



# Swift Navigation Binary Protocol

## Protocol Specification 2.3.0

### Contents

|          |  |           |
|----------|--|-----------|
| <b>1</b> | <b>Overview</b>                            | <b>1</b>  |
| <b>2</b> | <b>Message Framing Structure</b>           | <b>2</b>  |
| <b>3</b> | <b>NMEA-0183</b>                           | <b>2</b>  |
| <b>4</b> | <b>Basic Formats and Payload Structure</b> | <b>3</b>  |
| <b>5</b> | <b>Message Types</b>                       | <b>4</b>  |
| <b>6</b> | <b>Stable Message Definitions</b>          | <b>7</b>  |
| 6.1      | Logging . . . . .                          | 7         |
| 6.2      | Navigation . . . . .                       | 9         |
| 6.3      | Observation . . . . .                      | 24        |
| 6.4      | Settings . . . . .                         | 50        |
| 6.5      | System . . . . .                           | 57        |
| <b>7</b> | <b>Draft Message Definitions</b>           | <b>60</b> |
| 7.1      | Acquisition . . . . .                      | 60        |
| 7.2      | Ext Events . . . . .                       | 62        |
| 7.3      | File IO . . . . .                          | 63        |
| 7.4      | Imu . . . . .                              | 70        |
| 7.5      | Mag . . . . .                              | 72        |
| 7.6      | Orientation . . . . .                      | 73        |
| 7.7      | Piksi . . . . .                            | 77        |
| 7.8      | Tracking . . . . .                         | 97        |
| 7.9      | User . . . . .                             | 99        |
| 7.10     | Vehicle . . . . .                          | 100       |

## 1 Overview

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

This document provides a specification of SBP framing and the payload structures of the messages currently used with Swift devices. SBP client libraries in a variety of programming languages are available at [http://docs.swiftnav.com/wiki/SwiftNav\\_Binary\\_Protocol](http://docs.swiftnav.com/wiki/SwiftNav_Binary_Protocol).

## 2 Message Framing Structure

SBP consists of two pieces:

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

As of Version 2.3.0, the frame consists of a 6-byte binary header section, a variable-sized payload field, and a 16-bit CRC value. All multibyte values are ordered in **little-endian** format. SBP uses the CCITT CRC16 (XMODEM implementation) for error detection<sup>1</sup>.

| Offset (bytes) | Size (bytes) | Name               | Description  |
|----------------|--------------|--------------------|--|
| 0              | 1            | Preamble           | Denotes the start of frame transmission. Always 0x55.  |
| 1              | 2            | Message Type       | Identifies the payload contents.   |
| 3              | 2            | Sender             | A unique identifier of the sender. 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              | <i>N</i>     | Payload            | Binary message contents.   |
| <i>N</i> + 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).   |
| <i>N</i> + 8   |              | Total Frame Length |  |

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

## 3 NMEA-0183

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

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

<sup>1</sup>CCITT 16-bit CRC Implementation uses parameters used by XMODEM, i.e. the polynomial:  $x^{16} + x^{12} + x^5 + 1$ . For more details, please see the implementation at <https://github.com/swift-nav/libsbp/blob/master/c/src/edc.c#L59>. See also *A Painless Guide to CRC Error Detection Algorithms* at [http://www.ross.net/crc/download/crc\\_v3.txt](http://www.ross.net/crc/download/crc_v3.txt)

## 4 Basic Formats and Payload Structure

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

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

Table 4.0.2: 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. 12), 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<br>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 4.0.3: SBP breakdown for MSG\_BASELINE\_ECEF

## 5 Message Types

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

| Package       | Msg ID | Name                           | Size (bytes) | Description   |
|---------------|--------|--------------------------------|--------------|---|
| <b>Stable</b> |        |                                |              |   |
| 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 |
| 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                     |
|               | 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                       |
|               | 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                              |

|              |        |                                 |                |   |
|--------------|--------|---------------------------------|----------------|---|
| System       | 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                                     |
|              | 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                                      |
| <b>Draft</b> |        |                                 |                |   |
| Acquisition  | 0x002F | MSG_ACQ_RESULT                  | 14             | Satellite acquisition result                                  |
|              | 0x002E | MSG_ACQ_SV_PROFILE              | 33 <i>N</i>    | Acquisition performance measurement and debug                 |
| Ext Events   | 0x0101 | MSG_EXT_EVENT                   | 12             | Reports timestamped external pin event                        |
| 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   |
|              | 0x0900 | MSG_IMU_RAW                     | 17             | Raw IMU data  |
| Imu          | 0x0901 | MSG_IMU_AUX                     | 4              | Auxiliary IMU data  |
| Mag          | 0x0902 | MSG_MAG_RAW                     | 11             | Raw magnetometer data   |
| Orientation  | 0x020F | MSG_BASELINE_HEADING            | 10             | Heading relative to True North                                |
|              | 0x0220 | MSG_ORIENT_QUAT                 | 37             | Quaternion 4 component vector                                 |
|              | 0x0221 | MSG_ORIENT_EULER                | 23             | Euler angles  |
|              | 0x0222 | MSG_ANGULAR_RATE                | 11             | 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 = $j$ 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 = $j$ 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                                    |
|              | 0x0051 | MSG_SPECAN                      | $N + 28$       | Spectrum analyzer   |
| Tracking     | 0x0041 | MSG_TRACKING_STATE              | 4 <i>N</i>     | Signal tracking channel states                                |
|              | 0x002C | MSG_TRACKING_IQ                 | 8 <i>N</i> + 3 | Tracking channel correlations                                 |
| User         | 0x0800 | MSG_USER_DATA                   | $N$            | User data   |
| Vehicle      | 0x0903 | MSG_ODOMETRY                    | 9              | Vehicle forward (x-axis) velocity                             |

Table 5.0.5: SBP message types

## 6 Stable Message Definitions

### 6.1 Logging

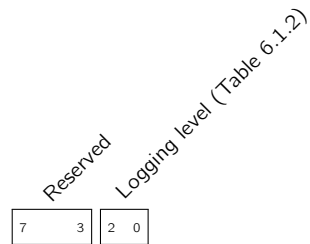
Logging and debugging messages from the device.

#### 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 6.1.1: MSG.LOG 0x0401 message structure



Field 6.1.1: Logging level (level)

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

Table 6.1.2: 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              | <i>N</i>     | string |       | fwd_payload | variable length wrapped binary message |
|                | <i>N + 2</i> |        |       |             | Total Payload Length                   |

Table 6.1.3: MSG\_FWD 0x0402 message structure



## 6.2 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.

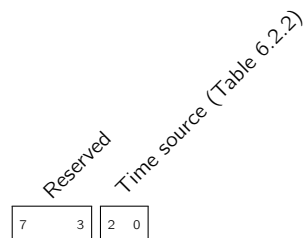
### MSG\_GPS.TIME — 0x0102 — 258

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 6.2.1: MSG\_GPS.TIME 0x0102 message structure



Field 6.2.1: Status flags (reserved) (flags)

| Value | Description    |
|-------|----------------|
| 0     | None (invalid) |
| 1     | GNSS Solution  |

Table 6.2.2: 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                                |

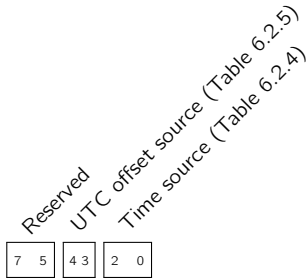
Table 6.2.3: MSG.UTC.TIME 0x0103 message structure

| Value | Description    |
|-------|----------------|
| 0     | None (invalid) |
| 1     | GNSS Solution  |

Table 6.2.4: Time source values (flags[0:2])

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

Table 6.2.5: UTC offset source values (flags[3:4])



Field 6.2.2: Indicates source and time validity (flags)

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 6.2.6: MSG\_DOPS 0x0208 message structure

7

6

3

2

0

RAM repair flag

Reserved

Fix mode (Table 6.2.7)

Field 6.2.3: 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                   |

Table 6.2.7: 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).

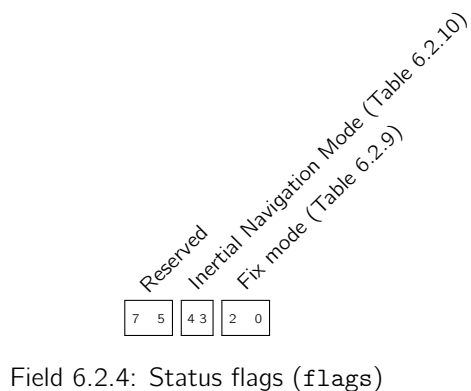
| Offset (bytes) | Size (bytes) | Format | Units | Name                  | Description                           |
|----------------|--------------|--------|-------|-----------------------|---------------------------------------|
| 0              | 4            | u32    | ms    | <code>tow</code>   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

Table 6.2.8: MSG\_POS\_ECEF 0x0209 message structure

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

Table 6.2.9: Fix mode values (`flags[0:2]`)

| Value | Description |
|-------|-------------|
| 0     | None        |
| 1     | INS used    |

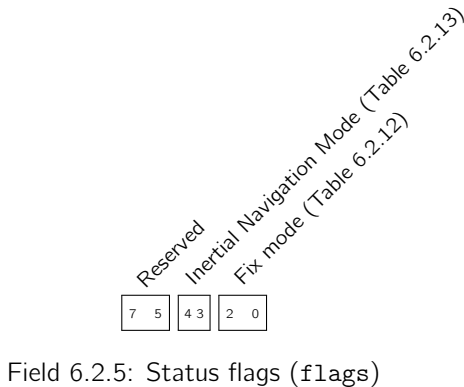
Table 6.2.10: Inertial Navigation Mode values (`flags[3:4]`)

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 6.2.11: MSG\_POS\_ECEF\_COV 0x0214 message structure



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

Table 6.2.12: Fix mode values (flags[0:2])

| Value | Description |
|-------|-------------|
| 0     | None        |
| 1     | INS used    |

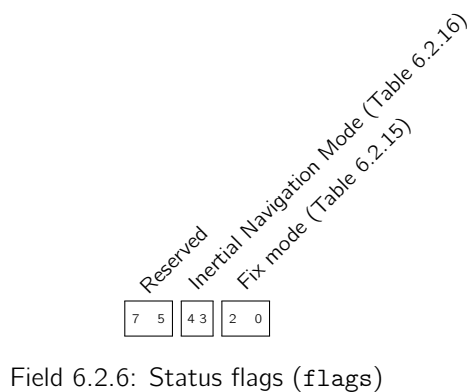
Table 6.2.13: Inertial Navigation Mode values (flags[3:4])

**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 6.2.14: MSG\_POS\_LLH 0x020A message structure



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

Table 6.2.15: Fix mode values (flags[0:2])

| Value | Description |
|-------|-------------|
| 0     | None        |
| 1     | INS used    |

Table 6.2.16: 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 <sup>2</sup> | cov_n_n | Estimated variance of northing                  |
| 32             | 4            | float  | m <sup>2</sup> | cov_n_e | Covariance of northing and easting              |
| 36             | 4            | float  | m <sup>2</sup> | cov_n_d | Covariance of northing and downward measurement |
| 40             | 4            | float  | m <sup>2</sup> | cov_e_e | Estimated variance of easting                   |
| 44             | 4            | float  | m <sup>2</sup> | cov_e_d | Covariance of easting and downward measurement  |
| 48             | 4            | float  | m <sup>2</sup> | 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                            |

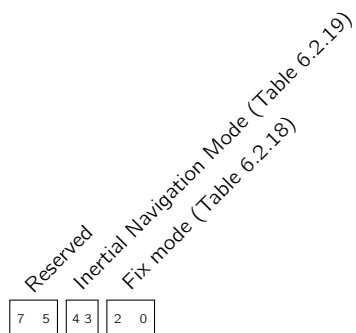
Table 6.2.17: MSG\_POS\_LLH\_COV 0x0211 message structure

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

Table 6.2.18: Fix mode values (flags[0:2])

| Value | Description |
|-------|-------------|
| 0     | None        |
| 1     | INS used    |

Table 6.2.19: Inertial Navigation Mode values (flags[3:4])



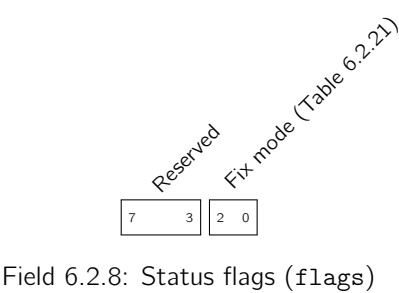
Field 6.2.7: Status flags (flags)

MSG\_BASELINE\_ECEF — 0x020B — 523

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

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

Table 6.2.20: MSG\_BASELINE\_ECEF 0x020B message structure



Field 6.2.8: Status flags (flags)

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

Table 6.2.21: Fix mode values (flags[0:2])

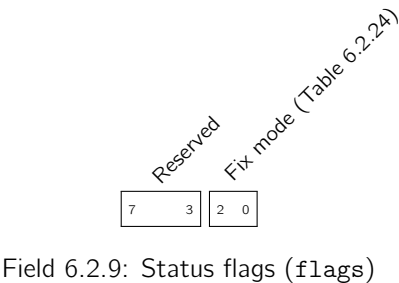


MSG\_BASELINE\_NED — 0x020C — 524

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 6.2.22: MSG\_BASELINE\_NED 0x020C message structure



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

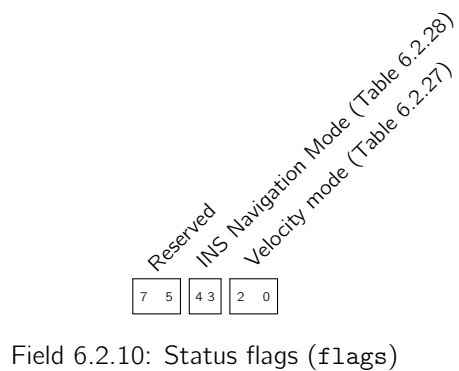
Table 6.2.23: Fix mode values (flags[0:2])

**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 6.2.24: MSG\_VEL\_ECEF 0x020D message structure



Field 6.2.10: Status flags (flags)

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

Table 6.2.25: Velocity mode values (flags[0:2])

| Value | Description |
|-------|-------------|
| 0     | None        |
| 1     | INS used    |

Table 6.2.26: INS Navigation Mode values (flags[3:4])

**MSG\_VEL\_ECEF\_COV — 0x0215 — 533**

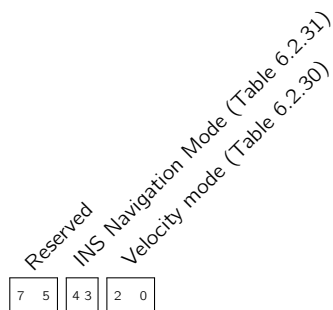
This message reports the velocity in Earth Centered Earth Fixed (ECEF) coordinates. The full GPS time is given by the preceding MSG\_GPS\_TIME with the matching time-of-week (tow).

| 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 <sup>2</sup> /s <sup>2</sup> | cov_x_x | Estimated variance of x               |
| 20             | 4            | float  | m <sup>2</sup> /s <sup>2</sup> | cov_x_y | Estimated covariance of x and y       |
| 24             | 4            | float  | m <sup>2</sup> /s <sup>2</sup> | cov_x_z | Estimated covariance of x and z       |
| 28             | 4            | float  | m <sup>2</sup> /s <sup>2</sup> | cov_y_y | Estimated variance of y               |
| 32             | 4            | float  | m <sup>2</sup> /s <sup>2</sup> | cov_y_z | Estimated covariance of y and z       |
| 36             | 4            | float  | m <sup>2</sup> /s <sup>2</sup> | cov_z_z | Estimated variance of z               |
| 40             | 1            | u8     |                                | n_sats  | Number of satellites used in solution |
| 41             | 1            | u8     |                                | flags   | Status flags                          |
| 42             |              |        |                                |         | Total Payload Length                  |

Table 6.2.27: MSG\_VEL\_ECEF\_COV 0x0215 message structure

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

Table 6.2.28: Velocity mode values (flags[0:2])



Field 6.2.11: Status flags (flags)

| Value | Description |
|-------|-------------|
| 0     | None        |
| 1     | INS used    |

Table 6.2.29: 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                             |

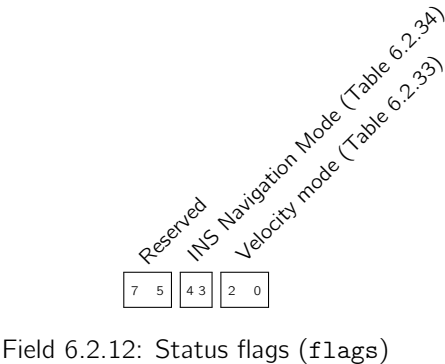
Table 6.2.30: MSG\_VEL\_NED 0x020E message structure

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

Table 6.2.31: Velocity mode values (flags[0:2])

| Value | Description |
|-------|-------------|
| 0     | None        |
| 1     | INS used    |

Table 6.2.32: INS Navigation Mode values (flags[3:4])

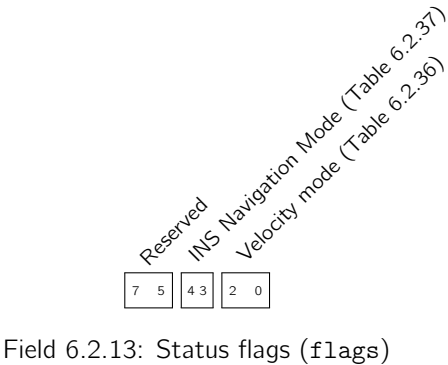


MSG\_VEL\_NED\_COV — 0x0212 — 530

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 6.2.33: MSG\_VEL\_NED\_COV 0x0212 message structure



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

Table 6.2.34: Velocity mode values (flags[0:2])

| Value | Description |
|-------|-------------|
| 0     | None        |
| 1     | INS used    |

Table 6.2.35: 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                  |

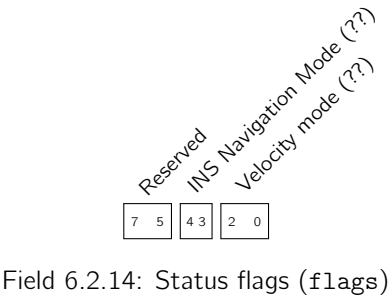
Table 6.2.36: MSG\_VEL\_BODY 0x0213 message structure

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

Table 6.2.37: Velocity mode values (flags[0:2])

| Value | Description |
|-------|-------------|
| 0     | None        |
| 1     | INS used    |

Table 6.2.38: 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 6.2.39: MSG\_AGE\_CORRECTIONS 0x0210 message structure

## 6.3 Observation

Satellite observation messages from the device.

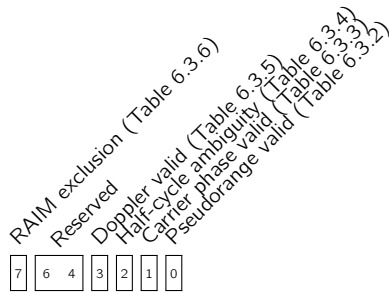
### MSG\_OBS — 0x004A — 74

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.

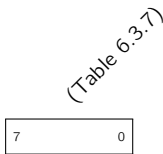
| Offset (bytes) | Size (bytes) | Format | Units        | Name                 | Description  |
|----------------|--------------|--------|--------------|----------------------|--|
| 0              | 4            | u32    | ms           | header.t.tow         | Milliseconds since start of GPS week   |
| 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  |
| 17N + 27       | 1            | u8     |              | obs[N].sid.code      | Signal constellation, band and code  |
| 17N + 11       |              |        |              |                      | Total Payload Length   |

Table 6.3.1: MSG\_OBS 0x004A message structure





Field 6.3.1: 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 6.3.2: Signal constellation, band and code (sid.code)

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

Table 6.3.2: Pseudorange valid values (flags[0])

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

Table 6.3.3: Carrier phase valid values (flags[1])

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

Table 6.3.4: Half-cycle ambiguity values (flags[2])

| Value | Description                 |
|-------|-----------------------------|
| 0     | Invalid doppler measurement |
| 1     | Valid doppler measurement   |

Table 6.3.5: Doppler valid values (flags[3])

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

Table 6.3.6: 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 6.3.7: 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 6.3.8: 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 coordinate    |
| 8              | 8            | double | m     | y    | ECEF Y coordinate    |
| 16             | 8            | double | m     | z    | ECEF Z coordinate    |
|                | 24           |        |       |      | Total Payload Length |

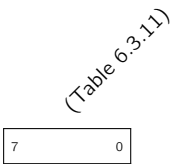
Table 6.3.9: MSG\_BASE\_POS\_ECEF 0x0048 message structure

**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.<br>Note: unlike GnssSignal, GPS satellites are encoded as (PRN - 1). Other constellations do not have this offset. |
| 2              | 1            | u8     |         | common.sid.cod | Signal constellation, band and code   |
| 3              | 1            | u8     |         | common.sid.res | 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.int | Curve fit interval  |
| 22             | 1            | u8     |         | common.valid   | Status of ephemeris, 1 = valid, 0 = invalid   |
| 23             | 1            | u8     |         | common.health  | 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_rsr          | Amplitude of the sine harmonic correction term to the orbit radius  |
| 40             | 8            | double | m       | c_rsc          | Amplitude of the cosine harmonic correction term to the orbit radius  |
| 48             | 8            | double | rad     | c_ucr          | Amplitude of the cosine harmonic correction term to the argument of latitude  |
| 56             | 8            | double | rad     | c_usr          | Amplitude of the sine harmonic correction term to the argument of latitude  |
| 64             | 8            | double | rad     | c_icr          | Amplitude of the cosine harmonic correction term to the angle of inclination  |
| 72             | 8            | double | rad     | c_isr          | 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 6.3.10: MSG\_EPHEMERIS\_GPS\_DEP\_E 0x0081 message structure



Field 6.3.3: 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 6.3.11: values (common.sid.code[0:7])

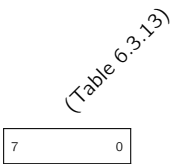
**MSG\_EPHEMERIS\_GPS — 0x0086 — 134**

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.sac | Constellation-specific satellite identifier  |
| 1              | 1            | u8     |         | common.sid.cob | 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.int | Curve fit interval   |
| 20             | 1            | u8     |         | common.valid   | Status of ephemeris, 1 = valid, 0 = invalid  |
| 21             | 1            | u8     |         | common.health  | 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 |
| 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 6.3.12: MSG\_EPHEMERIS\_GPS 0x0086 message structure





Field 6.3.4: 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 6.3.13: 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.<br>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.toe      | 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.int      | Curve fit interval  |
| 22             | 1            | u8        |       | common.valid        | Status of ephemeris, 1 = valid, 0 = invalid   |
| 23             | 1            | u8        |       | common.health       | 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 6.3.14: MSG\_EPHEMERIS\_SBAS\_DEP\_A 0x0082 message structure

(Table 6.3.15)

7

0

Field 6.3.5: 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 6.3.15: 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.<br>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.tb       | 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.int      | Curve fit interval  |
| 22             | 1            | u8        |       | common.valid        | Status of ephemeris, 1 = valid, 0 = invalid   |
| 23             | 1            | u8        |       | common.health       | 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 6.3.16: MSG\_EPHEMERIS\_GLO\_DEP\_A 0x0083 message structure

(Table 6.3.17)

7

0

Field 6.3.6: 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 6.3.17: 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  |
| 1              | 1            | u8        |       | common.sid.code      | Signal constellation, band and code  |
| 2              | 4            | u32       | s     | common.toe.toe       | 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.int       | Curve fit interval   |
| 20             | 1            | u8        |       | common.valid         | Status of ephemeris, 1 = valid, 0 = invalid  |
| 21             | 1            | u8        |       | common.health        | 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 |
| 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 6.3.18: MSG\_EPHEMERIS\_SBAS 0x0084 message structure

(Table 6.3.19)

7

0

Field 6.3.7: 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 6.3.19: 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  |
| 1              | 1            | u8        |       | common.sid.code | Signal constellation, band and code  |
| 2              | 4            | u32       | s     | common.toe.toe  | 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.int  | Curve fit interval   |
| 20             | 1            | u8        |       | common.valid    | Status of ephemeris, 1 = valid, 0 = invalid  |
| 21             | 1            | u8        |       | common.health   | 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 |
| 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 6.3.20: MSG\_EPHEMERIS\_GLO\_DEP\_B 0x0085 message structure

(Table 6.3.21)

7

0

Field 6.3.8: 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 6.3.21: 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  |
| 1              | 1            | u8        |       | common.sid.code | Signal constellation, band and code  |
| 2              | 4            | u32       | s     | common.toe.toe  | 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.int  | Curve fit interval   |
| 20             | 1            | u8        |       | common.valid    | Status of ephemeris, 1 = valid, 0 = invalid  |
| 21             | 1            | u8        |       | common.health   | 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 |
| 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 6.3.22: MSG\_EPHEMERIS\_GLO\_DEP\_C 0x0087 message structure

(Table 6.3.23)

7

0

Field 6.3.9: 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 6.3.23: 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  |
| 1              | 1            | u8        |       | common.sid.code | Signal constellation, band and code  |
| 2              | 4            | u32       | s     | common.toe.to   | 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.int  | Curve fit interval   |
| 20             | 1            | u8        |       | common.valid    | Status of ephemeris, 1 = valid, 0 = invalid  |
| 21             | 1            | u8        |       | common.health   | 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 |
| 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 6.3.24: MSG\_EPHEMERIS\_GLO 0x0088 message structure

(Table 6.3.25)

7

0

Field 6.3.10: 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 6.3.25: 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                            | <code>t_nmct.tow</code> | Seconds since start of GPS week |
| 4              | 2            | u16    | week                         | <code>t_nmct.wn</code>  | GPS week number                 |
| 6              | 8            | double | s                            | <code>a0</code>         |                                 |
| 14             | 8            | double | s/semi-circle                | <code>a1</code>         |                                 |
| 22             | 8            | double | s/(semi-circle) <sup>2</sup> | <code>a2</code>         |                                 |
| 30             | 8            | double | s/(semi-circle) <sup>3</sup> | <code>a3</code>         |                                 |
| 38             | 8            | double | s                            | <code>b0</code>         |                                 |
| 46             | 8            | double | s/semi-circle                | <code>b1</code>         |                                 |
| 54             | 8            | double | s/(semi-circle) <sup>2</sup> | <code>b2</code>         |                                 |
| 62             | 8            | double | s/(semi-circle) <sup>3</sup> | <code>b3</code>         |                                 |
| 70             |              |        |                              |                         | Total Payload Length            |

Table 6.3.26: 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     | <code>t_nmct.tow</code> | Seconds since start of GPS week                            |
| 4              | 2            | u16    | week  | <code>t_nmct.wn</code>  | GPS week number  |
| 6              | 4            | u32    |       | <code>l2c_mask</code>   | L2C capability mask, SV32 bit being MSB, SV1 bit being LSB |
|                | 10           |        |       |                         | Total Payload Length                                       |

Table 6.3.27: 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 <sub>op</sub> .tow | Milliseconds since start of GPS week  |
| 4              | 2            | u16    | week                 | t <sub>op</sub> .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 <sup>-35</sup> | tgd                  |   |
| 10             | 2            | s16    | s * 2 <sup>-35</sup> | isc <sub>11ca</sub>  |   |
| 12             | 2            | s16    | s * 2 <sup>-35</sup> | isc <sub>12c</sub>   |   |
| 14             |              |        |                      |                      | Total Payload Length  |

Table 6.3.28: 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.<br>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 6.3.29: MSG\_GROUP\_DELAY\_DEP\_B 0x0093 message structure

(Table 6.3.30)

7

0

Field 6.3.11: 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 6.3.30: 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   |
| 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 <sup>-35</sup> | tgd      |   |
| 11             | 2            | s16    | s * 2 <sup>-35</sup> | isc_l1ca |   |
| 13             | 2            | s16    | s * 2 <sup>-35</sup> | isc_l2c  |   |
| 15             |              |        |                      |          | Total Payload Length  |

Table 6.3.31: MSG\_GROUP\_DELAY 0x0094 message structure

(Table 6.3.32)

7

0

Field 6.3.12: 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     |

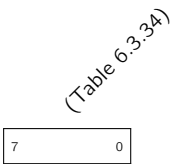
Table 6.3.32: values (sid.code[0:7])

**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.sac | Constellation-specific satellite identifier  |
| 1              | 1            | u8     |             | common.sid.cob | 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.int | Curve fit interval   |
| 20             | 1            | u8     |             | common.valid   | Status of almanac, 1 = valid, 0 = invalid  |
| 21             | 1            | u8     |             | common.health  | 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 6.3.33: MSG\_ALMANAC\_GPS 0x0072 message structure



Field 6.3.13: 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     |

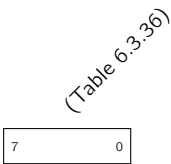
Table 6.3.34: values (`common.sid.code[0:7]`)

**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  |
| 1              | 1            | u8     |                                  | common.sid.band     | 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       | 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(In), '0' indicates the satellite is operational and suitable for navigation. |
| 22             | 8            | double | rad                              | lambda_na           | Longitude of the first ascending node of the orbit in PZ-90.02 coordinate system   |
| 30             | 8            | double | s                                | t_lambda_na         | Time of the first ascending node passage   |
| 38             | 8            | double | rad                              | i                   | Value of inclination at instant of t_lambda  |
| 46             | 8            | double | s/orbital period                 | t                   | Value of Draconian period at instant of t_lambda   |
| 54             | 8            | double | s/(orbital period <sup>2</sup> ) | t_dot               | Rate of change of the Draconian period   |
| 62             | 8            | double |                                  | epsilon             | Eccentricity at instant of t_lambda  |
| 70             | 8            | double | rad                              | omega               | Argument of perigee at instant of t_lambda   |
| 78             |              |        |                                  |                     | Total Payload Length   |

Table 6.3.35: MSG\_ALMANAC\_GLO 0x0073 message structure



Field 6.3.14: 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 6.3.36: 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<br>(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 6.3.37: MSG\_GLO\_BIASES 0x0075 message structure

## 6.4 Settings

Messages for reading and writing the device's device settings.

Note that some of these messages share the same message type ID for both the host request and the device response. See the accompanying document for descriptions of settings configurations and examples:

<https://github.com/swift-nav/piksi\ firmware/blob/master/docs/settings.pdf>

### **MSG\_SETTINGS\_SAVE — 0x00A1 — 161**

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

| Offset<br>(bytes) | Size (bytes) | Format | Units | Name | Description          |
|-------------------|--------------|--------|-------|------|----------------------|
|                   | 0            |        |       |      | Total Payload Length |

Table 6.4.1: MSG\_SETTINGS\_SAVE 0x00A1 message structure

**MSG\_SETTINGS\_WRITE — 0x00A0 — 160**

The setting message writes the device configuration.

| Offset (bytes) | Size (bytes) | Format | Units | Name                 | Description   |
|----------------|--------------|--------|-------|----------------------|---|
| 0              | <i>N</i>     | string |       | <code>setting</code> | A NULL-terminated and delimited string with contents [SECTION_SETTING, SETTING, VALUE]. A device will only process to this message when it is received from sender ID 0x42. |
|                | <i>N</i>     |        |       |                      | Total Payload Length  |

Table 6.4.2: MSG\_SETTINGS\_WRITE 0x00A0 message structure

**MSG.SETTINGS.READ.REQ — 0x00A4 — 164**

The setting message reads the device configuration.

| Offset (bytes) | Size (bytes) | Format | Units | Name                 | Description  |
|----------------|--------------|--------|-------|----------------------|--|
| 0              | <i>N</i>     | string |       | <code>setting</code> | A NULL-terminated and delimited string with contents [SECTION_SETTING, SETTING]. A device will only respond to this message when it is received from sender ID 0x42. |
|                | <i>N</i>     |        |       |                      | Total Payload Length   |

Table 6.4.3: MSG.SETTINGS.READ.REQ 0x00A4 message structure

**MSG\_SETTINGS\_READ\_RESP — 0x00A5 — 165**

The setting message reads the device configuration.

| Offset (bytes) | Size (bytes) | Format | Units | Name                 | Description   |
|----------------|--------------|--------|-------|----------------------|---|
| 0              | <i>N</i>     | string |       | <code>setting</code> | A NULL-terminated and delimited string with contents [SECTION_SETTING, SETTING, VALUE]. |
|                | <i>N</i>     |        |       |                      | Total Payload Length  |

Table 6.4.4: MSG\_SETTINGS\_READ\_RESP 0x00A5 message structure

**MSG\_SETTINGS\_READ\_BY\_INDEX\_REQ — 0x00A2 — 162**

The settings message for iterating through the settings values. It will read the setting at an index, returning a NULL-terminated and delimited string with contents [SECTION\_SETTING, SETTING, VALUE]. 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              | 2            | u16    |       | index | An index into the device settings, with values ranging from 0 to length(settings) |
|                | 2            |        |       |       | Total Payload Length  |

Table 6.4.5: MSG\_SETTINGS\_READ\_BY\_INDEX\_REQ 0x00A2 message structure

**MSG\_SETTINGS\_READ\_BY\_INDEX\_RESP — 0x00A7 — 167**

The settings message for iterating through the settings values. It will read the setting at an index, returning a NULL-terminated and delimited string with contents [SECTION\_SETTING, SETTING, VALUE].

| Offset<br>(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                 | <i>N</i>     | string |       | setting | A NULL-terminated and delimited string with contents [SECTION_SETTING, SETTING, VALUE]. |
|                   | <i>N + 2</i> |        |       |         | Total Payload Length  |

Table 6.4.6: 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<br>(bytes) | Size (bytes) | Format | Units | Name | Description          |
|-------------------|--------------|--------|-------|------|----------------------|
|                   | 0            |        |       |      | Total Payload Length |

Table 6.4.7: MSG\_SETTINGS\_READ\_BY\_INDEX\_DONE 0x00A6 message structure



## 6.5 System

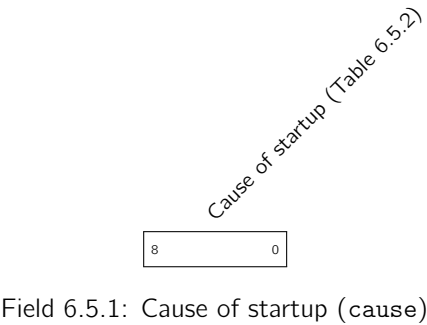
Standardized system messages from Swift Navigation devices.

### MSG\_STARTUP — 0xFF00 — 65280

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

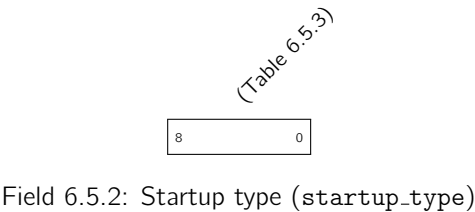
| Offset (bytes) | Size (bytes) | Format | Units | Name         | Description          |
|----------------|--------------|--------|-------|--------------|----------------------|
| 0              | 1            | u8     |       | cause        | Cause of startup     |
| 1              | 1            |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

Table 6.5.1: MSG\_STARTUP 0xFF00 message structure



| Value | Description    |
|-------|----------------|
| 0     | Power on       |
| 1     | Software reset |
| 2     | Watchdog reset |

Table 6.5.2: Cause of startup values (cause[0:8])



| Value | Description |
|-------|-------------|
| 0     | Cold start  |
| 1     | Warm start  |
| 2     | Hot start   |

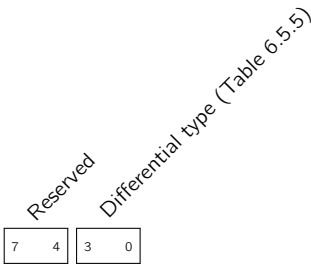
Table 6.5.3: values (startup\_type[0:8])

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     | deci-seconds | flags       | Status flags                        |
| 1              | 2            | u16    |              | 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 6.5.4: MSG\_DGNSS\_STATUS 0xFF02 message structure



Field 6.5.3: Status flags (flags)

| Value | Description     |
|-------|-----------------|
| 0     | Invalid         |
| 1     | Code Difference |
| 2     | RTK             |

Table 6.5.5: 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 6.5.6: MSG\_HEARTBEAT 0xFFFF message structure

| Value | Description           |
|-------|-----------------------|
| 0     | System Healthy        |
| 1     | An error has occurred |

Table 6.5.7: System Error Flag values (flags[0])

| Value | Description              |
|-------|--------------------------|
| 0     | System Healthy           |
| 1     | An IO error has occurred |

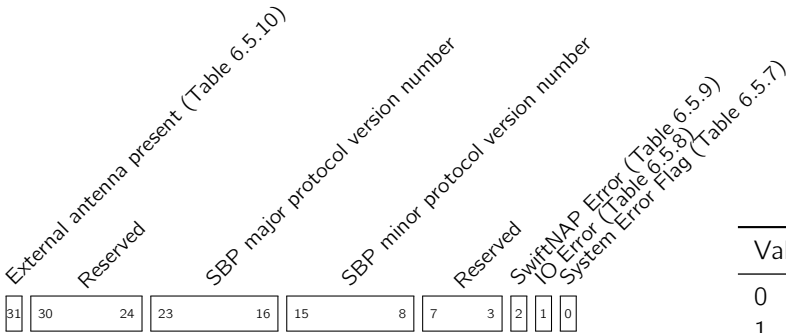
Table 6.5.8: IO Error values (flags[1])

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

Table 6.5.9: SwiftNAP Error values (flags[2])

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

Table 6.5.10: External antenna present values (flags[31])



Field 6.5.4: Status flags (flags)

## 7 Draft Message Definitions

### 7.1 Acquisition

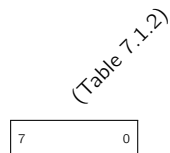
Satellite acquisition messages from the device.

#### MSG\_ACQ\_RESULT — 0x002F — 47

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

| Offset (bytes) | Size (bytes) | Format | Units | Name     | Description                                 |
|----------------|--------------|--------|-------|----------|---|
| 0              | 4            | float  | dB Hz | cn0      | CN/0 of best point                          |
| 4              | 4            | float  | chips | cp       | Code phase of best point                    |
| 8              | 4            | float  | hz    | cf       | Carrier frequency of best point             |
| 12             | 1            | u8     |       | sid.sat  | Constellation-specific satellite identifier |
| 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     |

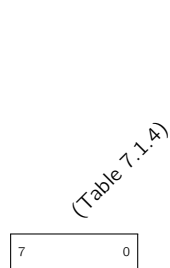
Table 7.1.2: values (sid.code[0:7])

**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     |          | <code>acq_sv_profile[N].job_type</code>   | SV search job type (deep, fallback, etc)                    |
| $33N + 1$      | 1            | u8     |          | <code>acq_sv_profile[N].status</code>     | Acquisition status 1 is Success, 0 is Failure               |
| $33N + 2$      | 2            | u16    | dB-Hz*10 | <code>acq_sv_profile[N].cn0</code>        | CN0 value. Only valid if status is '1'                      |
| $33N + 4$      | 1            | u8     | ms       | <code>acq_sv_profile[N].int_time</code>   | Acquisition integration time                                |
| $33N + 5$      | 1            | u8     |          | <code>acq_sv_profile[N].sid.sat</code>    | Constellation-specific satellite identifier                 |
| $33N + 6$      | 1            | u8     |          | <code>acq_sv_profile[N].sid.code</code>   | Signal constellation, band and code                         |
| $33N + 7$      | 2            | u16    | Hz       | <code>acq_sv_profile[N].bin_width</code>  | Acq frequency bin width                                     |
| $33N + 9$      | 4            | u32    | ms       | <code>acq_sv_profile[N].timestamp</code>  | Timestamp of the job complete event                         |
| $33N + 13$     | 4            | u32    | us       | <code>acq_sv_profile[N].time_spent</code> | Time spent to search for sid.code                           |
| $33N + 17$     | 4            | s32    | Hz       | <code>acq_sv_profile[N].cf_min</code>     | Doppler range lowest frequency                              |
| $33N + 21$     | 4            | s32    | Hz       | <code>acq_sv_profile[N].cf_max</code>     | Doppler range highest frequency                             |
| $33N + 25$     | 4            | s32    | Hz       | <code>acq_sv_profile[N].cf</code>         | Doppler value of detected peak. Only valid if status is '1' |
| $33N + 29$     | 4            | u32    | chips*10 | <code>acq_sv_profile[N].cp</code>         | 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]`)

## 7.2 Ext Events

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

### MSG\_EXT\_EVENT — 0x0101 — 257

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

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

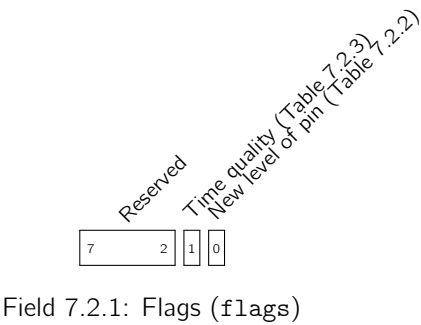
Table 7.2.1: MSG\_EXT\_EVENT 0x0101 message structure

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

Table 7.2.2: New level of pin values (flags[0])

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

Table 7.2.3: Time quality values (flags[1])



## 7.3 File IO

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

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

### MSG\_FILEIO\_READ\_REQ — 0x00A8 — 168

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

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

Table 7.3.1: MSG\_FILEIO\_READ\_REQ 0x00A8 message structure

**MSG\_FILEIO\_READ\_RESP — 0x00A3 — 163**

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

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

Table 7.3.2: 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    |       | <b>sequence</b> | Read sequence number                                       |
| 4              | 4            | u32    |       | <b>offset</b>   | The offset to skip the first $n$ elements of the file list |
| 8              | $N$          | string |       | <b>dirname</b>  | Name of the directory to list                              |
|                | $N + 8$      |        |       |                 | Total Payload Length                                       |

Table 7.3.3: 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 7.3.4: 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              | <i>N</i>     | string |       | <code>filename</code> | Name of the file to delete |
|                | <i>N</i>     |        |       |                       | Total Payload Length       |

Table 7.3.5: MSG\_FILEIO\_REMOVE 0x00AC message structure

**MSG\_FILEIO\_WRITE\_REQ — 0x00AD — 173**

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

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

Table 7.3.6: MSG\_FILEIO\_WRITE\_REQ 0x00AD message structure

**MSG\_FILEIO\_WRITE\_RESP — 0x00AB — 171**

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

| Offset (bytes) | Size (bytes) | Format | Units | Name                  | Description           |
|----------------|--------------|--------|-------|-----------------------|-----------------------|
| 0              | 4            | u32    |       | <code>sequence</code> | Write sequence number |
|                | 4            |        |       |                       | Total Payload Length  |

Table 7.3.7: MSG\_FILEIO\_WRITE\_RESP 0x00AB message structure

## 7.4 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  |

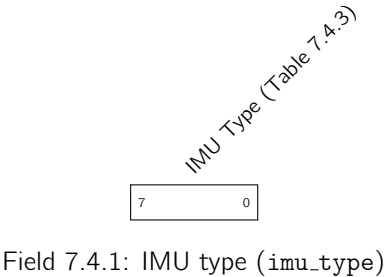
Table 7.4.1: MSG\_IMU\_RAW 0x0900 message structure

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'.

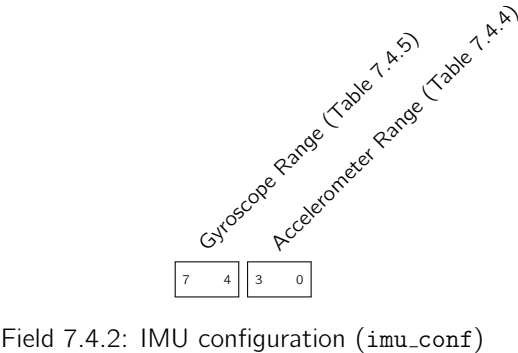
| Offset (bytes) | Size (bytes) | Format | Units | Name     | Description          |
|----------------|--------------|--------|-------|----------|----------------------|
| 0              | 1            | u8     |       | imu_type | IMU type             |
| 1              | 2            | s16    |   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

Table 7.4.2: MSG\_IMU\_AUX 0x0901 message structure



| Value | Description  |
|-------|--------------|
| 0     | Bosch BMI160 |

Table 7.4.3: IMU Type values (imu\_type[0:7])



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

Table 7.4.4: Accelerometer Range values (imu\_conf[0:3])

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

Table 7.4.5: Gyroscope Range values (imu\_conf[4:7])

## 7.5 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       | <code>tow</code>   | Milliseconds since start of GPS week. If the high bit is set, the time is unknown or invalid. |
| 4              | 1            | u8     | ms / 256 | <code>tow_f</code> | Milliseconds since start of GPS week, fractional part   |
| 5              | 2            | s16    |          | <code>mag_x</code> | Magnetic field in the body frame X axis   |
| 7              | 2            | s16    |          | <code>mag_y</code> | Magnetic field in the body frame Y axis   |
| 9              | 2            | s16    |          | <code>mag_z</code> | Magnetic field in the body frame Z axis   |
|                | 11           |        |          |                    | Total Payload Length  |

Table 7.5.1: MSG\_MAG\_RAW 0x0902 message structure



## 7.6 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 7.6.1: MSG\_BASELINE\_HEADING 0x020F message structure



Field 7.6.1: Status flags (f1ags)

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

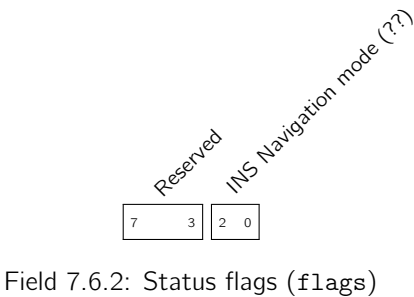
Table 7.6.2: Fix mode values (f1ags[0:2])

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.

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

Table 7.6.3: MSG\_ORIENT\_QUAT 0x0220 message structure



| Value | Description               |
|-------|---------------------------|
| 0     | None                      |
| 1     | INS only (Dead reckoning) |
| 2     | INS with GNSS             |
| 2     | INS with GNSS Attitude    |

Table 7.6.4: 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              | 2            | s16    | centidegrees | roll      | rotation about the forward axis of the vehicle   |
| 6              | 2            | s16    | centidegrees | pitch     | rotation about the rightward axis of the vehicle |
| 8              | 2            | s16    | centidegrees | yaw       | rotation about the downward axis of the vehicle  |
| 10             | 4            | float  | degrees      | var_roll  | Estimated standard deviation of roll             |
| 14             | 4            | float  | degrees      | var_pitch | Estimated standard deviation of pitch            |
| 18             | 4            | float  | degrees      | var_yaw   | Estimated standard deviation of yaw              |
| 22             | 1            | u8     |              | flags     | Status flags                                     |
| 23             |              |        |              |           | Total Payload Length                             |

Table 7.6.5: MSG\_ORIENT\_EULER 0x0221 message structure

7

3

2

0

Reserved

INS Navigation mode (??)

| Value | Description               |
|-------|---------------------------|
| 0     | None                      |
| 1     | INS only (Dead reckoning) |
| 2     | INS with valid GNSS       |
| 3     | INS with GNSS Attitude    |

Field 7.6.3: Status flags (flags)

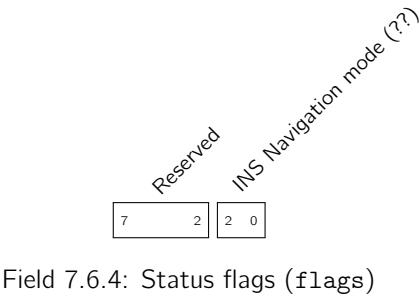
Table 7.6.6: INS Navigation mode values (flags[0:2])

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              | 2            | s16    | decidegrees/s | x     | angular rate about x axis |
| 6              | 2            | s16    | decidegrees/s | y     | angular rate about y axis |
| 8              | 2            | s16    | decidegrees/s | z     | angular rate about z axis |
| 10             | 1            | u8     |               | flags | Status flags              |
| 11             |              |        |               |       | Total Payload Length      |

Table 7.6.7: MSG\_ANGULAR\_RATE 0x0222 message structure



Field 7.6.4: Status flags (flags)

| Value | Description               |
|-------|---------------------------|
| 0     | None                      |
| 1     | INS only (Dead reckoning) |
| 2     | INS with valid GNSS       |
| 3     | INS with GNSS Attitude    |

Table 7.6.8: INS Navigation mode values (flags[0:2])

## 7.7 Piksi

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

### **MSG\_ALMANAC — 0x0069 — 105**

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

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

Table 7.7.1: 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 |

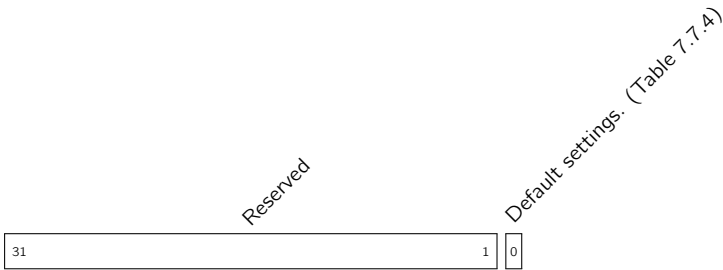
Table 7.7.2: MSG\_SET\_TIME 0x0068 message structure

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 7.7.3: MSG\_RESET 0x00B6 message structure



Field 7.7.1: Reset flags (flags)

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

Table 7.7.4: 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 7.7.5: 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 7.7.6: 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 |

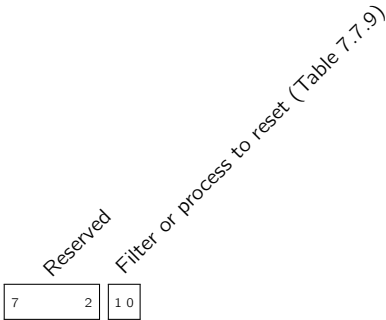
Table 7.7.7: MSG\_CW\_START 0x00C1 message structure

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 7.7.8: MSG\_RESET\_FILTERS 0x0022 message structure



Field 7.7.2: Filter flags (`filter`)

| Value | Description     |
|-------|-----------------|
| 0     | DGNSS filter    |
| 1     | IAR process     |
| 2     | Inertial filter |

Table 7.7.9: 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 7.7.10: 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 7.7.11: 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<br>(bytes) | Size<br>(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 7.7.12: MSG\_UART\_STATE 0x001D message structure

**MSG\_UART\_STATE\_DEPA — 0x0018 — 24**

Deprecated

| Offset<br>(bytes) | Size<br>(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 7.7.13: 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 7.7.14: MSG\_IAR\_STATE 0x0019 message structure

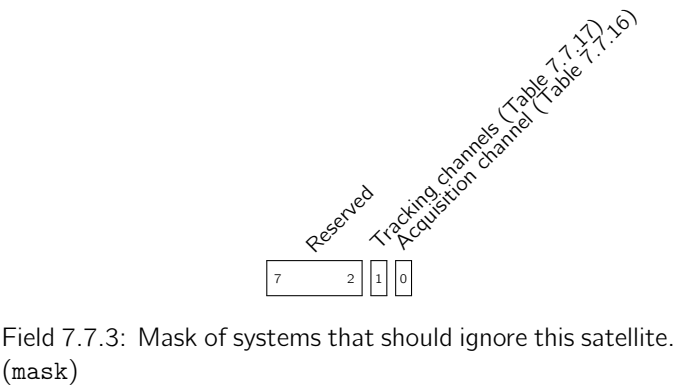


MSG\_MASK\_SATELLITE — 0x002B — 43

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        |
| 2              | 1            | u8     |       | sid.code | Signal constellation, band and code                |
|                |              |        |       | 3        | Total Payload Length                               |

Table 7.7.15: MSG\_MASK\_SATELLITE 0x002B message structure



| Value | Description                                |
|-------|--|
| 0     | Enabled                                    |
| 1     | Skip this satellite on future acquisitions |

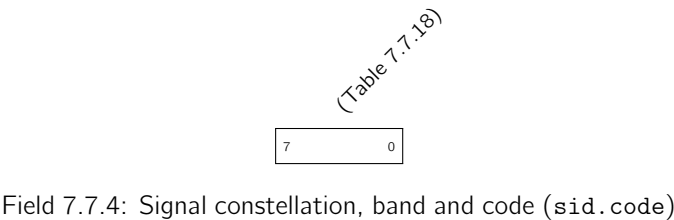
Table 7.7.16: Acquisition channel values (mask[0])

| Value | Description                         |
|-------|-------------------------------------|
| 0     | Enabled                             |
| 1     | Drop this PRN if currently tracking |

Table 7.7.17: Tracking channels values (mask[1])

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

Table 7.7.18: 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 <sub>in</sub>              |
| 2              | 2            | s16    | V / 1000        | cpu_vint        | Processor V <sub>int</sub>          |
| 4              | 2            | s16    | V / 1000        | cpu_vaux        | Processor V <sub>aux</sub>          |
| 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 7.7.19: 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 7.7.20: 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 7.7.21: 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    |       | <code>sequence</code> | Sequence number                           |
| 4              | $N$          | string |       | <code>line</code>     | Line of standard output or standard error |
|                | $N + 4$      |        |       |                       | Total Payload Length                      |

Table 7.7.22: 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 7.7.23: 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 7.7.24: MSG\_NETWORK\_STATE\_RESP 0x00BB 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             | <i>N</i>     | u8[ <i>N</i> ] |       | amplitude_value | Amplitude values (in the above units) of points in this packet                 |
| <i>N</i> + 28  |              |                |       |                 | Total Payload Length   |

Table 7.7.25: MSG\_SPECAN 0x0051 message structure



## 7.8 Tracking

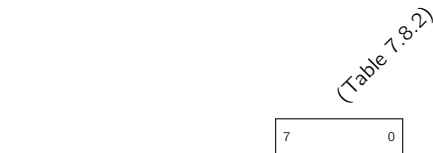
Satellite code and carrier-phase tracking messages from the device.

### 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     |           | <code>states[N].sid.sat</code>  | Constellation-specific satellite identifier                       |
| $4N + 1$       | 1            | u8     |           | <code>states[N].sid.code</code> | Signal constellation, band and code                               |
| $4N + 2$       | 1            | u8     |           | <code>states[N].fcn</code>      | Frequency channel number (GLONASS only)                           |
| $4N + 3$       | 1            | u8     | dB Hz / 4 | <code>states[N].cn0</code>      | Carrier-to-Noise density. Zero implies invalid <code>cn0</code> . |
| $4N$           |              |        |           |                                 | Total Payload Length  |

Table 7.8.1: MSG\_TRACKING\_STATE 0x0041 message structure



Field 7.8.1: Signal constellation, band and code (`sid.code`)

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

Table 7.8.2: values (`sid.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 |
| 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 7.8.3: MSG\_TRACKING\_IQ 0x002C message structure

(Table 7.8.4)

7

0

Field 7.8.2: Signal constellation, band and code (sid.code)

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

Table 7.8.4: values (sid.code[0:7])

## 7.9 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 7.9.1: MSG\_USER\_DATA 0x0800 message structure

## 7.10 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    | <code>tow</code>      | Time field representing either milliseconds in the GPS Week or local CPU time from the producing system in milliseconds. See the <code>tow_source</code> flag for the exact source of this timestamp. |
| 4              | 4            | s32    | mm/s  | <code>velocity</code> | The signed forward component of vehicle velocity.   |
| 8              | 1            | u8     |       | <code>flags</code>    | Status flags  |
|                | 9            |        |       |                       | Total Payload Length  |

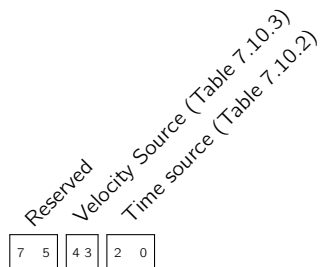
Table 7.10.1: MSG\_ODOMETRY 0x0903 message structure

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

Table 7.10.2: Time source values (`flags[0:2]`)

| Value | Description |
|-------|-------------|
| 0     | Source 0    |
| 1     | Source 1    |
| 2     | Source 2    |
| 3     | Source 3    |

Table 7.10.3: Velocity Source values (`flags[3:4]`)



Field 7.10.1: Status flags (`flags`)