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## 1 Overview

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

This document provides a specification of SBP framing and the payload structures of the messages currently used with Swift devices. SBP client libraries in a variety of programming languages are available at [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 0.52 , 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. 9), which reports the baseline position solution of the rover receiver relative to the base station receiver in Earth Centered Earth Fixed (ECEF) coordinates. The segments of this byte array and its contents break down as follows:

Field Name	Type	Value	Bytestring Segment
Preamble	u8	0x55	55
Message Type	u16	MSG_BASELINE_ECEF	02 02
Sender	u16	1228	cc 04
Length	u8	20	14
Payload	—	—	70 3d d0 18 cf ef ff ff ef e8 ff ff f0 18 00 00 00 00 05 00
MSG_BASELINE_ECEF			
.tow	u32	416300400 msec	70 3d d0 18
.x	s32	−4145 mm	cf ef ff ff
.y	s32	−5905 mm	ef e8 ff ff
.z	s32	6384 mm	f0 18 00 00
.accuracy	u16	0	00 00
.nsats	u8	5	05
.flags	u8	0	00
CRC	u16	0x9443	43 94

Table 4.0.3: 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
Navigation	0x0100	MSG_GPS_TIME	11	GPS Time
	0x0206	MSG_DOPS	14	Dilution of Precision
	0x0200	MSG_POS_ECEF	32	Single-point position in ECEF
	0x0201	MSG_POS_LLH	34	Geodetic Position
	0x0202	MSG_BASELINE_ECEF	20	Baseline Position in ECEF
	0x0203	MSG_BASELINE_NED	22	Baseline in NED
	0x0204	MSG_VEL_ECEF	20	Velocity in ECEF
	0x0205	MSG_VEL_NED	22	Velocity in NED
	0x0207	MSG_BASELINE_HEADING	10	Heading relative to True North
Observation	0x0049	MSG_OBS	$14N + 7$	GPS satellite observations
	0x0044	MSG_BASE_POS_LLH	24	Base station position
	0x0048	MSG_BASE_POS_ECEF	24	Base station position in ECEF
	0x0080	MSG_EPHEMERIS	185	Satellite broadcast ephemeris
	0x0047	MSG_EPHEMERIS_DEP_C	185	Ephemeris (Deprecated)
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
	0x00A7	MSG_SETTINGS_READ_BY_INDEX_RESP	$N + 2$	Read setting by direct index
	0x00A6	MSG_SETTINGS_READ_BY_INDEX_DONE	0	Finished reading settings
System	0xFF00	MSG_STARTUP	4	System start-up message
	0xFFFF	MSG_HEARTBEAT	4	System heartbeat message
<b>Draft</b>				
Acquisition	0x0014	MSG_ACQ_RESULT	16	Satellite acquisition result
Bootload	0x00B3	MSG_BOOTLOADER_HANDSHAKE_REQ	0	Bootloading handshake request
	0x00B4	MSG_BOOTLOADER_HANDSHAKE_RESP	$N + 4$	Bootloading handshake response
	0x00B1	MSG_BOOTLOADER_JUMP_TO_APP	1	Bootloader jump to application
	0x00DE	MSG_NAP_DEVICE_DNA_REQ	0	Read FPGA device ID over UART request
	0x00DD	MSG_NAP_DEVICE_DNA_RESP	8	Read FPGA device ID over UART response
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
Flash	0x00E6	MSG_FLASH_PROGRAM	$N + 5$	Program flash addresses
	0x00E0	MSG_FLASH_DONE	1	Flash response message
	0x00E7	MSG_FLASH_READ_REQ	5	Read STM or M25 flash address request

	0x00E1	MSG_FLASH_READ_RESP	5	Read STM or M25 flash address response
	0x00E2	MSG_FLASH_ERASE	5	Erase sector of device flash memory
	0x00E3	MSG_STM_FLASH_LOCK_SECTOR	4	Lock sector of STM flash memory
	0x00E4	MSG_STM_FLASH_UNLOCK_SECTOR	4	Unlock sector of STM flash memory
	0x00E8	MSG_STM_UNIQUE_ID_REQ	0	Read device's hardcoded unique ID request
	0x00E5	MSG_STM_UNIQUE_ID_RESP	12	Read device's hardcoded unique ID response
	0x00F3	MSG_M25_FLASH_WRITE_STATUS	1	Write M25 flash status register
Piksi	0x0069	MSG_ALMANAC	0	Legacy message to load satellite almanac
	0x0068	MSG_SET_TIME	0	Send GPS time from host
	0x00B2	MSG_RESET	0	Reset the device
	0x00C0	MSG_CW_RESULTS	0	Legacy message for CW interference channel (Piksi = <sub>i</sub> 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
	0x001B	MSG_MASK_SATELLITE	5	Mask a satellite from use in Piksi subsystems
Tracking	0x0013	MSG_TRACKING_STATE	9 <i>N</i>	Satellite tracking channel states
	0x001C	MSG_TRACKING_IQ	8 <i>N</i> + 5	Tracking channel correlations
User	0x0800	MSG_USER_DATA	<i>N</i>	User data

Table 5.0.5: SBP message types

## 6 Stable Message Definitions

### 6.1 Logging

Logging and debugging messages from the device.

#### MSG\_LOG — 0x0401

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])

## 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.

### MSG\_GPS\_TIME — 0x0100

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	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 0x0100 message structure

**MSG\_DOPS — 0x0206**

This dilution of precision (DOP) message describes the effect of navigation satellite geometry on positional measurement precision.

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				Total Payload Length

Table 6.2.2: MSG\_DOPS 0x0206 message structure



MSG\_POS\_ECEF — 0x0200

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

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32	ms	tow	GPS Time of Week
4	8	double	m	x	ECEF X coordinate
12	8	double	m	y	ECEF Y coordinate
20	8	double	m	z	ECEF Z coordinate
28	2	u16	mm	accuracy	Position accuracy estimate (not implemented). Defaults to 0.
30	1	u8		n_sats	Number of satellites used in solution
31	1	u8		flags	Status flags
32					Total Payload Length

Table 6.2.3: MSG\_POS\_ECEF 0x0200 message structure

Value	Description
0	Single Point Positioning (SPP)
1	Float RTK
2	Fixed RTK

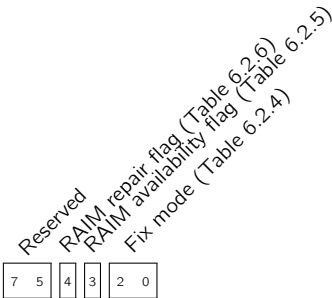
Table 6.2.4: Fix mode values (flags[0:2])

Value	Description
0	RAIM check was explicitly disabled or unavailable
1	RAIM check was available

Table 6.2.5: RAIM availability flag values (flags[3])

Value	Description
0	No repair
1	Solution came from RAIM repair

Table 6.2.6: RAIM repair flag values (flags[4])



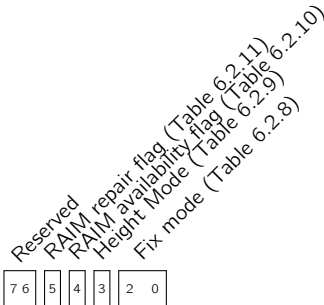
Field 6.2.1: Status flags (flags)

**MSG\_POS\_LLH — 0x0201**

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
28	2	u16	mm	h_accuracy	Horizontal position accuracy estimate (not implemented). Defaults to 0.
30	2	u16	mm	v_accuracy	Vertical position accuracy estimate (not implemented). Defaults to 0.
32	1	u8		n_sats	Number of satellites used in solution.
33	1	u8		flags	Status flags
34					Total Payload Length

Table 6.2.7: MSG\_POS\_LLH 0x0201 message structure



Field 6.2.2: Status flags (flags)

Value	Description
0	Single Point Positioning (SPP)
1	Fixed RTK
2	Float RTK

Table 6.2.8: Fix mode values (flags[0:2])

Value	Description
0	Height above WGS84 ellipsoid
1	Height above mean sea level

Table 6.2.9: Height Mode values (flags[3])

Value	Description
0	RAIM check was explicitly disabled or unavailable
1	RAIM check was available

Table 6.2.10: RAIM availability flag values (flags[4])

Value	Description
0	No repair
1	Solution came from RAIM repair

Table 6.2.11: RAIM repair flag values (flags[5])

MSG.BASELINE\_ECEF — 0x0202

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 accuracy estimate (not implemented). Defaults to 0.
18	1	u8		n_sats	Number of satellites used in solution
19	1	u8		flags	Status flags
20					Total Payload Length

Table 6.2.12: MSG.BASELINE\_ECEF 0x0202 message structure

Value	Description
0	Float RTK
1	Fixed RTK

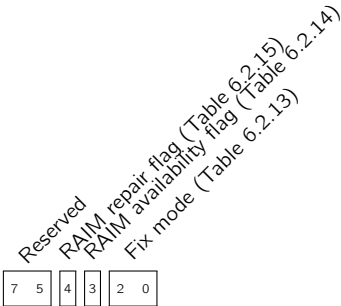
Table 6.2.13: Fix mode values (flags[0:2])

Value	Description
0	RAIM check was explicitly disabled or unavailable
1	RAIM check was available

Table 6.2.14: RAIM availability flag values (flags[3])

Value	Description
0	No repair
1	Solution came from RAIM repair

Table 6.2.15: RAIM repair flag values (flags[4])



Field 6.2.3: Status flags (flags)

MSG\_BASELINE\_NED — 0x0203

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 accuracy estimate (not implemented). Defaults to 0.
18	2	u16	mm	v_accuracy	Vertical position accuracy estimate (not implemented). Defaults to 0.
20	1	u8		n_sats	Number of satellites used in solution
21	1	u8		flags	Status flags
22					Total Payload Length

Table 6.2.16: MSG\_BASELINE\_NED 0x0203 message structure

Value	Description
0	Float RTK
1	Fixed RTK

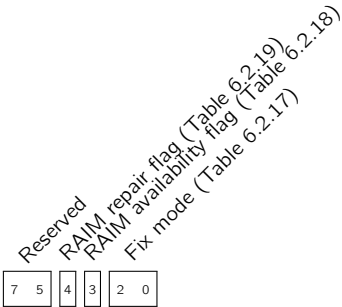
Table 6.2.17: Fix mode values (flags[0:2])

Value	Description
0	RAIM check was explicitly disabled or unavailable
1	RAIM check was available

Table 6.2.18: RAIM availability flag values (flags[3])

Value	Description
0	No repair
1	Solution came from RAIM repair

Table 6.2.19: RAIM repair flag values (flags[4])



Field 6.2.4: Status flags (flags)

**MSG\_VEL\_ECEF — 0x0204**

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 accuracy estimate (not implemented). Defaults to 0.
18	1	u8		n_sats	Number of satellites used in solution
19	1	u8		flags	Status flags (reserved)
20					Total Payload Length

Table 6.2.20: MSG\_VEL\_ECEF 0x0204 message structure

**MSG\_VEL\_NED — 0x0205**

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 accuracy estimate (not implemented). Defaults to 0.
18	2	u16	mm/s	v_accuracy	Vertical velocity accuracy estimate (not implemented). Defaults to 0.
20	1	u8		n_sats	Number of satellites used in solution
21	1	u8		flags	Status flags (reserved)
22					Total Payload Length

Table 6.2.21: MSG\_VEL\_NED 0x0205 message structure

MSG\_BASELINE\_HEADING — 0x0207

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).

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 6.2.22: MSG\_BASELINE\_HEADING 0x0207 message structure

Value	Description
0	Float RTK
1	Fixed RTK

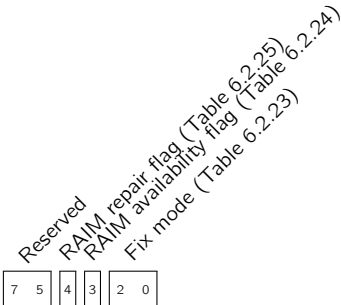
Table 6.2.23: Fix mode values (flags[0:2])

Value	Description
0	RAIM check was explicitly disabled or unavailable
1	RAIM check was available

Table 6.2.24: RAIM availability flag values (flags[3])

Value	Description
0	No repair
1	Solution came from RAIM repair

Table 6.2.25: RAIM repair flag values (flags[4])



Field 6.2.5: Status flags (flags)



## 6.3 Observation

Satellite observation messages from the device.

### MSG\_OBS — 0x0049

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 phaserange - pseudorange. The observations should 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	2	u16	week	header.t.wn	GPS week number
6	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)
14N + 7	4	u32	2 cm	obs[N].P	Pseudorange observation
14N + 11	4	s32	0.5 mm	obs[N].L	Phase Range minus pseudorange. Phaserange can be reconstructed by adding pseudorange to this value. This follows the convention from DF0012 or the DF042 field from the RTCM 10403.2 Amendment 2 specification. Importantly, this assumes the phaserange has the same sign as the pseudorange.
14N + 15	1	u8	dB Hz * 4	obs[N].cn0	Carrier-to-Noise density
14N + 16	1	u8		obs[N].lock	Lock indicator. This value gives an indication of the time for which a satellite has maintained continuous phase lock. Whenever a satellite 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. Given a lock time (t) in milliseconds, the field value (n) is given by $\text{floor}(\log_2(t) - 4)$ when t is greater than 32 ms or 0 if (t) is less than 32 ms. Conversely, given the field, n, the lower range of possible lock times is given by $2^{(n+4)}$ ms and the upper range is given by $2^{(n+5)}$ ms provided n is not 0. If n is 0 the lower range is given to be 0 ms.
14N + 17	2	u16		obs[N].sid.sa	Constellation-specific satellite identifier
14N + 19	1	u8		obs[N].sid.co	Signal constellation, band and code
14N + 20	1	u8		obs[N].sid.res	Reserved
14N + 7					Total Payload Length

Table 6.3.1: MSG\_OBS 0x0049 message structure

**MSG\_BASE\_POS\_LLH — 0x0044**

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 6.3.2: MSG\_BASE\_POS\_LLH 0x0044 message structure

**MSG\_BASE\_POS\_ECEF — 0x0048**

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 6.3.3: MSG\_BASE\_POS\_ECEF 0x0048 message structure

**MSG\_EPHEMERIS — 0x0080**

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	8	double	s	tgd	Group delay differential between L1 and L2
8	8	double	m	c_rs	Amplitude of the sine harmonic correction term to the orbit radius
16	8	double	m	c_rc	Amplitude of the cosine harmonic correction term to the orbit radius
24	8	double	rad	c_uc	Amplitude of the cosine harmonic correction term to the argument of latitude
32	8	double	rad	c_us	Amplitude of the sine harmonic correction term to the argument of latitude
40	8	double	rad	c_ic	Amplitude of the cosine harmonic correction term to the angle of inclination
48	8	double	rad	c_is	Amplitude of the sine harmonic correction term to the angle of inclination
56	8	double	rad/s	dn	Mean motion difference
64	8	double	radians	m0	Mean anomaly at reference time
72	8	double		ecc	Eccentricity of satellite orbit
80	8	double	$m^{(1/2)}$	sqrta	Square root of the semi-major axis of orbit
88	8	double	rad	omega0	Longitude of ascending node of orbit plane at weekly epoch
96	8	double	rad/s	omegadot	Rate of right ascension
104	8	double	rad	w	Argument of perigee
112	8	double	rad	inc	Inclination
120	8	double	rad/s	inc_dot	Inclination first derivative
128	8	double	s	af0	Polynomial clock correction coefficient (clock bias)
136	8	double	s/s	af1	Polynomial clock correction coefficient (clock drift)
144	8	double	s/s <sup>2</sup>	af2	Polynomial clock correction coefficient (rate of clock drift)
152	8	double	s	toe_tow	Time of week
160	2	u16	week	toe_wn	Week number
162	8	double	s	toc_tow	Clock reference time of week
170	2	u16	week	toc_wn	Clock reference week number
172	1	u8		valid	Is valid?
173	1	u8		healthy	Satellite is healthy?
174	2	u16		sid.sat	Constellation-specific satellite identifier
176	1	u8		sid.code	Signal constellation, band and code
177	1	u8		sid.reserved	Reserved
178	1	u8		iode	Issue of ephemeris data
179	2	u16		iodc	Issue of clock data
181	4	u32		reserved	Reserved field
185					Total Payload Length

Table 6.3.4: MSG.EPHEMERIS 0x0080 message structure

**MSG\_EPHEMERIS\_DEP\_C — 0x0047**

This ephemeris message has been deprecated to allow the ephemerides to be masked separately from GNSS observations. The ephemeris message returns a set of satellite orbits 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	8	double	s	tgd	Group delay differential between L1 and L2
8	8	double	m	c_rs	Amplitude of the sine harmonic correction term to the orbit radius
16	8	double	m	c_rc	Amplitude of the cosine harmonic correction term to the orbit radius
24	8	double	rad	c_uc	Amplitude of the cosine harmonic correction term to the argument of latitude
32	8	double	rad	c_us	Amplitude of the sine harmonic correction term to the argument of latitude
40	8	double	rad	c_ic	Amplitude of the cosine harmonic correction term to the angle of inclination
48	8	double	rad	c_is	Amplitude of the sine harmonic correction term to the angle of inclination
56	8	double	rad/s	dn	Mean motion difference
64	8	double	radians	m0	Mean anomaly at reference time
72	8	double		ecc	Eccentricity of satellite orbit
80	8	double	$m^{(1/2)}$	sqrta	Square root of the semi-major axis of orbit
88	8	double	rad	omega0	Longitude of ascending node of orbit plane at weekly epoch
96	8	double	rad/s	omegadot	Rate of right ascension
104	8	double	rad	w	Argument of perigee
112	8	double	rad	inc	Inclination
120	8	double	rad/s	inc_dot	Inclination first derivative
128	8	double	s	af0	Polynomial clock correction coefficient (clock bias)
136	8	double	s/s	af1	Polynomial clock correction coefficient (clock drift)
144	8	double	$s/s^2$	af2	Polynomial clock correction coefficient (rate of clock drift)
152	8	double	s	toe_tow	Time of week
160	2	u16	week	toe_wn	Week number
162	8	double	s	toc_tow	Clock reference time of week
170	2	u16	week	toc_wn	Clock reference week number
172	1	u8		valid	Is valid?
173	1	u8		healthy	Satellite is healthy?
174	2	u16		sid.sat	Constellation-specific satellite identifier
176	1	u8		sid.code	Signal constellation, band and code
177	1	u8		sid.reserved	Reserved
178	1	u8		iode	Issue of ephemeris data
179	2	u16		iodc	Issue of clock data
181	4	u32		reserved	Reserved field
185					Total Payload Length

Table 6.3.5: MSG\_EPHEMERIS\_DEP\_C 0x0047 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/blob/master/docs/settings.pdf>

### MSG\_SETTINGS\_SAVE — 0x00A1

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

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

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



**MSG\_SETTINGS\_WRITE — 0x00A0**

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**

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**

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**

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**

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 (bytes)	Size (bytes)	Format	Units	Name	Description
0	2	u16		<code>index</code>	An index into the device settings, with values ranging from 0 to length(settings)
2	$N$	string		<code>setting</code>	A NULL-terminated and delimited string with contents [SECTION_SETTING, SETTING, VALUE].
	$N + 2$				Total Payload Length

Table 6.4.6: MSG\_SETTINGS\_READ\_BY\_INDEX\_RESP 0x00A7 message structure

**MSG\_SETTINGS\_READ\_BY\_INDEX\_DONE — 0x00A6**

The settings message for indicating end of the settings values.

Offset (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

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	4	u32		reserved	Reserved
	4				Total Payload Length

Table 6.5.1: MSG\_STARTUP 0xFF00 message structure

MSG\_HEARTBEAT — 0xFFFF

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 6.5.2: MSG\_HEARTBEAT 0xFFFF message structure

Value	Description
0	System Healthy
1	An error has occurred

Table 6.5.3: System Error Flag values (flags[0])

Value	Description
0	System Healthy
1	An IO error has occurred

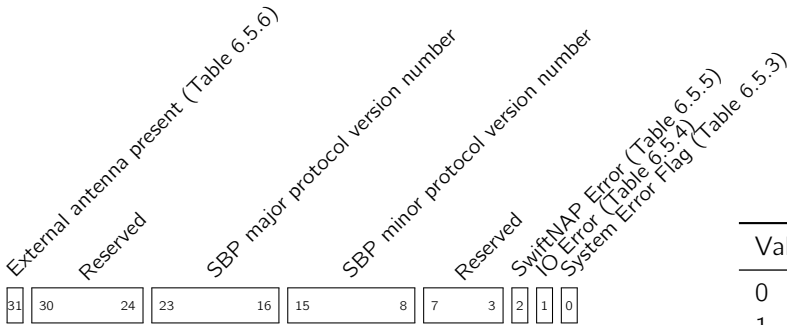
Table 6.5.4: IO Error values (flags[1])

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

Table 6.5.5: SwiftNAP Error values (flags[2])

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

Table 6.5.6: External antenna present values (flags[31])



Field 6.5.1: Status flags (flags)



## 7 Draft Message Definitions

### 7.1 Acquisition

Satellite acquisition messages from the device.

#### MSG\_ACQ\_RESULT — 0x0014

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 signal-to-noise (SNR) ratio.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	float		snr	SNR of best point. Currently in arbitrary SNR points, but will be in units of dB Hz in a later revision of this message.
4	4	float	chips	cp	Code phase of best point
8	4	float	hz	cf	Carrier frequency of best point
12	2	u16		sid.sat	Constellation-specific satellite identifier
14	1	u8		sid.code	Signal constellation, band and code
15	1	u8		sid.reserved	Reserved
16					Total Payload Length

Table 7.1.1: MSG\_ACQ\_RESULT 0x0014 message structure

## 7.2 Bootload

Messages for the bootloading configuration on the device.

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

### **MSG\_BOOTLOADER\_HANDSHAKE\_REQ — 0x00B3**

The handshake message request from the host establishes a handshake between the device bootloader and the host. The response from the device is MSG\_BOOTLOADER\_HANDSHAKE\_RESP.

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

Table 7.2.1: MSG\_BOOTLOADER\_HANDSHAKE\_REQ 0x00B3 message structure

**MSG\_BOOTLOADER\_HANDSHAKE\_RESP — 0x00B4**

The handshake message response from the device establishes a handshake between the device bootloader and the host. The request from the host is MSG\_BOOTLOADER\_HANDSHAKE\_REQ. The payload contains the bootloader version number and the SBP protocol version number.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		flags	Bootloader flags
4	<i>N</i>	string		version	Bootloader version number
<i>N + 4</i>					Total Payload Length

Table 7.2.2: MSG\_BOOTLOADER\_HANDSHAKE\_RESP 0x00B4 message structure

**MSG\_BOOTLOADER\_JUMP\_TO\_APP — 0x00B1**

The host initiates the bootloader to jump to the application.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		jump	Ignored by the device
	1				Total Payload Length

Table 7.2.3: MSG\_BOOTLOADER\_JUMP\_TO\_APP 0x00B1 message structure

**MSG\_NAP\_DEVICE\_DNA\_REQ — 0x00DE**

The device message from the host reads a unique device identifier from the SwiftNAP, an FPGA. The host requests the ID by sending a MSG\_NAP\_DEVICE\_DNA\_REQ message. The device responds with a MSG\_NAP\_DEVICE\_DNA\_RESP message with the device ID in the payload. Note that this ID is tied to the FPGA, and not related to the Piksi's serial number.

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

Table 7.2.4: MSG\_NAP\_DEVICE\_DNA\_REQ 0x00DE message structure

**MSG\_NAP\_DEVICE\_DNA\_RESP — 0x00DD**

The device message from the host reads a unique device identifier from the SwiftNAP, an FPGA. The host requests the ID by sending a MSG\_NAP\_DEVICE\_DNA\_REQ message. The device responds with a MSG\_NAP\_DEVICE\_DNA\_RESP message with the device ID in the payload. Note that this ID is tied to the FPGA, and not related to the Piksi's serial number.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	8	u8[8]		dna	57-bit SwiftNAP FPGA Device ID. Remaining bits are padded on the right.
	8				Total Payload Length

Table 7.2.5: MSG\_NAP\_DEVICE\_DNA\_RESP 0x00DD message structure

## 7.3 Ext Events

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

### MSG\_EXT\_EVENT — 0x0101

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	<b>wn</b>	GPS week number
2	4	u32	ms	<b>tow</b>	GPS time of week rounded to the nearest millisecond
6	4	s32	ns	<b>ns</b>	Nanosecond residual of millisecond-rounded TOW (ranges from -500000 to 500000)
10	1	u8		<b>flags</b>	Flags
11	1	u8		<b>pin</b>	Pin number. 0..9 = DEBUG0..9.
	12				Total Payload Length

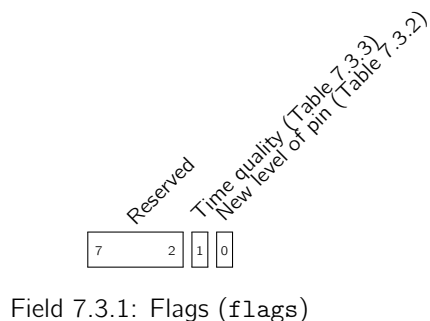
Table 7.3.1: MSG\_EXT\_EVENT 0x0101 message structure

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

Table 7.3.2: New level of pin values (**flags**[0])

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

Table 7.3.3: Time quality values (**flags**[1])



## 7.4 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

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 7.4.1: MSG\_FILEIO\_READ\_REQ 0x00A8 message structure



**MSG\_FILEIO\_READ\_RESP — 0x00A3**

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 7.4.2: MSG\_FILEIO\_READ\_RESP 0x00A3 message structure

**MSG\_FILEIO\_READ\_DIR\_REQ — 0x00A9**

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 7.4.3: MSG\_FILEIO\_READ\_DIR\_REQ 0x00A9 message structure

**MSG\_FILEIO\_READ\_DIR\_RESP — 0x00AA**

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 7.4.4: MSG\_FILEIO\_READ\_DIR\_RESP 0x00AA message structure

**MSG\_FILEIO\_REMOVE — 0x00AC**

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 7.4.5: MSG\_FILEIO\_REMOVE 0x00AC message structure

**MSG\_FILEIO\_WRITE\_REQ — 0x00AD**

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 7.4.6: MSG\_FILEIO\_WRITE\_REQ 0x00AD message structure

**MSG\_FILEIO\_WRITE\_RESP — 0x00AB**

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 7.4.7: MSG\_FILEIO\_WRITE\_RESP 0x00AB message structure

## 7.5 Flash

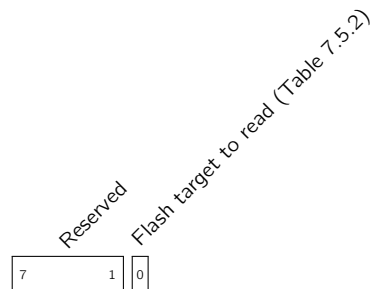
Messages for reading/writing the device's onboard flash memory. Many of these messages target specific flash memory peripherals used in Swift Navigation devices: the STM32 flash and the M25Pxx FPGA configuration flash.

### MSG\_FLASH\_PROGRAM — 0x00E6

The flash program message programs a set of addresses of either the STM or M25 flash. The device replies with either a MSG\_FLASH\_DONE message containing the return code FLASH\_OK (0) on success, or FLASH\_INVALID\_LEN (2) if the maximum write size is exceeded. Note that the sector-containing addresses must be erased before addresses can be programmed.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		target	Target flags
1	3	u8[3]	bytes	addr_start	Starting address offset to program
4	1	u8	bytes	addr_len	Length of set of addresses to program, counting up from starting address
5	$N$	u8[ $N$ ]		data	Data to program addresses with, with length $N=addr\_len$
$N + 5$					Total Payload Length

Table 7.5.1: MSG\_FLASH\_PROGRAM 0x00E6 message structure



Field 7.5.1: Target flags (target)

Value	Description
0	FLASH_STM
1	FLASH_M25

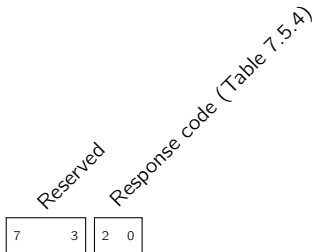
Table 7.5.2: Flash target to read values (target[0])

MSG\_FLASH\_DONE — 0x00E0

This message defines success or failure codes for a variety of flash memory requests from the host to the device. Flash read and write messages, such as MSG\_FLASH\_READ\_REQ, or MSG\_FLASH\_PROGRAM, may return this message on failure.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		response	Response flags
	1				Total Payload Length

Table 7.5.3: MSG\_FLASH\_DONE 0x00E0 message structure



Field 7.5.2: Response flags (response)

Value	Description
0	FLASH_OK
1	FLASH_INVALID_FLASH
2	FLASH_INVALID_LEN
3	FLASH_INVALID_ADDR
4	FLASH_INVALID_RANGE
5	FLASH_INVALID_SECTOR

Table 7.5.4: Response code values (response[0:2])

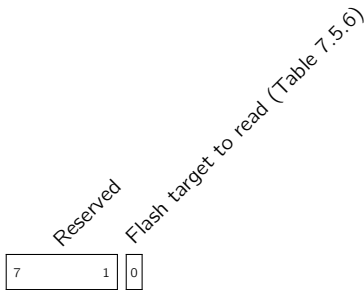


MSG\_FLASH\_READ\_REQ — 0x00E7

The flash read message reads a set of addresses of either the STM or M25 onboard flash. The device replies with a MSG\_FLASH\_READ\_RESP message containing either the read data on success or a MSG\_FLASH\_DONE message containing the return code FLASH\_INVALID\_LEN (2) if the maximum read size is exceeded or FLASH\_INVALID\_ADDR (3) if the address is outside of the allowed range.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		target	Target flags
1	3	u8[3]	bytes	addr_start	Starting address offset to read from
4	1	u8	bytes	addr_len	Length of set of addresses to read, counting up from starting address
5					Total Payload Length

Table 7.5.5: MSG\_FLASH\_READ\_REQ 0x00E7 message structure



Field 7.5.3: Target flags (target)

Value	Description
0	FLASH_STM
1	FLASH_M25

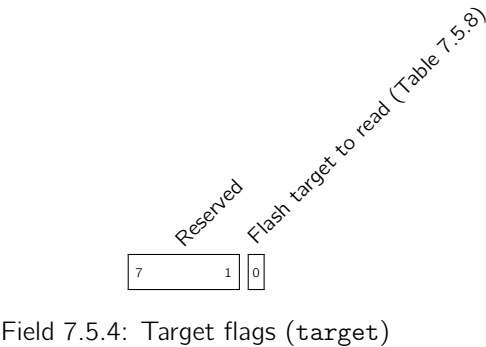
Table 7.5.6: Flash target to read values (target[0])

MSG\_FLASH\_READ\_RESP — 0x00E1

The flash read message reads a set of addresses of either the STM or M25 onboard flash. The device replies with a MSG\_FLASH\_READ\_RESP message containing either the read data on success or a MSG\_FLASH\_DONE message containing the return code FLASH\_INVALID\_LEN (2) if the maximum read size is exceeded or FLASH\_INVALID\_ADDR (3) if the address is outside of the allowed range.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		target	Target flags
1	3	u8[3]	bytes	addr_start	Starting address offset to read from
4	1	u8	bytes	addr_len	Length of set of addresses to read, counting up from starting address
5					Total Payload Length

Table 7.5.7: MSG\_FLASH\_READ\_RESP 0x00E1 message structure



Field 7.5.4: Target flags (target)

Value	Description
0	FLASH_STM
1	FLASH_M25

Table 7.5.8: Flash target to read values (target[0])

MSG\_FLASH\_ERASE — 0x00E2

The flash erase message from the host erases a sector of either the STM or M25 onboard flash memory. The device will reply with a MSG\_FLASH\_DONE message containing the return code - FLASH\_OK (0) on success or FLASH\_INVALID\_FLASH (1) if the flash specified is invalid.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		target	Target flags
1	4	u32		sector_num	Flash sector number to erase (0-11 for the STM, 0-15 for the M25)
5					Total Payload Length

Table 7.5.9: MSG\_FLASH\_ERASE 0x00E2 message structure

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Reserved

Flash target to read (Table 7.5.10)

Field 7.5.5: Target flags (target)

Value	Description
0	FLASH_STM
1	FLASH_M25

Table 7.5.10: Flash target to read values (target[0])

**MSG\_STM\_FLASH\_LOCK\_SECTOR — 0x00E3**

The flash lock message locks a sector of the STM flash memory. The device replies with a MSG\_FLASH\_DONE message.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		sector	Flash sector number to lock
	4				Total Payload Length

Table 7.5.11: MSG\_STM\_FLASH\_LOCK\_SECTOR 0x00E3 message structure

**MSG\_STM\_FLASH\_UNLOCK\_SECTOR — 0x00E4**

The flash unlock message unlocks a sector of the STM flash memory. The device replies with a MSG\_FLASH\_DONE message.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	u32		sector	Flash sector number to unlock
	4				Total Payload Length

Table 7.5.12: MSG\_STM\_FLASH\_UNLOCK\_SECTOR 0x00E4 message structure

**MSG\_STM\_UNIQUE\_ID\_REQ — 0x00E8**

This message reads the device's hardcoded unique ID. The host requests the ID by sending a MSG\_STM\_UNIQUE\_ID\_REQ. The device responds with a MSG\_STM\_UNIQUE\_ID\_RESP with the 12-byte unique ID in the payload.

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

Table 7.5.13: MSG\_STM\_UNIQUE\_ID\_REQ 0x00E8 message structure

**MSG\_STM\_UNIQUE\_ID\_RESP — 0x00E5**

This message reads the device's hardcoded unique ID. The host requests the ID by sending a MSG\_STM\_UNIQUE\_ID\_REQ. The device responds with a MSG\_STM\_UNIQUE\_ID\_RESP with the 12-byte unique ID in the payload..

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	12	u8[12]		stm_id	Device unique ID
	12				Total Payload Length

Table 7.5.14: MSG\_STM\_UNIQUE\_ID\_RESP 0x00E5 message structure

**MSG\_M25\_FLASH\_WRITE\_STATUS — 0x00F3**

The flash status message writes to the 8-bit M25 flash status register. The device replies with a MSG\_FLASH\_DONE message.

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8[1]		status	Byte to write to the M25 flash status register
	1				Total Payload Length

Table 7.5.15: MSG\_M25\_FLASH\_WRITE\_STATUS 0x00F3 message structure



## 7.6 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**

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 7.6.1: MSG\_ALMANAC 0x0069 message structure

**MSG\_SET\_TIME — 0x0068**

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 7.6.2: MSG\_SET\_TIME 0x0068 message structure

**MSG\_RESET — 0x00B2**

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 7.6.3: MSG\_RESET 0x00B2 message structure

**MSG\_CW\_RESULTS — 0x00C0**

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 7.6.4: MSG\_CW\_RESULTS 0x00C0 message structure

**MSG\_CW\_START — 0x00C1**

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

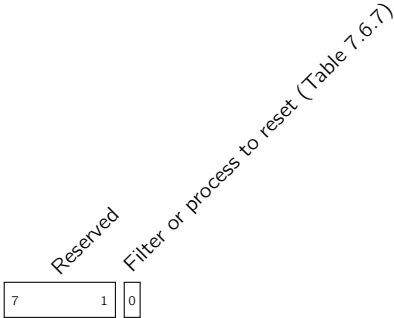
Table 7.6.5: MSG\_CW\_START 0x00C1 message structure

MSG\_RESET\_FILTERS — 0x0022

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 7.6.6: MSG\_RESET\_FILTERS 0x0022 message structure



Field 7.6.1: Filter flags (`filter`)

Value	Description
0	DGNSS filter
1	IAR process

Table 7.6.7: Filter or process to reset values (`filter[0]`)

**MSG\_INIT\_BASE — 0x0023**

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 7.6.8: MSG\_INIT\_BASE 0x0023 message structure

**MSG\_THREAD\_STATE — 0x0017**

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 7.6.9: MSG\_THREAD\_STATE 0x0017 message structure



**MSG\_UART\_STATE — 0x001D**

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

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

Table 7.6.10: MSG\_UART\_STATE 0x001D message structure

**MSG\_UART\_STATE\_DEPA — 0x0018**

Deprecated

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	4	float	kB/s	uart.a.tx.throughput	UART transmit throughput
4	4	float	kB/s	uart.a.rx.throughput	UART receive throughput
8	2	u16		uart.a.crc.error.count	UART CRC error count
10	2	u16		uart.a.io.error.count	UART IO error count
12	1	u8		uart.a.tx.buffer.level	UART transmit buffer percentage utilization (ranges from 0 to 255)
13	1	u8		uart.a.rx.buffer.level	UART receive buffer percentage utilization (ranges from 0 to 255)
14	4	float	kB/s	uart.b.tx.throughput	UART transmit throughput
18	4	float	kB/s	uart.b.rx.throughput	UART receive throughput
22	2	u16		uart.b.crc.error.count	UART CRC error count
24	2	u16		uart.b.io.error.count	UART IO error count
26	1	u8		uart.b.tx.buffer.level	UART transmit buffer percentage utilization (ranges from 0 to 255)
27	1	u8		uart.b.rx.buffer.level	UART receive buffer percentage utilization (ranges from 0 to 255)
28	4	float	kB/s	uart.ftdi.tx.throughput	UART transmit throughput
32	4	float	kB/s	uart.ftdi.rx.throughput	UART receive throughput
36	2	u16		uart.ftdi.crc.error.count	UART CRC error count
38	2	u16		uart.ftdi.io.error.count	UART IO error count
40	1	u8		uart.ftdi.tx.buffer.level	UART transmit buffer percentage utilization (ranges from 0 to 255)
41	1	u8		uart.ftdi.rx.buffer.level	UART receive buffer percentage utilization (ranges from 0 to 255)
42	4	s32	ms	latency.avg	Average latency
46	4	s32	ms	latency.lmin	Minimum latency
50	4	s32	ms	latency.lmax	Maximum latency
54	4	s32	ms	latency.current	Smoothed estimate of the current latency
58					Total Payload Length

Table 7.6.11: MSG\_UART\_STATE\_DEPA 0x0018 message structure

**MSG\_IAR\_STATE — 0x0019**

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

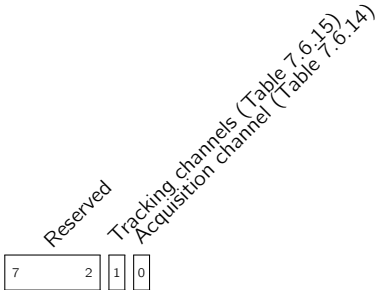
Table 7.6.12: MSG\_IAR\_STATE 0x0019 message structure

MSG\_MASK\_SATELLITE — 0x001B

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	2	u16		sid.sat	Constellation-specific satellite identifier
3	1	u8		sid.code	Signal constellation, band and code
4	1	u8		sid.reserved	Reserved
					Total Payload Length
					5

Table 7.6.13: MSG\_MASK\_SATELLITE 0x001B message structure



Field 7.6.2: Mask of systems that should ignore this satellite. (mask)

Value	Description
0	Enabled
1	Skip this satellite on future acquisitions

Table 7.6.14: Acquisition channel values (mask[0])

Value	Description
0	Enabled
1	Drop this PRN if currently tracking

Table 7.6.15: Tracking channels values (mask[1])

## 7.7 Tracking

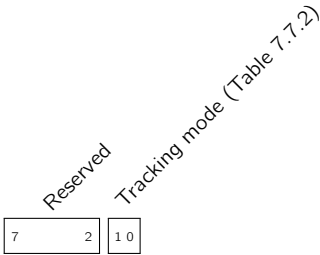
Satellite code and carrier-phase tracking messages from the device.

### MSG\_TRACKING\_STATE — 0x0013

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
$9N + 0$	1	u8		<code>states[N].state</code>	Status of tracking channel
$9N + 1$	2	u16		<code>states[N].sid.sat</code>	Constellation-specific satellite identifier
$9N + 3$	1	u8		<code>states[N].sid.code</code>	Signal constellation, band and code
$9N + 4$	1	u8		<code>states[N].sid.reserved</code>	Reserved
$9N + 5$	4	float	dB Hz	<code>states[N].cn0</code>	Carrier-to-noise density
$9N$					Total Payload Length

Table 7.7.1: MSG\_TRACKING\_STATE 0x0013 message structure



Field 7.7.1: Status of tracking channel (`state`)

Value	Description
0	Disabled
1	Running

Table 7.7.2: Tracking mode values (`state[0:1]`)

**MSG\_TRACKING\_IQ — 0x001C**

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

Offset (bytes)	Size (bytes)	Format	Units	Name	Description
0	1	u8		<code>channel</code>	Tracking channel of origin
1	2	u16		<code>sid.sat</code>	Constellation-specific satellite identifier
3	1	u8		<code>sid.code</code>	Signal constellation, band and code
4	1	u8		<code>sid.reserved</code>	Reserved
$8N + 5$	4	s32		<code>corrs[N].I</code>	In-phase correlation
$8N + 9$	4	s32		<code>corrs[N].Q</code>	Quadrature correlation
$8N + 5$					Total Payload Length

Table 7.7.3: MSG\_TRACKING\_IQ 0x001C message structure

## 7.8 User

Messages reserved for use by the user.

### **MSG\_USER\_DATA — 0x0800**

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]		<b>contents</b>	User data payload
	$N$				Total Payload Length

Table 7.8.1: MSG\_USER\_DATA 0x0800 message structure