table 7.4.19: 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 7.4.20: 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 7.4.21: 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 7.4.22: 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 7.4.23: 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 7.4.24: MSG_NETWORK_STATE_RESP 0x00BB message structure

MSG NETWORK BANDWIDTH USAGE — 0x00BD — 189

The bandwidth usage, a list of usage by interface.

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

Table 7.4.25: 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 7.4.26: 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 7.4.27: MSG_SPECAN 0x0051 message structure

Sbas

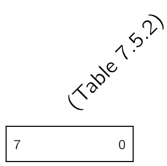
SBAS data

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 identifier. This field for Glonass 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 7.5.1: MSG_SBAS_RAW 0x7777 message structure



Field 7.5.1: 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

Table 7.5.2: values (`sid.code[0:7]`)

Ssr

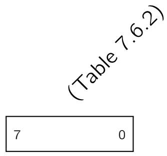
Precise State Space Representation (SSR) corrections format

MSG SSR ORBIT CLOCK — 0x05DC — 1500

The precise orbit and clock correction message is to be applied as a delta correction to broadcast ephemeris and is typically an equivalent to the 1060 and 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 identifier. This field for Glonass 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	s	`update_interval`	Update interval between consecutive corrections
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		`iod`	Issue of broadcast ephemeris data
11	4	s32	0.1 mm	`radial`	Orbit radial delta correction
15	4	s32	0.4 mm	`along`	Orbit along delta correction
19	4	s32	0.4 mm	`cross`	Orbit along delta correction
23	4	s32	0.001 mm/s	`dot_radial`	Velocity of orbit radial delta correction
27	4	s32	0.004 mm/s	`dot_along`	Velocity of orbit along delta correction
31	4	s32	0.004 mm/s	`dot_cross`	Velocity of orbit cross delta correction
35	4	s32	0.1 mm	`c0`	C0 polynomial coefficient for correction of broadcast satellite clock
39	4	s32	0.001 mm/s	`c1`	C1 polynomial coefficient for correction of broadcast satellite clock
43	4	s32	0.00002 mm/s^-2	`c2`	C2 polynomial coefficient for correction of broadcast satellite clock
	47				Total Payload Length

Table 7.6.1: MSG_SSR_ORBIT_CLOCK 0x05DC message structure



Field 7.6.1: Signal constellation, band and code (`sid.code`)

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

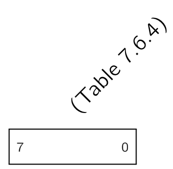
Table 7.6.2: values (`sid.code[0:7]`)

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 typically an equivalent to the 1059 and 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 identifier. This field for Glonass 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	s	`update_interval`	Update interval between consecutive corrections
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 constellation, band and code
$3N+11$	2	s16	0.01 m	`biases[N].value`	Code bias value
	$3N+10$				Total Payload Length

Table 7.6.3: MSG_SSR_CODE_BIASES 0x05E1 message structure



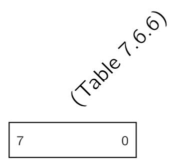
Field 7.6.2: Signal constellation, band and code (`sid.code`)

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

Table 7.6.4: values (`sid.code[0:7]`)

MSG SSR PHASE BIASES — 0x05E6 — 1510

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



Field 7.6.3: 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

Table 7.6.6: values (`sid.code[0:7]`)

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 identifier. This field for Glonass 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	s	`update_interval`	Update interval between consecutive corrections
9	1	u8		`iod_ssr`	IOD of the SSR correction. A change of Issue Of Data SSR is used to indicate a change in the SSR generating configuration
10	1	u8		`dispersive_bias`	Indicator for the dispersive phase biases property.
11	1	u8		`mw_consistency`	Consistency indicator for Melbourne-Wubbena linear combinations
12	2	u16	1 / 256 semi-circle	`yaw`	Satellite yaw angle
14	1	s8	1 / 8192 semi-circle / s	`yaw_rate`	Satellite yaw angle rate
$8N+15$	1	u8		`biases[N].code`	Signal constellation, band and code
$8N+16$	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 7.6.5: MSG_SSR_PHASE_BIASES 0x05E6 message structure

Tracking

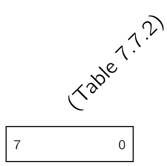
Satellite code and carrier-phase tracking messages from the device.

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 identifier. This field for Glonass 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 7.7.1: MSG_TRACKING_STATE 0x0041 message structure



Field 7.7.1: 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

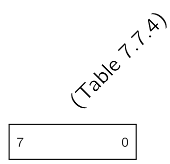
Table 7.7.2: values (`sid.code[0:7]`)

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 identifier. This field for Glonass 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 7.7.3: MSG_MEASUREMENT_STATE 0x0061 message structure



Field 7.7.2: Signal constellation, band and code (`mesid.code`)

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

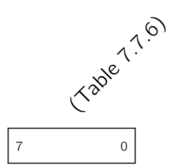
Table 7.7.4: values (`mesid.code[0:7]`)

MSG TRACKING IQ — 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 identifier. This field for Glonass 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 7.7.5: MSG_TRACKING_IQ 0x002C message structure



Field 7.7.3: 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

Table 7.7.6: values (`sid.code[0:7]`)

User

Messages reserved for use by the user.

MSG USER DATA — 0x0800 — 2048

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

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

Table 7.8.1: MSG_USER_DATA 0x0800 message structure

Vehicle

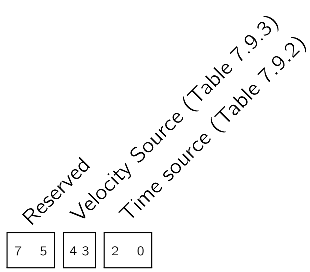
Messages from a vehicle.

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.

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

Table 7.9.1: MSG_ODOMETRY 0x0903 message structure



Field 7.9.1: Status flags (`flags`)

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

Table 7.9.2: Time source values (`flags[0:2]`)

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

Table 7.9.3: Velocity Source values (`flags[3:4]`)