
Jupiter GPS receiver module

Designer's guide

(11/12/T/Pico/Pico T series)

Related products

Jupiter 11 (low power)

- Development kit TU10-D007-051

Jupiter 11 (standard 5 V)

- Development kit TU10-D007-061

Jupiter 11 (dead-reckoning)

- Development kit TU10-D007-101

Jupiter 12 (standard)

- Development kit TU10-D007-351

Jupiter 12 (dead-reckoning)

- DR Development kit TU10-D007-352

Jupiter Pico (standard)

- Development kit TU10-D007-361

Jupiter Pico (timing)

- Development kit TU10-D007-363

Related documents

Jupiter T

- Product brief LA010039

- Data sheet LA010050

Jupiter 12

- Product brief LA010040

- Data sheet LA010065

Jupiter Pico (and Pico T)

- Product brief LA010041

- Data sheet LA010066

- Data sheet LA010093

Jupiter series (T/12/Pico/Pico T)

- Development kit: Quick start guide LA010088

- Development kit: Guide LA010089

- DR receiver: Gyro application note LA010090

Contents

Features	5
1.0 Introduction.....	6
1.1 Product overview	6
1.1.1 Description.....	6
1.1.2 Receiver architecture	6
2.0 Hardware interface	8
3.0 Serial data I/O interface	8
3.1 Binary message format and word structure	8
3.1.1 Binary message format	8
3.1.2 Word structure.....	8
3.2 Binary message header	9
3.2.1 Message header word 1	9
3.2.2 Message header word 2	9
3.2.3 Message header word 3	9
3.2.4 Message header word 4	9
3.2.5 Message header word 5	10
3.2.6 Log request messages	10
3.3 Binary message data	10
3.4 NMEA messages, format, and sentence structure	10
3.4.1 NMEA output messages	10
3.4.2 NMEA input messages	11
3.4.3 NMEA message format.	11
3.4.5 NMEA-0183 approved sentences	11
3.4.6 Proprietary sentences.....	11
3.4.7 Checksum	11
3.5 Jupiter binary data messages	14
3.5.1 Binary output message descriptions.....	14
3.5.1.1 Message 1000 (geodetic position status output)	14
3.5.1.2 Message 1002 (channel summary).....	16
3.5.1.3 Message 1003 (visible satellites)	17
3.5.1.4 Message 1005 (DGPS Status).....	18
3.5.1.5 Message 1007 (channel measurement).....	19
3.5.1.6 Message 1009 (reduced ECEF position status output)	20
3.5.1.7 Message 1011 (receiver ID)	21
3.5.1.8 Message 1012 (user settings output)	22
3.5.1.9 Message 1100 (built-in test results)	23
3.5.1.10 Message 1108 (UTC time mark pulse output).....	24
3.5.1.11 Message 1110 (frequency standard parameters in use)	25
3.5.1.12 Message 1117 (power management duty cycle in use).	26
3.5.1.13 Message 1130 (serial port communication parameters in use).	27
3.5.1.14 Message 1135 (EEPROM Update).	29
3.5.1.15 Message 1136 (EEPROM status).....	30
3.5.1.16 Message 1160 (frequency standard table output data).	31
3.5.1.17 Message 1180 (flash boot status).	32
3.5.1.18 Message 1190 (error/status)	32
3.5.2 Binary input message descriptions.	33
3.5.2.1 Message 1200 (geodetic position and velocity initialisation)	33
3.5.2.2 Message 1210 (user-defined datum).....	34
3.5.2.3 Message 1211 (map datum select).	34
3.5.2.4 Message 1212 (satellite elevation mask control).	35
3.5.2.5 Message 1213 (satellite candidate select).	35
3.5.2.6 Message 1214 (DGPS control)	36
3.5.2.7 Message 1216 (cold start control)	36
3.5.2.8 Message 1217 (solution validity input).....	37
3.5.2.9 Message 1219 (user-entered altitude input).	38
3.5.2.10 Message 1220 (application platform control).	39
3.5.2.11 Message 1221 (nav configuration).	40
3.5.2.12 Message 1300 (perform built-in test command).	40

3.5.2.13 Message 1303 (restart command)	41
3.5.2.14 Message 1310 (frequency standard input parameters)	42
3.5.2.15 Message 1317 (power management control)	43
3.5.2.16 Message 1330 (serial port communication parameters)	44
3.5.2.17 Message 1331 (message protocol control)	45
3.5.2.18 Message 1350 (factory calibration input).....	45
3.5.2.19 Message 1351 (raw DGPS RTCM SC-104 data).....	46
3.5.2.20 Message 1360 (frequency standard table input data)	47
3.5.2.21 Message 1380 (flash reprogram)	47
3.6 Jupiter NMEA data messages	48
3.6.1 NMEA output message descriptions	48
3.6.1.1 Navman proprietary Built-In Test (BIT) results	48
3.6.1.2 Navman proprietary error/status (ERR).....	49
3.6.1.3 GPS fix data (GGA).....	49
3.6.1.4 GPS satellites active and DOP (GSA)	50
3.6.1.5 GPS satellites in view (GSV).....	50
3.6.1.6 Navman proprietary receiver ID (RID)	51
3.6.1.7 Recommended minimum specific GPS data (RMC).....	52
3.6.1.8 Course over ground and ground speed (VTG)	53
3.6.1.9 Navman proprietary Jupiter channel status (ZCH)	54
3.6.2 NMEA input message descriptions	55
3.6.2.1 Navman proprietary built-in test command message (IBIT)	55
3.6.2.2 Navman proprietary log control message (ILOG)	55
3.6.2.3 Navman proprietary receiver initialisation message (INIT)	56
3.6.2.4 Navman proprietary protocol message (IPRO)	57
3.6.2.5 Standard query message (Q)	57
4.0 Jupiter GPS receiver operation.....	58
4.1 Internal (on board) data sources	58
4.1.1 Static Random Access Memory (SRAM).....	58
4.1.2 Real-time clock (RTC).....	58
4.1.3 Electrically Erasable Programmable Read- Only Memory (EEPROM)	58
4.1.4 Read-Only Memory (ROM).....	58
4.2 Initialisation	58
4.2.1 Definition	58
4.2.2 Position, Velocity, Time (PVT) data.....	58
4.2.3 Satellite ephemeris	58
4.2.4 Satellite almanac	58
4.2.5 Universal Time Coordinated (UTC) and ionospheric parameters	58
4.3 Configuration	59
4.3.1 Definition	59
4.3.2 Geodetic datums.....	59
4.3.3 Satellite selection	59
4.3.4 Differential GPS (DGPS) control	60
4.3.5 Cold start control	60
4.3.6 Solution validity criteria.....	60
4.3.7 User-entered altitude	60
4.3.8 Vehicle platform select	60
4.3.9 Navigation control.....	60
4.3.10 Configuration straps.....	60
4.3.10.1 National Marine Electronics Association (NMEA) Select	60
4.3.10.2 ROM defaults	60
4.4 Start-up modes	60
4.4.1 Warm start.....	60
4.4.2 Initialised start.....	60
4.4.3 Cold start	60
4.4.4 Frozen start.....	61
4.5 Satellite management.....	61
4.5.1 Visible list generation	61
4.5.1.1 Dilution Of Precision (DOP)	61
4.5.2 Acquisition modes	62
4.5.2.1 Sequential acquisition	62

4.5.2.2 Parallel acquisition.....	62
4.5.2.3 Adaptive threshold-based signal detection.....	62
4.5.2.4 Overall search process.....	62
4.5.3 Data collection.....	62
4.5.3.1 Ephemeris.....	62
4.5.3.2 Almanac.....	62
4.5.3.3 UTC and ionospheric corrections.....	62
4.6 Navigation.....	64
4.6.1 Geodetic datums.....	64
4.6.1.1 User selection of geodetic datums.....	64
4.6.1.2 User defined datums.....	64
4.6.2 Platform class.....	65
4.6.2.1 Pedestrian.....	65
4.6.2.2 Automotive.....	65
4.6.2.3 Aircraft.....	65
4.6.3 Navigation cycle.....	65
4.6.3.1 State propagation.....	65
4.6.3.2 Measurement processing.....	65
4.6.3.3 Altitude processing.....	65
4.6.3.4 Position pinning.....	65
4.6.3.5 Ground track smoothing.....	66
4.6.4 Solution validity.....	66
4.6.4.1 Altitude measurement validity criterion.....	66
4.6.4.2 DGPS used validity criterion.....	66
4.6.4.3 Number of satellites used validity criterion.....	66
4.6.4.4. Maximum EHPE validity criterion.....	67
4.6.4.5 Maximum EVPE validity criterion.....	67
4.6.5 Mean Sea Level (MSL).....	67
4.6.6 Magnetic variation.....	67
4.7 Support functions.....	67
4.7.1 Serial communication interfaces.....	67
4.7.1.1 The host port.....	67
4.7.1.2 The auxiliary port.....	68
4.7.2 EEPROM services.....	68
4.7.3 RTC services.....	68
4.7.4 Differential GPS (DGPS).....	68
4.7.4.1 The RTCM protocol.....	69
4.7.4.2 The RTCM message types.....	69
4.7.4.3 Compliance with RTCM SC-104 requirements.....	69
4.7.4.4 DGPS initialisation and configuration.....	69
4.7.4.5 Disabling DGPS operation.....	70
4.7.4.6 DGPS reset.....	70
4.7.4.7 DGPS status request.....	70
4.7.5 Built-In Test (BIT).....	70
4.7.5.1 Interpreting BIT results.....	70
Appendix A: Acronyms, abbreviations, and glossary.....	72
Appendix B: References.....	76
APPENDIX C: NAVSTAR GPS operation.....	76
APPENDIX D: Frequently Asked Questions (FAQ).....	81
APPENDIX E: Reference ellipsoids and datum tables for Jupiter and NavCore receivers.....	82
APPENDIX F: 2 x 10 pin field connector information.....	89
APPENDIX G: RG-142 and RG-316 Specifications.....	89
Typical Specification for RG-316:.....	89
I. Electrical Characteristics:.....	89
II. Physical Characteristics:.....	89
<i>measurement processor</i>	80
<i>differential data processor</i>	80

Features

The Jupiter series of GPS receivers offers the following physical, operational, and support features:

- OEM product development that is fully supported through application's engineering.
- compact GPS receiver footprint.
- 12 parallel satellite tracking channels.
- supports NMEA-0183 data protocol.
- direct, differential RTCM SC-104 data capability for improved positioning accuracy (available in both Navman binary and NMEA host modes.)
- static navigation enhancements to minimise wander due to SA (Selective Availability).
- designed for passive or active antennas for lowest system cost.
- adaptive threshold-based signal detection for improved reception of weak signals.
- maximum navigation accuracy achievable with the Standard Positioning Service (SPS).
- enhanced TTFB upon power-up when in a 'keep-alive' power condition before start-up.
- meets strict shock and vibration requirements including low-frequency vibration.
- automatic altitude hold mode from three-dimensional to two-dimensional navigation.
- automatic cold start acquisition process (when no initialisation data is entered by user).
- maximum operational flexibility and configurability via user commands.
- ability to accept externally supplied initialisation data.
- three-satellite navigation start-up from acquisition.
- user selectable satellites.
- user selectable visible satellite mask angle.

1.0 Introduction

This document provides technical information common to the entire Navman Jupiter series.

Navman's Jupiter series of Global Positioning System (GPS) receivers are single-board, 12 parallel-channel receiver engines. Each board is intended as a component for an Original Equipment Manufacturer (OEM) product.

GPS satellites, in various orbits around the Earth, broadcast Radio Frequency (RF) ranging codes and navigational data messages. The Navman Jupiter series GPS receivers continuously track all 'visible' satellites and decode all available signals from them, producing a highly accurate and robust navigation solution.

The Jupiter series receivers are designed for high performance and maximum flexibility in a wide range of OEM applications including handhelds, panel mounts, sensors, and in-vehicle automotive products. These highly integrated digital receivers incorporate two custom SiRF devices that have the SiRF Jupiter chip set: the RF1A and the Scorpio Digital Signal Processor (DSP). The combination of custom devices minimises the receivers' size and satisfies harsh industrial requirements.

1.1 Product overview

1.1.1 Description

The receivers require DC power and a GPS signal from a passive or active antenna. To provide the lowest total system cost with minimal power consumption, each of the receivers provides only those components that are required for the majority of applications (e.g. if a passive antenna can be used with a short cable, no pre-amplifier is required).

The all-in-view tracking of Jupiter series receivers provides robust performance in applications that require high vehicle dynamics or that operate in areas of high signal blockage, such as dense urban centres. By continuously tracking all visible GPS satellites and using all of the measurements to produce an 'over-determined' and 'smoothed' navigation solution, the Jupiter receiver provides a solution that is relatively immune to blockage induced position jumps that can occur in other receivers with fewer channels.

The 12-channel architecture provides rapid Time-To First Fix (TTFF) under all start-up conditions. The best TTFF performance is normally achieved when time of day and current position estimates are provided to the receiver. However, the flexible

Jupiter signal acquisition system takes advantage of all available information to provide a rapid TTFF. Acquisition is guaranteed under all initialisation conditions as long as available satellites are not obscured.

To minimise TTFF following a power interruption, each of the Jupiter receivers can accept external voltage to maintain power to the Static Random Access Memory (SRAM) and Real-Time Clock (RTC) for periods following the loss of primary power. The use of external voltage assures the shortest possible TTFF following a short power interruption. The OEM may extend the operation of the RTC by providing stand-by power on a connector pin, in which case a short TTFF is achieved by using the RTC time data and prior position data from the receiver's Electrical Erasable Programmable Read-Only Memory (EEPROM).

The Jupiter series supports two dimensional (2D) operation when less than four satellites are available or when required by operating conditions. Altitude information required for 2D operation is determined by the receiver or may be provided by the OEM.

The Jupiter receivers contain two independent serial ports, one of which is configured for primary input and output data flow using the National Marine Electronics Association (NMEA) 0183 format or Navman binary message format. The second port is used to receive Differential GPS (DGPS) corrections in the Radio Technical Commission For Maritime Services (RTCM) SC-104 format. The receivers support DGPS operations for improved accuracies over standard GPS.

A complete description of the serial data interface for the entire Jupiter series of GPS receivers is contained in this document.

For applications that require timing synchronisation to GPS accuracies, the Jupiter receivers provide an output timing pulse that is synchronised to one second Universal Time Coordinated (UTC) boundaries.

1.1.2 Receiver architecture

Figure 1-2 illustrates the internal architecture of the Jupiter receivers. Each receiver is designed around two custom SiRF devices that contain most of the required GPS functionality.

1. The RF1A, which contains all the RF down-conversion and amplification circuitry, and which presents sampled data to the Scorpio device.

2. The Scorpio device, which contains an integral microprocessor and all GPS specific signal processing hardware.

In addition, memory and other supporting components configure the receiver into a complete navigation system. Figure 1-3 illustrates an

architecture that might be used to integrate a particular Jupiter receiver with an application processor that drives peripheral devices such as a display and keyboard. The interface between the application's processor and the Jupiter receiver is through the serial data interface.

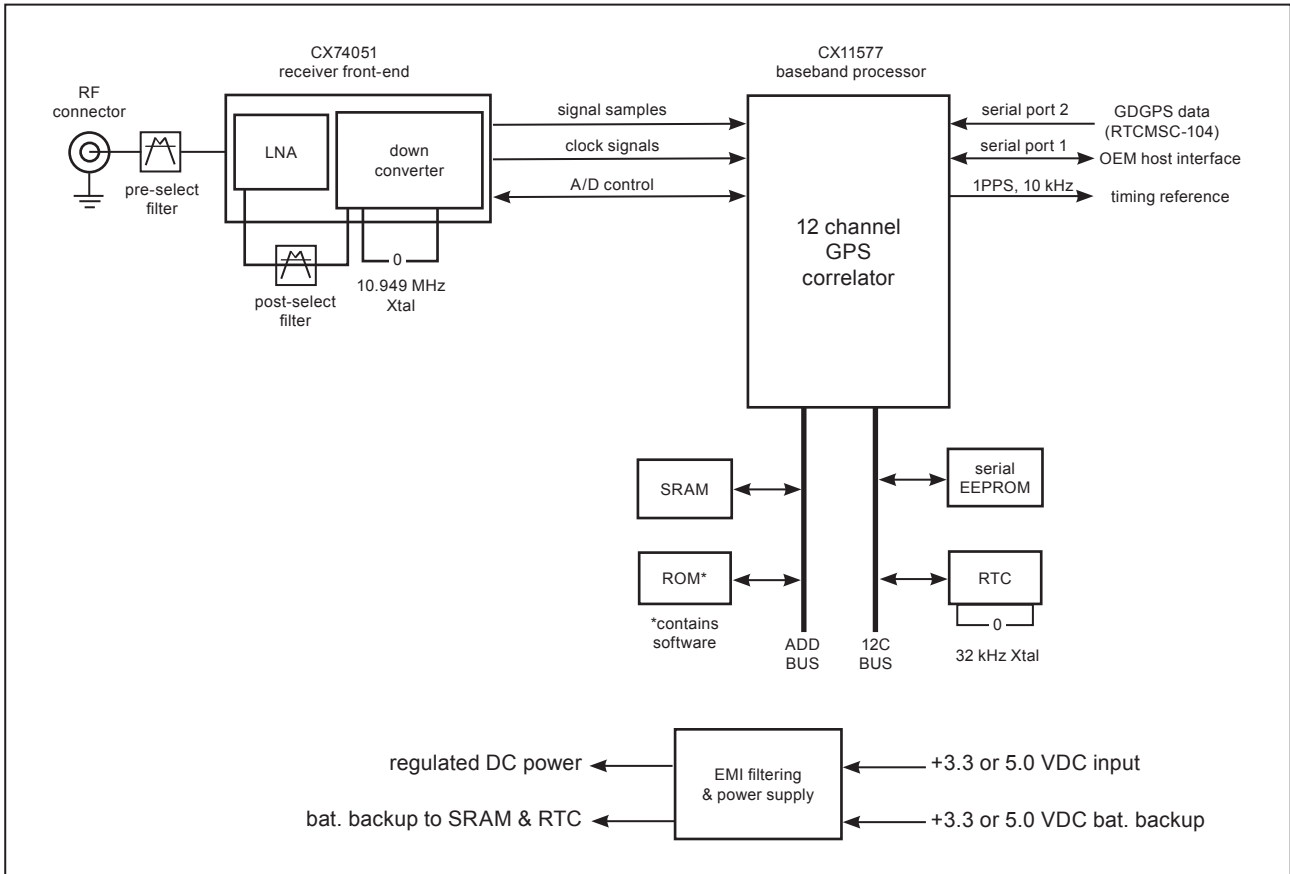


Figure 1-2 Internal Jupiter architecture

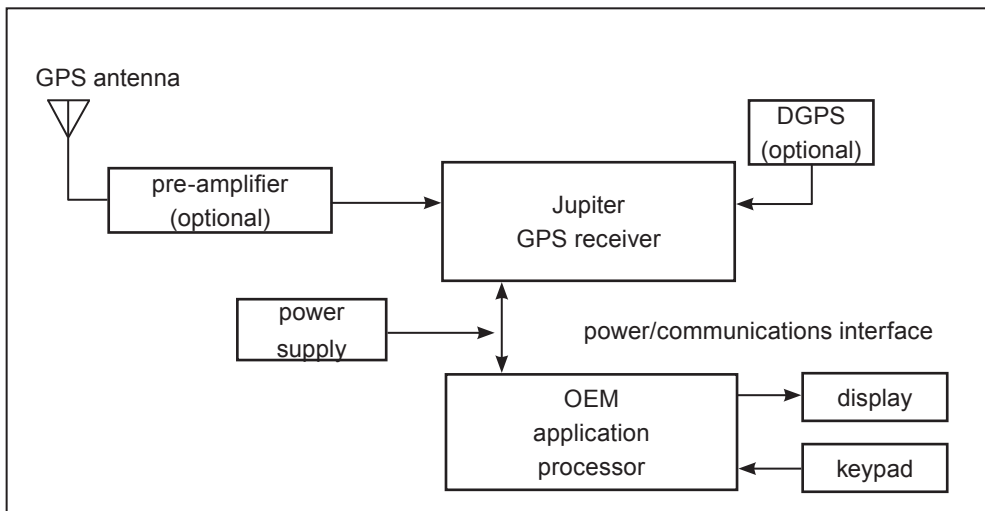


Figure 1-3 Possible Jupiter/OEM architecture

2.0 Hardware interface

Details of the specific Jupiter GPS receiver's electrical interface are contained in the applicable data sheet for the receiver (the latest Jupiter series data sheets and product briefs can be downloaded from the Navman OEM website at www.navman.com/oem/). For information about the 2 x 10 pin field connector, see Appendix F.

3.0 Serial data I/O interface

This section describes the formats of the two types of messages that can be communicated across the serial data interface for the Jupiter GPS receivers. The structure and contents of each binary message are described in section 3.2. The structure and contents of each National Marine Electronics Association (NMEA) message is described in section 3.3.

3.1 Binary message format and word structure

3.1.1 Binary message format

The input/output binary data stream format is a low byte/high byte pattern. Each byte is output with its Least Significant Bit (LSB) first, followed by its higher order bits, ending with the Most Significant Bit (MSB) of the data byte.

The binary message format is almost identical to that used by the previous NavCore/MicroTracker series of receivers, except that all floating point values are now represented as fixed-point integer numbers with explicit or implied scale factors.

Each binary message consists of a header portion and a data portion, each with its own checksum. Each message will have a header, but some messages may not have data. Message acknowledgements are in the form of a header, and message requests are also made using headers. Table 3-1 shows the data types used to define the elements of the binary interface messages.

3.1.2 Word structure

An integer is defined as 16 bits. While offsets are incorporated in the message description tables, the most convenient specification of memory layout in application implementation is likely to be a structure definition. If the item is a fixed point quantity, the value of the LSB of the integer is given.

To convert a fixed point item to a floating point variable, the integer representation is floated and multiplied by the resolution. When converting to float, consideration must be given to the range and resolution of the item to ensure that the type of float selected for the conversion has an adequate mantissa length to preserve the accuracy of the data item. Triple word items may require scaling portions of the variable separately and then adding them in floating point form.

Composite words may have independent definitions for each bit field in the word. Flag bits are either zero (false) or one (true). All bits that are designated as reserved within the bit descriptions of binary data have undefined values for outputs and must be set to zero for inputs.

Type	Abbreviation	Words (Note 1)	Bits	Maximum range
Bit (Note 2)	Bit	n/a	0 to 15	0 to 1
Character (Note 3)	C	n/a	8	ASCII 0 to 255
Integer	I	1	16	-32768 to +32767
Double integer	DI	2	32	-2 147 483 648 to +2 147 483 647
Triple integer	TI	3	48	-140 737 488 355 328 to + 140 737 488 355 327
Unsigned integer	UI	1	16	0 to 65 535
Unsigned double integer	UDI	2	32	0 to 4 294 967 295
Unsigned triple integer	UTI	3	48	0 to 281 474 976 710 656

Note 1: The term 'word' is used throughout this document to specify a quantity which occupies 16 bits of storage.
 Note 2: Data items using bit storage are specified with a format of w.b, where 'w' is the word number and 'b' is the bit number (0-15,0 LSB) within the word. Multiple-bit items (bit fields) are indicated by a range of 'word.bit' values (e.g. 8.4-8.7).
 Note 3: Although the AAMP2 processor and C compiler use 16-bit character representations, this data interface will use the more common 8-bit representation. The Jupiter receiver software will pack/unpack the character data internally as needed.

Table 3-1 Binary message data type

High Byte		Low Byte		
1000	0001	1111	1111	Word 1
MSB	LSB	MSB	LSB	
Message ID				Word 2
Data Word Count				Word 3
DCL0 QRAN 00XX XXXX				Word 4
Header Checksum				Word 5

Figure 3-1 Binary message header format

3.2 Binary message header

The binary message header format has been modified slightly from the NavCore V format to accommodate message logging requests. The format of the new message header is shown in Figure 3-1.

3.2.1 Message header word 1

Each input/output message starts with a synchronisation word of the form 0x81FF_{HEX} with DEL (255 decimal) occupying the first eight bits followed by the Start Of Header (SOH) (129 decimal) occupying the second eight bits of the synchronisation word.

3.2.2 Message header word 2

Word 2 contains the numeric message ID. For example, word 2 for Message ID 1000 would be:

High Byte		Low Byte	
0000	0011	1110	1000
MSB	LSB	MSB	LSB

or 0x03E8_{HEX}.

3.2.3 Message header word 3

Word 3 contains the word count for the data portion of the message. The word count does not include the data checksum word. A zero data word count indicates a 'header-only' message.

3.2.4 Message header word 4

The fourth word of the message header is a 16-bit field allocated to protocol and message related flags. These flag bits extend control over ACK/NAK requests and implement message logging requests. The zero's represented in the word 4 field shown in Figure 3-1 are reserved bits and should be set to zero within this word.

The ACK/NAK control mechanism gives the user the ability to request either ACK or NAK, or both,

independently for each message request. The user sets the request (R) bit and either the acknowledge (A) bit or negative acknowledge (N) bit, or both, to select the proper acknowledge behaviour. With this approach, the user can configure requests only to be NAKed, alerting the user when a problem arises without incurring the overhead necessary to continuously process ACKs.

The lower six bits of the flags word can be used as an additional input identifier. This identifier is not explicitly processed by the receiver; it is echoed back, in the same location, as part of the header in ACK/NAK responses. This feature allows the user to uniquely distinguish which input message an acknowledgement corresponds to when multiple input messages with the same message ID were processed during a particular period of time. The flags word now supports message logging requests. The connect (C) and disconnect (D) bits are used to enable and disable, respectively, message outputs, and can be used either independently or in conjunction with the log request bits.

A 'header-only' message, with a message ID and the connect bit set, enables the specified message with existing timing characteristics. Likewise, a header-only message, with message ID and the disconnect bit set, disables the specified message.

Trigger (on time, on update)	Word 6
Interval (sec)	Word 7
Offset (sec)	Word 8
Data Checksum	Word 9

Figure 3-2 Standard log request message format (data portion)

A message with both connect and disconnect bits is ignored. Note that enabling and disabling a message does not modify its timing characteristics (trigger, interval, or offset). A log request with the connect bit set will set up the message's timing characteristics and then enable the message. Similarly, for a combined log and disable request, the message will be disabled after the timing characteristics are set. To disable all messages, set the message ID to FFFF_{HEX} (all bits set) and set the disconnect (D) bit.

Setting the query (Q) request bit will output the message specified by the message ID one time

during the next output interval. Standard log requests will be accepted if the log (L) bit is set and if the required data parameters are present in the data portion of the request message.

3.2.5 Message header word 5

Word 5 of the message header is the data checksum, used to validate the header portion of the message. It is computed by summing (modulo 216) all words (including the word containing DEL and SOH) contained in the header and then performing a two's complement on the sum.

$$\text{SUM} = \text{Mod } 2^{16} \sum_{i=1}^4 \text{word}(i)$$

The computation of the header checksum may be expressed mathematically as:

if sum = -32768, header checksum = SUM; else header checksum = -SUM

where:

- Unary negation is computed as the two's complement of a 16-bit data word.
- Mod 216 indicates the least 16 bits of an arithmetic process. That is, carry bits from bit position 16 are ignored.
- The summation is the algebraic binary sum of the words indicated by the subscript i.
- The -32768 sum value must be treated as a special case since it cannot be negated.

(NOTE: A CURRENT BUG CAUSES CHECKSUM ERRORS FOR A VALUE OF ZERO or -32768)

3.2.6 Log request messages

Figure 3-2 shows the format of the data portion of standard log request messages. The ranges for words 6, 7, and 8 of these messages are as follows:

Trigger: 0 = on time, 1 = on update

Interval: 0 to 65535 seconds (an interval of zero produces a query as if the query bit [Q] in word 4 of the message header has been set).

Offset relative to the next even minute, zero to 60 seconds. An offset of zero specifies an initial output relative to the current time, an offset of 60 specifies an initial output seconds into the next minute.

When the Trigger field is set to 'on time' (integer value 0), the first output will occur at the next 'offset' seconds into the minute, and will repeat every 'interval' seconds thereafter. When the trigger field is set to 'on update', the specified message will be output only when the data is updated (e.g. when satellite almanac is collected).

3.3 Binary message data

The data portion of a binary message, if it exists, can be variable in length, as specified by the

data word count found in the header. The data checksum follows the data and is not included in the data word count.

The data checksum is a 16-bit word used to validate the data portion of the message. It is transmitted as the last word of any message containing data (see Figure 3-2).

When the word count field is zero, the data checksum does not exist. It is computed by summing (modulo 216) all words in the data portion of the message and then complementing that sum. The mathematical expression for the data checksum is:

$$\text{SUM} = \text{Mod } 2^{16} \sum_{i=1}^{5+n} \text{word}(i)$$

If sum = -32768, data checksum = SUM; else data checksum = -SUM

where:

- Unary negation is computed as the two's complement of a 16-bit data word.
- Mod 216 indicates the least 16 bits of an arithmetic process. That is, carry bits from bit position 16 are ignored.
- The summation is the algebraic binary sum of the words indicated by the subscript (i).
- The -32768 sum value must be treated as a special case since it cannot be negated.

(NOTE: A CURRENT BUG CAUSES CHECKSUM ERRORS FOR A VALUE OF ZERO or -32768)

Data elements identified as 'reserved' must be set to 5+N zero for input messages and are undefined for output messages. All data storage that is not explicitly 1-6 defined should be handled as if marked 'reserved'. Unless otherwise stated, the resolution of each numeric data item is one integer unit, as specified by that item in the 'units' field.

3.4 NMEA messages, format, and sentence structure

NMEA messages are output in response to standard Query (Q) or proprietary Log Control (ILOG) messages as described in Section 3.6. The timing of output messages is synchronised with the time mark output event.

3.4.1 NMEA output messages

The following supported NMEA output messages comply with the NMEA-0183 version 2.01 standard:

GGA: GPS fix data

GSA: GPS DOP and active satellites

GSV: GPS satellites in view

RMC: recommended minimum specific GPS data

The Jupiter receiver also supports the following Navman proprietary output messages:

BIT: built-In test results

ERR: error/status

RID: receiver ID

ZCH: Jupiter channel status

These Navman proprietary messages conform to the message format described below.

3.4.2 NMEA input messages

The Jupiter receiver supports the following proprietary input messages:

IBIT: built-in test command, Navman proprietary

ILOG: log control, Navman proprietary

INIT: receiver initialisation, Navman proprietary

IPRO: protocol, Navman proprietary

The INIT message is used to command initialisation of the receiver and the IPRO message is used to change the message protocol. The first character of the message sentence is 'P,' followed by a three-character mnemonic code for Navman Systems Inc. (RWI) according to Appendix III of the NMEA -0183 standard.

3.4.3 NMEA message format.

All NMEA-0183 data messages are in ASCII form. Each message begins with ASCII \$ (24_{HEX}) and ends with ASCII <CR> <LF>(0D_{HEX} and 0A_{HEX}). The valid character set consists of all printable ASCII characters, 20_{HEX} to 7E_{HEX}, except for the reserved characters listed in Table 3-2.

Each NMEA message, or sentence, consists of a set of fields separated by a comma delimiter character. Each field can contain either a string of valid characters or no characters (null field). Valid characters must conform with the formats described in Table 3-3.

The maximum number of characters in a sentence is 82, consisting of a maximum of 79 characters between the starting delimiter '\$' and the terminating <CR> and <LF>. Since the number of data fields can vary from sentence to sentence, it is important that the 'listener' (or application software) locate fields by counting delimiters rather than counting the total number of characters received from the start of the sentence.

3.4.5 NMEA-0183 approved sentences

An approved NMEA-0183 sentence contains the following elements, in the order shown:

'\$' Start of the sentence (24_{HEX})

<address field> Talker identifier and sentence formatter.

[';<data field>] Zero or more data fields.

['* <checksum field>] Optional checksum field

<CR><LF> End of sentence delimiter (0D 0A_{HEX})

Note: Since the Jupiter receiver is a GPS device, the 'talker' identifier is always 'GP'.

3.4.6 Proprietary sentences

Proprietary sentences allow OEMs to transfer data that does not fall within the scope of approved NMEA sentences. A proprietary sentence contains the following elements, in the order shown:

'\$' start of the sentence (24_{HEX})

'P' proprietary sentence ID (50_{HEX})

<aaa> OEMs mnemonic code

[<valid characters, OEMs data>]

[['* <checksum field>] optional checksum field.

<CR><LF> end of sentence delimiter (0D 0A_{HEX}).

3.4.7 Checksum

The checksum is the 8-bit exclusive OR (no start or stop bits) of all characters in the sentence, including delimiters (except for the \$ and the optional * delimiters). The hexadecimal value of the most significant and least significant four bits of the result are converted to two ASCII characters (0 to 9, A to F) for transmission. The most significant character is transmitted first.

Character	Hex value	Decimal value	Description
<CR>	0D	13	Carriage return (end of sentence delimiter)
<LF>	0A	10	Line feed (end of sentence delimiter)
\$	24	36	Start of sentence delimiter
*	2A	42	Checksum field delimiter
,	2C	44	Field delimiter
!	21	33	Reserved
\	5C	92	Reserved
^	5E	94	Reserved
.	7E	126	Reserved

Table 3-2 NMEA reserved characters

Field Type	Symbol	Definition
Special format fields		
Status	A	Single character field: A = yes, data valid, warning flag clear V = no, data invalid, warning flag set
Latitude	1111.11	Fixed/variable length field (degrees/minutes.decimal) two fixed digits of degrees, two fixed digits of minutes, and a variable number of digits for decimal-fraction of minutes Note: Leading zeros always included for degrees and minutes to maintain fixed length (the decimal point and associated decimal-fraction are optional if full resolution is not required).
Longitude	yyyyy.yy	Fixed/variable length field (degrees/minutes.decimal) three fixed digits of degrees, two fixed digits of minutes and a variable number of digits for decimal-fraction of minutes. Note: Leading zeros always included for degrees and minutes to maintain fixed length (the decimal point and associated decimal-fraction are optional if full resolution is not required).
Time	hhmmss.ss	Fixed/variable length field (hours/minutes/seconds.decimal) two fixed digits of hours, two fixed digits of minutes, two fixed digits of seconds and a variable number of digits for decimal-fraction of seconds. Note: Leading zeros always included for hours, minutes, and seconds to maintain fixed length (the decimal point and associated decimal-fraction are optional if full resolution is not required).
Defined field		Some fields are specified to contain pre-defined constants, most often alpha characters. Such a field is indicated in the NMEA-0183 standard by the presence of one or more valid characters. The following characters and character strings used to indicate field types are excluded from the list of allowable characters: 'A', 'a', 'c', 'hh', 'hhmmss.ss', '1111.11', 'x', and 'yyyyy.yy'.
Numeric value fields		
Variable numbers	X.x	Variable length integer or floating point numeric field (optional leading and trailing zeros) Note: The decimal point and associated decimal-fraction are optional if full resolution is not required (eg 73.10 = 73.1 = 073.1 = 73).
Fixed HEX field	Hh__	Fixed length HEX numbers only, most significant bit on the left.
Information fields		
Variable text	Cn C	Variable length valid character field
Fixed alpha field	Aa__	Fixed length field of uppercase or lowercase alpha characters
Fixed number field	Xx__	Fixed length field of numeric characters
Fixed text field	Cc__	Fixed length field of valid characters
<p>Note 1: Spaces may only be used in variable text fields.</p> <p>Note 2: A negative sign ('-' or 2DHEX) is the first character in a field if the value is negative. The sign is omitted if the value is positive.</p> <p>Note 3: All data fields are delimited by a comma (,).</p> <p>Note 4: Null fields are indicated by no data between two delimiters.</p>		

Table 3-3 NMEA field type summary

Output message name	Message ID	Input message name	Message ID
Geodetic position status output (*)	1000	Geodetic position and velocity initialisation	1200
Channel summary (*)	1002	User-defined datum definition	1210
Visible satellites (*)	1003	Map datum select	1211
Differential GPS status	1005	Satellite elevation mask control	1212
Channel measurement	1007	Satellite candidate select	1213
ECEF position output	1009	Differential GPS control	1214
Receiver I D (**)	1011	Cold start control	1216
User-settings output	1012	Solution validity criteria	1217
Built-in test results	1100	User-entered altitude Input	1219
UTC time mark pulse output (*)	1108	Application platform control	1220
Frequency standard parameters in use	1110	Nav configuration	1221
Power management duty cycle in use	1117	Perform built-in test command	1300
Serial port communication parameters in use	1130	Restart command	1303
EEPROM update	1135	Frequency standard input parameters	1310
EEPROM status	1136	Power management control	1317
Frequency standard table output data	1160	Serial port communications parameters	1330
Flash boot status	1180	Factory calibration input	1350
Error/status	1190	Frequency standard table input data	1360
		Message protocol control	1331
		Raw DGPS RTCM SC-104 data	1351
		Flash re-program request	1380
(*) Enable by default at power-up			
(**) Once at power-up/reset			

Table 3-4 Jupiter binary data messages

3.5 Jupiter binary data messages

This section describes the binary data messages of the Jupiter GPS receiver. All output and input binary messages are listed in Table 3-4 together with their corresponding message IDs. Power-up default messages are also identified.

Binary messages are transmitted and received across the host port serial I/O interface (RS-232), default communication parameters are: 9600 bps, no parity, 8 data bits, 1 stop bit

3.5.1 Binary output message descriptions

This section provides details for each of the output binary messages.

3.5.1.1 Message 1000 (geodetic position status output)

This message outputs the receiver's estimate of position, ground speed, course over ground, climb rate, and map datum. A solution status indicates if the solution is valid (based on the solution validity criteria), the type of solution, and the number of measurements used to compute the solution.

The polar navigation flag is used to indicate that the solution estimate is too close to the North or South Pole to estimate longitude. When this flag is true, the longitude and true course outputs are invalid and are not updated. Users operating near the poles should use the 'ECEF position status output' message. (See Table 3-5.)

Message ID: 1000				
Rate: variable; defaults to 1 Hz				
Message length: 55 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4 294 967 295
8	Sequence number (Note 2)	I		0 to 32 767
9	Satellite measurement sequence number (Note 3)	I		0 to 32 767
Navigation solution validity (10.0-10.15)				
10.0	Solution invalid—altitude used (Note 4)	Bit		1 = true
10.1	Solution invalid—no differential GPS (Note 4)	Bit		1 = true
10.2	Solution invalid—not enough satellites in track (Note 4)	Bit		1 = true
10.3	Solution invalid—exceeded max EHPE (Note 4)	Bit		1 = true
10.4	Solution invalid—exceeded max EVPE (Note 4)	Bit		1 = true
10.5	Solution invalid—no DR measurements (Note 5)	Bit		1 = true
10.6	Solution invalid—no DR calibration (Note 6)	Bit		1 = true
10.7	Solution invalid—no concurrent DR calibration by GPS (Note 7)	Bit		1 = true
10.8-10.15	Reserved			
Navigation solution type (11.0-11.15)				
11.0	Solution type - propagated solution (Note 8)	Bit		1 = propagated
11.1	Solution type - altitude used	Bit		1 = altitude used
11.2	Solution type - differential	Bit		1 = differential
11.3	Solution type - PM	Bit		1 = RF off
11.4	Solution type - GPS (Note 9)	Bit		1 = true
11.5	Solution type - concurrent GPS calibrated DR (Note 10)	Bit		1 = true
11.6	Solution type - stored calibration DR (Note 11)	Bit		1 = true
11.7-11.15	Reserved			
12	Number of measurements used in solution	UI		0 to 12

Table 3-5 (1 of 2) Message 1000 (geodetic position status output)

Word No	Name	Type	Units	Range	Resolution
13	Non-DR link: polar navigation DR navigation link: Bit 0 = polar navigation Bit 15 to 1 = heading uncertainty standard deviation (Note 12)	Bit Bit UI	degrees	1 = true 1 = true 0 to 300	0.01
14	GPS week number	UI	weeks	0 to 32767	
15-16	GPS seconds from epoch	UDI	s	0 to 604799	
17-18	GPS nanoseconds from epoch	UDI	ns	0 to 999999999	
19	UTC day	UI	day	1 to 31	
20	UTC month	UI	month	1 to 12	
21	UTC year	UI	year	1980 to 2079	
22	UTC hours	UI	h	0 to 23	
23	UTC minutes	UI	min	0 to 59	
24	UTC seconds	UI	s	0 to 59	
25-26	UTC nanoseconds from epoch	UDI	ns	0 to 999999999	
27-28	Latitude	DI	rad	± 0 to $\pi/2$	10^{-8}
29-30	Longitude	DI	rad	± 0 to π	10^{-8}
31-32	Height	DI	m	± 0 to 50000	10^{-2}
33	Geoidal separation	1	m	± 0 to 200	10^{-2}
34-35	Ground speed	UDI	m/s	0 to 1000	10^{-2}
36	True course	UI	rad	0 to 2π	10^{-3}
37	Magnetic variation	1	rad	± 0 to $\pi/4$	10^{-4}
38	Climb rate	1	m/s	± 300	10^{-2}
39	Map datum (Note 13)	UI		0 to 188 and 300 to 304	
40-41	Expected horizontal position error (Note 14)	UDI	m	0 to 320000000	10^{-2}
42-43	Expected vertical position error (Note 14)	UDI	m	0 to 250000	10^{-2}
44-45	Expected time error (Note 14)	UDI	m	0 to 300000000	10^{-2}
46	Expected horizontal velocity error (Note 14)	UI	m/s	0 to 10000	10^{-2}
47-48	Clock bias (Note 14)	DI	m	± 0 to 9000000	10^{-2}
49-50	Clock bias standard deviation (Note 14)	DI	m	± 0 to 9000000	10^{-2}
51-52	Clock drift (Note 14)	DI	m/s	± 0 to 1000	10^{-2}
53-54	Clock drift standard deviation (Note 14)	DI	m/s	± 0 to 1000	10^{-2}
55	Data checksum				

Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.

Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.

Note 3: The satellite measurement sequence number relates the position solution data to a particular set of satellite measurements found in binary Messages 1002 and 1007 (channel summary message and channel measurement message, respectively).

Note 4: The value of this data item was initially set using the solution validity criteria message (Message 1217).

Note 5: Either no DR messages are being received or data has been detected as inconsistent with GPS.

Note 6: No calibration is available for DR measurements from concurrent GPS or from stored values.

Note 7: No calibration is available for DR measurements from concurrent GPS.

Note 8: It should be noted that bit zero of word 11 does not refer to a solution propagated by the navigation software. This bit is used to indicate if the solution was propagated by the serial I/O manager to generate a 1 Hz output message when no new navigation state data was available. This is an error condition potentially caused by a shortage of throughput in one cycle. It is unlikely to occur and is self correcting. Normal state propagation which occurs within the navigation software with or without measurements available for processing does not cause this bit to be set.

Note 9: Navigation is based on GPS alone. Current system or GPS/DR with no DR measurements available.

Note 10: DR is running with concurrent calibration by GPS.

Note 11: DR is running with calibration from stored values from prior operating session.

Note 12: An uncertainty value of 0x7FFF indicates unknown heading. A message value 0x000D indicates Polar navigation equals true and heading uncertainty SD equals 0.06 (hex value 0x000C).

Note 13: Appendix B contains map datum codes from 0 to 188. Codes 300 to 304 are user-defined.

Note 14: The data displayed by this field is not valid until the receiver is in navigation mode.

Table 3-5 (2 of 2) Message 1000 (geodetic position status output)

3.5.1.2 Message 1002 (channel summary)

This message provides a summary form of the satellite range measurements and signal tracking

information on a per- channel basis. The contents of the 'channel summary' message are described in Table 3-6

Message ID: 1002				
Rate: Variable; defaults to 1 Hz				
Message Length: 51 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4 294 967 295
8	Sequence number (Note 2)	I		0 to 32 767
9	Satellite measurement sequence number (Note 3)	I		0 to 32 767
10	GPS week number	UI	weeks	0 to 32 767
11-12	GPS seconds into week	UDI	s	0 to 604 799
13-14	GPS nanoseconds from epoch	UDI	ns	0 to 999 999 999
Channel summary data				
15.0+(3*n)	Measurement used (Note 4)	Bit		1 = used
15.1+(3*n)	Ephemeris available	Bit		1 = available
15.2+(3*n)	Measurement valid	Bit		1 = valid
15.3+(3*n)	DGPS corrections available	Bit		1 = available
16+(3*n)	Satellite PRN	UI		0 to 32
17+(3*n)	C/No	UI	dBHz	0 to 60
51	Data checksum			
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.</p> <p>Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.</p> <p>Note 3: The satellite measurement sequence number relates the position solution data to a particular set of satellite measurements found in binary Messages 1002 and 1007 (channel summary message and channel measurement message, respectively).</p> <p>Note 4: n = 0 to 11.</p>				

Table 3-6 Message 1002 (channel summary)

3.5.1.3 Message 1003 (visible satellites)

This message outputs the list of satellites visible to the receiver and their corresponding elevations and azimuths. The best possible DOPs, calculated

from this visible list, are also provided. The contents of the 'visible satellites' message are described in Table 3-7.

Message ID: 1003					
Rate: Variable; default on update					
Message Length: 51 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4 294 967 295	
8	Sequence number (Note 2)	I		0 to 32 767	
9	Best possible GDOP	I		0 to 99	10 ⁻²
10	Best possible PDOP	I		0 to 99	10 ⁻²
11	Best possible HDOP	I		0 to 99	10 ⁻²
12	Best possible VDOP	I		0 to 99	10 ⁻²
13	Best possible TDOP	I		0 to 99	10 ⁻²
14	Number of visible satellites	UI		1 to 12	
Visible satellite set (Note 3)					
15 + (3*j)	Satellite PRN (Note 4)	UI		0 to 32	
16 + (3*j)	Satellite azimuth	I	rad	±π	10 ⁻⁴
17 + (3*j)	Satellite elevation	I	rad	±π/2	10 ⁻⁴
51	Data checksum				
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.</p> <p>Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.</p> <p>Note 3: Only the satellite sets for the number of satellites reported in word 14 of this message are valid.</p> <p>Note 4: j = the number of visible satellites minus one when the number of visible satellites is greater than zero.</p>					

Table 3-7 Message 1003 (visible satellites)

3.5.1.4 Message 1005 (DGPS Status)

This message contains DGPS status information derived from the last set of differential corrections

processed by the receiver. The contents of the 'DGPS status' message are described in Table 3-8.

Message ID: 1005				
Rate: Variable				
Message Length: 25 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4 294 967 295
8	Sequence number (Note 2)	I		0 to 32 767
Status (9.0-9.15)				
9.0	Station health	Bit		1 = station bad
9.1	User disabled	Bit		1 = user disabled
9.2-9.15	Reserved			
10	Station ID	UI		0 to 1023
11	Age of last correction	UI	s	0 to 999
12	Number of available corrections	UI		0 to 12
Correction status per satellite (Note 3)				
j.0-j.5	Satellite PRN (Note 4)	UI		1 to 32
j.6	Local ephemeris	Bit		1 = ephemeris not available
j.7	RTCM corrections	Bit		1 = corrections not available
j.8	RTCM UDRE	Bit		1 = UDRE too high
j.9	Satellite health	Bit		1 = satellite data indicates bad health
j.10	RTCM satellite health	Bit		1 = RTCM source declares satellite bad
j.11	Corrections stale	Bit		1 = received stale corrections
j.12	IODE mismatch	Bit		1 = IODE mismatch
j.13-j.15	Reserved			
25	Data checksum			
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.</p> <p>Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.</p> <p>Note 3: Only the correction status words for the number of available corrections reported in word 12 of this message are valid.</p> <p>Note 4: The word number, j, ranges from 13 to 24.</p>				

Table 5-8 Message 1005 (DGPS status)

3.5.1.5 Message 1007 (channel measurement)

This message provides measurement and associated data for each of the receiver's

12 channels. The contents of the 'channel measurement' message are described in Table 3-9.

Message ID: 1007					
Rate: Variable					
Message Length: 154 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4 294 967 295	
8	Sequence number (Note 2)	I		0 to 32 767	
9	Satellite measurement sequence number (Note 3)	I		0 to 32 767	
Channel measurement data					
10 + 12*j	Pseudo-range (Note 4)	TI	m	$\pm 1.4^{14}$	10^{-3}
13 + 12*j	Pseudo-range rate	DI	m/s	$\pm 21 474 836$	10^{-3}
15 + 12*j	Carrier phase	TI	m	$\pm 1.4^{14}$	10^{-3}
18 + 12*j	Carrier phase bias	TI	m	$\pm 1.4^{14}$	10^{-3}
21 + 12*j	Phase bias count	UI		0 to 65 535	
154	Data checksum				
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.</p> <p>Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.</p> <p>Note 3: The satellite measurement sequence number relates the position solution data to a particular set of satellite measurements found in binary Messages 1002 and 1007 (channel summary message and channel measurement message, respectively).</p> <p>Note 4: j = 0 to 11</p>					

Table 3-9 Message 1007 (channel measurement)

3.5.1.6 Message 1009 (reduced ECEF position status output)

This message provides measurement and associated data for each of the receiver's

12 channels. The contents of the 'channel measurement' message are described in Table 3-10.

Message ID: 1009					
Rate: variable					
Message length: 22 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4 294 967 295	
8	Sequence number (Note 2)	I		0 to 32 767	
9	Satellite measurement sequence number (Note 3)	I		0 to 32 767	
ECEF navigation solution					
10-11	ECEF Position - X (Note 4)	DI	m	±0 to 9 000 000	10 ⁻²
12-13	ECEF Position - Y (Note 4)	DI	m	±0 to 9 000 000	10 ⁻²
14-15	ECEF Position - Z (Note 4)	DI	m	±0 to 9 000 000	10 ⁻²
16-17	ECEF Velocity - X (Note 4)	DI	m/s	±0 to 1000	10 ⁻²
18-19	ECEF Velocity - Y (Note 4)	DI	m/s	±0 to 1000	10 ⁻²
20-21	ECEF Velocity - Z (Note 4)	DI	m/s	±0 to 1000	10 ⁻²
22	Data checksum	UI			
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. The set time indicated is at the time the message is submitted to the output queue.</p> <p>Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.</p> <p>Note 3: The satellite measurement sequence number relates the position solution data to a particular set of satellite measurements found in binary Messages 1002 and 1007 (channel summary message and channel measurement message, respectively).</p> <p>Note 4: The data displayed by this field is not valid until the receiver is in navigation mode.</p>					

Table 3-10 Message 1009 (ECEF position output)

3.5.1.7 Message 1011 (receiver ID)

This message is output automatically at start-up after the receiver has completed its initialisation. It can be used to determine when the receiver is ready to accept serial input. Manual requests for

this message are also honoured. This message consists of five 20-byte (two characters per word), null-padded ASCII data fields. The contents of the 'receiver ID' message are described in Table 3-11.

Message ID: 1011				
Rate: variable (see above)				
Message length: 59 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4 294 967 295
8	Sequence number (Note 2)	I		0 to 32 767
9-18	Number of channels	C		
19-28	Software version	C		
29-38	Software date	C		
39-48	Options list (Note 3)	C		
49-58	Reserved	UI		
59	Data checksum			
Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.				
Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.				
Note 3: The options list is a bit-encoded configuration word represented as an ASCII four-digit hexadecimal number: bit 0 minimises ROM usage bit 1 minimises RAM usage bits 2-15 reserved				

Table 3-11 Message 1011 (receiver ID)

3.5.1.8 Message 1012 (user settings output)

This message provides a summary of the settings for many of the user-definable parameters.

The contents of the 'user settings output' message are described in Table 3-12.

Message ID: 1012					
Rate: variable					
Message length: 22 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 2 147 483 647	
8	Sequence number (Note 2)	I		0 to 32 767	
Operational status (9.0-9.15)					
9.0	Power management enabled	Bit		1 = enabled	
9.1	Cold start disabled	Bit		1 = disabled	
9.2	DGPS disabled	Bit		1 = disabled	
9.3	Held altitude disabled	Bit		1 = disabled	
9.4	Ground track smoothing disabled	Bit		1 = disabled	
9.5	Position pinning disabled	Bit		1 = disabled	
9.6	Quality measurement disabled (Note 3)	Bit		1 = disabled	
9.7	Jamming detection enabled	Bit		1 = enabled	
9.8	Active antenna	Bit		1 = active, 0 = passive	
9.9-9.15	C/No threshold		dBHz	0 to 50	
10	Cold start time-out	UI	s	0 to 32 767	
11	DGPS correction time-out	UI	s	0 to 32 767	
12	Elevation mask	I	rad	0 to $\pm\pi/2$	10^{-3}
Selected candidates					
13.0-14.15	Selected candidate (Note 4)	Bit		1 = included candidate	
Solution validity criteria (15-20)					
15.0	Attitude not used	Bit		1 = required	
15.1	Differential GPS	Bit		1 = required	
15.2	DR measurement	Bit		1 = required	
15.3	GPS calibration	Bit		1 = required	
15.4	GPS only	Bit		1 = required	
155-15.15	Reserved				
16	Number of satellites in track required	UI		0 to 12	
17-18	Minimum expected horizontal error	UDI	m	0 to 1000	10^{-2}
19-20	Minimum expected vertical error	UDI	m	0 to 1000	10^{-2}
21	Application platform	UI		0 = default, 1 = static 2 = pedestrian 3 = marine (lakes) 4 = marine (sea level) 5 = land (auto), 6 = air	
22	Data checksum				
<p>Note 1: Set time is an internal 10 ms (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but provides sequence of events knowledge. The T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.</p> <p>Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.</p> <p>Note 3: If this bit is set, the receiver only uses 'perfect' measurements (i.e. without errors in tracking status or data). If the bit is not set, measurements that are not perfect, but still good enough to use under SPS conditions, are used.</p> <p>Note 4: The selected candidate list is a 32-bit flag, each bit representing candidate selection status for one satellite (ie bit 0 = SV1 status, bit 1 = SV2 status, bit 31 = SV32 status).</p>					

Table 3-12 Message 1012 (user-settings output)

3.5.1.9 Message 1100 (built-in test results)

This message provides detailed test results of the last BIT commanded since power-up. It is output automatically after the completion of a commanded

BIT, but may also be queried manually as needed. Non-zero device failure status indicates failure. The contents of the 'BIT results' message are described in Table 3-13.

Message ID: 1100					
Rate: Variable					
Message Length: 20 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4 294 967 295	
8	Sequence number (Note 2)	I		0 to 32 767	
9	ROM failure (Note 3)	UI			
10	RAM failure (Note 3)	UI			
11	EEPROM failure (Note 3)	UI			
12	Dual port RAM failure (Note 3)	UI			
13	Digital signal processor (DSP) failure (Note 3)	UI			
14	Real-time clock (RTC) failure (Note 3)	UI			
15	Serial port 1 receive error count	UI		0 to 65 535	
16	Serial port 2 receive error count	UI		0 to 65 535	
17	Serial port 1 receive byte count	UI		0 to 65 535	
18	Serial port 2 receive byte count	UI		0 to 65 535	
19	Software version	UI		0.00 to 655.35	0.01
20	Data checksum				

Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.

Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.

Note 3: A value of zero indicates a test has passed. A non-zero value indicates a device failure. Missing devices will be reported as failures. Therefore, the OEM's BIT pass/fail should ignore words for components that are not in the system under test. Notice that the Dual Port RAM Failure test is currently not implemented. Therefore, word 12 will report a value of zero.

Table 3-13 Message 1100 (BIT Results)

3.5.1.10 Message 1108 (UTC time mark pulse output)

This message provides the UTC seconds into week associated with the UTC synchronised time mark pulse. This message is output approximately

400 milliseconds before the time mark pulse strobe signal. The contents of the 'UTC time mark pulse output' message are described in Table 3-14.

Message ID: 1108					
Rate: 1 Hz					
Message length: 20 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4 294 967 295	
8	Sequence number (Note 2)	I		0 to 32 767	
UTC time					
9-13	Reserved				
14-15	UTC Seconds Of Week	UDI	s	0 to 604 799	1 s
16	GPS to UTC time offset (integer part)	I	s	-32 768 to +32 767	1 s
17-18	GPS to UTC time offset (fractional part)	UDI	ns	0 to 999 999 999	1 ns
UTC time validity (19.0-19.15)					
19.0	Time mark validity	Bit		1 = true	
19.1	GPS/UTC sync	Bit		0 = GPS 1 = UTC	
19.2-19.15	Reserved				
20	Data checksum				
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.</p> <p>Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.</p>					

Table 3-14 Message 1108 (UTC time mark pulse output)

3.5.1.11 Message 1110 (frequency standard parameters in use)

This message outputs the parameters used to support the receiver's uncompensated crystal oscillator. The contents of the 'frequency standard parameters in use' message are described in Table 3-15.

Note: Message 1110 is primarily used to output key parameters to GPS systems without non-volatile storage. This is why the format of input Message 1310 is exactly the same—the output message is used to capture data, while the input message is used to restore data.

Message ID: 1110					
Rate: variable					
Message length: 22 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4 294 967 295	
8	Sequence number (Note 2)	I		0 to 32 767	
9	Frequency standard issue number (Note 3)	UI		0 to 65 535	
Temperature characteristic					
10	C0 (aging and calibration offset) (Note 4)	I	s/s	0 to $\pm 2^{-14}$	2^{-29}
11	C1 (linear term) (Note 4)	I	s/s/°C	0 to $\pm 2^{-20}$	2^{-35}
12	C2 (second order term) (Note 4)	I	s/s/(°C) ²	0 to $\pm 2^{-26}$	2^{-41}
13	C3 (third order term) (Note 4)	I	s/s/(°C) ³	0 to $\pm 2^{-32}$	2^{-47}
14	TINF (inflection point) (Note 4)	I	°C	0 to ± 100	0.01
Temperature dynamics					
15	D0 (Note 5)	I			
16	D1 (Note 5)	I			
Temperature sensor calibration					
17	TREF (calibration reference temperature) (Note 6)	I	°C	0 to ± 100	0.01
18	T0 (temperature sensor reading at TREF) (Note 6)	UI	counts	0 to 65 535	1
19	S0 (temperature sensor scale factor) (Note 6)	I	°C/count	0 to $\pm 2^{-3}$	2^{-18}
Uncertainty coefficients					
20	U0 (Note 7)	I	s/s	0 to $\pm 2^{-14}$	2^{-29}
21	U1 (Note 7)	I	s/s/°C	0 to $\pm 2^{-20}$	2^{-35}
22	Data checksum				
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.</p> <p>Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.</p> <p>Note 3: Unique identification of each update. This allows a different set of data to be in use while newer data are only stored to EEPROM. The issue number is preserved from run to run if non-volatile storage is available.</p> <p>Note 4: Defines a cubic in (T - TINF). Over a range of TINF+65 degrees C, each term can produce from 0.002 to 60 ppm, approximately.</p> <p>Note 5: Unused.</p> <p>Note 6: These parameters define the temperature sensor scaling according to the equation: $T = TREF + (TFILT - T0)S0$</p> <p>Note 7: Defines a linear equation in (T - TINF). Over a range of TINF +65°C, each term can produce from 0.002 to 60 ppm, approximately.</p>					

Table 3-15 Message 1110 (frequency standard parameters in use)

3.5.1.12 Message 1117 (power management duty cycle in use).

This message controls the use of power management in the receiver. The contents of the

'power management duty cycle in use' message are described in Table 3-16.

Message ID: 1117					
Rate: Variable					
Message Length: 10 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4 294 967 295	
8	Sequence number (Note 2)	I		0 to 32 767	
9	Power management on duty cycle (Note 3)	I	s	0 = off 1 to 4 = on	
10	Data checksum				
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.</p> <p>Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.</p> <p>Note 3: In power management mode, the RF power may be switched off to reduce power consumption. The digital circuitry may be gated off and the processor idled when not needed. This field gives the measurement engine permission to turn off the RF for the minimum off time in seconds.</p>					

Table 3-16 Message 1117 (power management duty cycle in use)

3.5.1.13 Message 1130 (serial port communication parameters in use).

This message contains the communication parameters for the receiver's two serial ports.

The contents of the 'serial port communication parameters in use' message are described in Table 3-17.

Message ID: 1130				
Rate: Variable				
Message Length: 21 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4 294 967 295
8	Sequence number (Note 2)	I		0 to 32 767
Port 1 communication parameters (9.0-11)				
9	Port 1 character width	Bit		0 = 7 bits 1 = 8 bits
10	Port 1 stop bits	Bit		0 = 1 1 = 2
11	Port 1 parity	Bit		0 = no parity 1 = odd parity 2 = even parity
12	Port 1 bps rate (Note 3)	Bit		0 = custom 1 = 300 2 = 600 3 = 1200 4 = 2400 5 = 4800 6 = 9600 7 = 19200 8 = 38400 9 = 57600 10 = 76800 11 = 115200
13	Port 1 pre-scale (Note 3)	UI		0 to 255
14	Port 1 post-scale (Note 3)	UI		0 to 7

Table 3-17 (1 of 2) Message 1130 (serial port communication parameters in use)

Word No.	Name	Type	Units	Range
Port 2 communication parameters (12.0-14)				
15	Port 2 character width	Bit		0 = 7 bits 1 = 8 bits
16	Port 2 stop bits	Bit		0 = 1 1 = 2
17	Port 2 parity	Bit		0 = no parity 1 = odd parity 2 = even parity
18	Port 2 bps rate (Note 3)	Bit		0 = custom 1 = 300 2 = 600 3 = 1200 4 = 2400 5 = 4800 6 = 9600 7 = 19200 8 = 38400 9 = 57600 10 = 76800 11 = 115200
19	Port 2 pre-scale (Note 3)	UI		0 to 255
20	Port 2 post-scale (Note 3)	UI		0 to 7
21	Data checksum			
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.</p> <p>Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.</p> <p>Note 3: When a custom bits-per-second (bps) rate is selected, the bps rate is equal to 'CPU clock / (16 x pre-scale x 2post-scale)'.</p>				

Table 3-17 (2 of 2) Message 1130 (serial port communication parameters in use message)

3.5.1.14 Message 1135 (EEPROM Update).

This message provides dynamic status notification for EEPROM writes. It contains the data block ID for the last set of data which was written to EEPROM. This message is most useful when

configured for output on update (the default), as it will provide a notification of all stored configuration changes as they occur. The contents of the 'EEPROM update' message are described in Table 3-18.

Message ID: 1135				
Rate: variable; default on update				
Message length: 10 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4 294 967 295
8	Sequence number (Note 2)	I		0 to 32 767
9.0-9.7	Data ID (Note 3)	Bit		0 to 27
9.8-9.15	Satellite PRN (Note 4)	Bit		0 to 32
10	Data checksum			
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.</p> <p>Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.</p> <p>Note 3:</p> <ul style="list-style-type: none"> 0 = status 14 = antenna selection 1 = position 15 = user entered altitude 2 = UTC/iono 16 = DGPS control 3 = frequency standard cubic parameters 17 = host port protocol selection 4 = host port communication configuration 18 = auxiliary port protocol selection 5 = auxiliary port communication configuration 19 = host port enable messages 6 = memory options 20 = reserved (auxiliary port enabled messages) 7 = solution validity criteria 21 = user datums 8 = power management selections 22 = frequency/temperature table 9 = selected datum 23 = almanac 10 = platform class 24 = frequency standard calibration data 11 = cold start control 25 = nav configuration data 12 = elevation mask angle 26 = DR navigation parameters 13 = satellite candidate list 27 = gyro temperature table <p>Note 4: This field is only valid when the data ID = 23 (Almanac).</p>				

Table 3-18 Message 1135 (EEPROM update)

3.5.1.15 Message 1136 (EEPROM status)

This message provides failure and storage status information for the EEPROM. Bits set in the failure words represent write failures during attempts to update the corresponding blocks of data. Bits set

in the status words indicate that those data blocks have been updated at least once in the EEPROM. The contents of the 'EEPROM status' message are described in Table 3-19.

Message ID: 1136				
Rate: variable				
Message length: 18 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4294967295
8	Sequence number (Note 2)	I		0 to 32767
9.0	Device not present	Bit		1 = not present
9.1-9.15	Reserved			
10-11	Almanac failure (Note 3)	Bit		
12-13	Failure (Note 4)	Bit		0 to 31
14-15	Almanac status (Note 3)	Bit		
16-17	Status (Note 4)	Bit		0 to 31
18	Data checksum			
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.</p> <p>Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.</p> <p>Note 3: The Almanac Failure and Almanac Status words are 32-bit bit maps where the LSB = PRN 1 and the MSB = PRN 32.</p> <p>Note 4: The 'failure' and 'status' words are bit maps with values as follows: 0 = status 16 = DGPS control 1 = position 17= host port protocol selection 2 = UTC/lono 18 = auxiliary port protocol selection 3 = frequency standard cubic parameters 19 = host port enabled messages 4 = host port communication configuration 20 = reserved (auxiliary port enabled messages) 5 = auxiliary port communication configuration 21 = user datums 6 = memory options 22 = frequency/temperature table 7 = solution validity criteria 23 = reserved 8 = power management selections 24 = frequency standard calibration data 9 = selected datum 25 = nav configuration data 10 = platform class 26 = DR navigation parameters 11 = cold start control 27 = gyro temperature table 12 = elevation mask angle 28 = reserved 13 = satellite candidate list 29 = reserved 14 = antenna selection 30 = reserved 15 = user entered altitude 31 = data is being updated</p>				

Table 3-19 Message 1136 (EEPROM status)

3.5.1.16 Message 1160 (frequency standard table output data).

This message contains parameters and table data used in the receiver's frequency standard compensation model. It is intended that this

message will be used in conjunction with Message 1360 to retrieve and restore this information for external storage. The contents of the 'frequency standard table output data' message are described in Table 3-20.

Message ID: 1160					
Rate: variable					
Message length: 270 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4294967295	
8	Sequence Number (Note 2)	I		0 to 32767	
9	Table frequency offset (Note 3)	I	ppm	0 to ±51	0.15
10.0	Table frequency offset valid (Note 4)	bit		1 = valid	
10.1-10.15	Reserved				
11	Offset error estimate (Note 5)	I	ppm	0 to ±51	0.002
12	Aging rate estimate (Note 6)	I	ppm/yr	0 to ±5	0.0002
13	Last rate update week (Note 7)	I	weeks	0 to 32767	1
14-269	Frequency standard table (Note 8): LSB, MSB	I	weeks ppm	0 to 1023 0 to ±19.05	4 0.15
270	Data checksum				
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks.</p> <p>Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output.</p> <p>Note 3: Each value of frequency error in the table shares this common offset value.</p> <p>Note 4: Flag to indicate that the offset has been established.</p> <p>Note 5: Filtered estimate of accumulated error in the table offset value.</p> <p>Note 6: Filtered estimate of the current aging rate.</p> <p>Note 7: Whole week number of the last update of the aging rate.</p> <p>Note 8: LSB = the approximate time of last table entry update. MSB = the frequency error at each table temperature, less the table offset.</p>					

Table 3-20 Message 1160 (frequency standard table output data)

3.5.1.17 Message 1180 (flash boot status).

This message is output in the Jupiter flash board receiver only at start-up to control the flash download process and to report the results of the flash ROM checksum validation test. The contents of the 'flash boot status' message are described in Table 3-21.

3.5.1.18 Message 1190 (error/status)

This message provides diagnostic information if the receiver encounters an error during execution of its firmware. The contents of the 'error/status' message are described in Table 3-22.

Message ID: 1180				
Rate: as required				
Message length: 7 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6	Boot status (Note 1)	IU short		
7	Data checksum			
Note 1: 0: checksum = pass 1: checksum = fail 2: copying header 3: waiting for a command				

Table 3-21. Message 1180 (flash boot status)

Message ID: 1190				
Rate: variable				
Message length: 13 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6-7	Set time (Note 1)	UDI	10 ms ticks	0 to 4294 967 295
8	Sequence number (Note 2)	I		0 to 32 767
9	Class (Note 3)	UI		0 to 5
10	Number	I		
11	Code environment (CENV)	UI		
12	Program counter (PC)	UI		
13	Data checksum			
Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialisation enabled the processor interrupts. It is not used to derive GPS time, but only serves to provide a sequence of events knowledge. The set time or T10 count references the receiver's internal time at which the message was created for output. The T10 range is approximately 71 weeks. Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message output. Note 3: 0 = user mode exception 1 = exec mode exception 2 = trap 3 = executive error 4 = executive Service Routine error 5 = user error				

Table 3-22 Message 1190 (error/status)

3.5.2 Binary input message descriptions.

This section provides details for each of the input binary messages.

3.5.2.1 Message 1200 (geodetic position and velocity initialisation)

This message allows the user to initialise the receiver with the specified geodetic position, ground speed, course over ground, and climb

rate. The course may be either true or magnetic, as indicated by the magnetic course field. The GPS/UTC time represents the time at which the solution was computed and, if present, will be used to propagate the solution to the current time. The contents of the 'geodetic position and velocity initialisation' message are described in Table 3-23.

Message ID: 1200					
Rate: as required - maximum rate is 1 Hz					
Message length: 27 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6	Sequence number (Note 1)	i		0 to 32767	
Initialisation Control (7.0-7.15)					
7.0	Force time	Bit		0 = normal 1 = forced	
7.1	GPS time valid	Bit		1 = valid	
7.2	UTC time valid	Bit		1 = valid	
7.3	Lat/lon valid	Bit		1 = valid	
7.4	Altitude Valid	Bit		1 = valid	
7.5	Speed/course valid	Bit		1 = valid	
7.6	Magnetic course	Bit		1 = magnetic	
7.7	Climb rate valid	Bit		1 = valid	
7.8-7.15	Reserved				
8	GPS week number	UI	weeks	0 to 32 767	
9-10	GPS seconds into week	UDI	s	0 to 604 799	
11	UTC day	UI	days	1 to 31	
12	UTC month	UI	months	1 to 12	
13	UTC year	UI	years	1980 to 2079	
14	UTC hours	UI	h	0 to 23	
15	UTC minutes	UI	min	0 to 59	
16	UTC seconds	UI	s	0 to 59	
17-18	Latitude	DI	rad	± 0 to $\pi/2$	10^{-9}
19-20	Longitude	DI	rad	± 0 to π	10^{-9}
21-22	Altitude	DI	m	± 0 to 50 000	10^{-2}
23-24	Ground speed	UI	m/s	0 to 1000	10^{-2}
25	Course	UI	rad	0 to 2π	10^{-3}
26	Climb rate	i	m/s	± 300	10^{-2}
27	Data checksum				
Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.					

Table 3-23 Message 1200 (geodetic position and velocity initialisation)

3.5.2.2 Message 1210 (user-defined datum)

This message allows the user to define a datum to be used by the receiver to transform its position solution. Up to five user-defined datums may be stored. Storage of these parameters requires EEPROM. The contents of the 'user-defined datum' message are described in Table 3-24.

Note that datum definition does not imply datum use. Message 1211 is used to specify the 'datum in

use' for the navigation function. Also, any message 1210 that contains an undefined datum code is ignored.

3.5.2.3 Message 1211 (map datum select).

This message allows the user to select a datum to be used by the receiver to transform its position solution. The contents of the 'map datum select' message are described in Table 3-25.

Message ID: 1210					
Rate: as required (maximum rate is 1 Hz)					
Message length: 20 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6	Sequence number (Note 1)	I		0 to 32767	
7	User datum ID	UI		300-304	
8-9	Semi-major axis - integer part	UDI	m	6 300 000 to 6 400 000	
10	Semi-major axis - fractional part	UI	m	0 to 9999	10 ⁻⁴
11	Inverse flattening -integer part	UI		280 to 320	
12-13	Inverse flattening - fractional Part	UDI		0 to 999999999	10 ⁻⁹
14-15	WGS-84 datum offset - dX	DI	m	0 to ±9000000	10 ⁻²
16-17	WGS-84 datum offset - dY	DI	m	0 to ±9000000	10 ⁻²
18-19	WGS-84 datum offset - dZ	DI	m	0 to ±9000000	10 ⁻²
20	Data checksum				
Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.					

Table 3-24 Message 1210 (user-defined datum)

Message ID: 1211					
Rate: as required (maximum rate 1 Hz)					
Message length: 8 words					
Word No.	Name	Type	Units	Range	
1-4	Message header				
5	Header checksum				
6	Sequence number (Note 1)	I		0 to 32767	
7	Datum ID (Note 2)	UI		0 to 188 and 300 to 304	
8	Data checksum				
Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.					
Note 2: Appendix B contains map datum codes from 0 to 188. Codes 300 to 304 are user-defined.					

Table 3-25 Message 1211 (map datum select)

3.5.2.4 Message 1212 (satellite elevation mask control).

This message allows the user to set the elevation mask angle used by the receiver to select visible satellites. Storage of the Elevation Mask Angle parameter requires EEPROM. The contents of the 'satellite elevation mask control' message are described in Table 3-26.

3.5.2.5 Message 1213 (satellite candidate select).

This message allows the user to construct the list of satellites which will be considered for selection by the receiver. The contents of the 'satellite candidate select' message are described in Table 3-27.

Message ID: 1212					
Rate: as required (maximum rate 1 Hz)					
Message length: 8 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6	Sequence number (Note 1)	I		0 to 32767	
7	Elevation mask angle	UI	rad	0 to $\pm\pi/2$	10^{-3}
8	Data checksum				
Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.					

Table 3-26 Message 1212 (satellite elevation mask control)

Message ID: 1213				
Rate: as required (maximum rate 1 Hz)				
Message length: 10 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6	Sequence number (Note 1)	I		0 to 32767
7.0	Satellite PRN #1	Bit		1 = included
•				
•				
•				
7.15	Satellite PRN #16	Bit		1 = included
8.0	Satellite PRN #17	Bit		1 = included
•				
•				
•				
8.15	Satellite PRN #32	Bit		1 = included
9.0	Non-volatile storage select	Bit		1 = store in non-volatile memory
9.1-9.15	Reserved			
10	Data checksum			
Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.				

Table 3-27 Message 1213 (satellite candidate select)

3.5.2.6 Message 1214 (DGPS control)

This message allows the user to control the behavior of the receiver's differential capability. Storage of this message's parameters requires EEPROM. The contents of the 'DGPS control' message are described in Table 3-28.

3.5.2.7 Message 1216 (cold start control)

This message allows the user to disable the cold start acquisition mode of the receiver. When cold start is enabled at power-on, the cold start timer is set to 0. If a satellite is not acquired before the cold start time-out is exceeded, the cold start acquisition mode starts. If a satellite is acquired, the cold start timer is reset to 0, the receiver is re-positioned under the satellite, and the search

continues until either the receiver navigates or the timer is exceeded.

Cold start acquisition mode does not use the initial conditions of position, time, and almanac. This causes the receiver to look at a wider range of frequencies and satellites. The default cold start timer is 5 minutes. Normal operation is to leave cold start enabled. However, in certain enclosed situations (e.g. garages, houses, office buildings, etc.), faster acquisitions may be achieved with cold start disabled storage of the cold start disable parameter requires EEPROM. The contents of the 'cold start control' message are described in Table 3-29.

Message ID: 1214				
Rate: as required (maximum rate 1 Hz)				
Message length: 9 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6	Sequence number (Note 1)	I		0 to 32767
7.0	DGPS disable	bit		1 = disable
7.1	Correction data base reset	bit		1 = reset
7.2-7.15	Reserved			
8	Correction timeout	UI		0 to 32767
9	Data checksum			
Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.				

Table 3-28 Message 1214 (differential GPS control)

Message ID: 1216					
Rate: as required (maximum rate 1 Hz)					
Message length: 9 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6	Reserved (sequence number)	I		0 to 32767	
7.0	Cold start disable	Bit		1 = disable	
7.1-7.15	Reserved				
8	Cold start timeout	UI	s	0 to 32767	
9	Data checksum				
Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.					

Table 3-29 Message 1216 (cold start control)

3.5.2.8 Message 1217 (solution validity input)

The receiver will always output the best position solution it can attain, depending on the number and quality of available measurements. The Solution Validity Input Message allows the user to define the criteria for setting the position validity

status specified in the position output messages. The status will be set to 'invalid' if any of the specified requirements are not met. Storage of this message's parameters requires EEPROM. The contents of the 'solution validity input' message are described in Table 3-30.

Message ID: 1217					
Rate: as required (maximum rate is 1 Hz)					
Message length: 13 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6	Sequence number (Note 1)	I		0 to 32767	
7.0	Altitude not used	Bit		1 = required	
7.1	Differential GPS	Bit		1 = required	
7.2	DR measurements required (Note 2)	Bit		1 = required	
7.3	Concurrent GPS calibration of DR required (Note 3)	Bit		1 = required	
7.4	GPS only solution required (Note 4)	Bit		1 = required	
7.5-7.15	Reserved				
8	Minimum number of satellites used	UI		0 to 12	
9-10	Maximum expected horizontal position error	UDI	m	0 to 1000	10 ⁻²
11-12	Maximum expected vertical position error	UDI	m	0 to 1000	10 ⁻²
13	Data checksum				
<p>Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.</p> <p>Note 2: Must operate with DR. stand-alone GPS not acceptable.</p> <p>Note 3: DR must be calibrated by concurrent GPS. Stored calibration from past sessions not acceptable.</p> <p>Note 4: DR must NOT be used, even if available.</p>					

Table 3-30 Message 1217 (solution validity input)

3.5.2.9 Message 1219 (user-entered altitude input).

This message allows the user to enter an altitude to be used for altitude hold during 2D navigation. If the 'force use' field is not set, the receiver may ignore the altitude input if it thinks it has a better estimate.

Setting the 'clear' field will clear out the last estimate of altitude which the receiver uses for altitude hold. Setting the 'MSL select' field allows

entry of mean-sea-level altitude. A standard deviation can be specified to indicate the uncertainty associated with the entered altitude.

The receiver will weight the altitude measurement according to this uncertainty. As a special case, a zero standard deviation indicates that the quality of the altitude is not known. The contents of the 'user-entered altitude input' message are described in Table 3-31.

Message ID: 1219					
Rate: as required (maximum rate is 1 Hz)					
Message length: 12 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6	Sequence Number (Note 1)	I		0 to 32767	
Altitude input control (7.0-7.15)					
7.0	Force use	Bit		1 = force	
7.1	MSL select	Bit		1 = MSL	
7.2	Store (RAM) (Note 2)	Bit		1 = store	
7.3	Store (EEPROM) (Note 2)	Bit		1 = store	
7.4	Clear (RAM)	Bit		1 = clear	
7.5	Clear (EEPROM)	Bit		1 = clear	
7.6-7.15	Reserved				
8-9	Altitude	DI	m	±0 to 50 000	10 ⁻²
10	Altitude standard deviation	UDI	m	0 to 10 000	10 ⁻²
11	Data checksum				
<p>Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.</p> <p>Note 2: For an altitude sensor that is supplying data in real-time, the OEM must ensure that bits 7.2 and 7.3 are set to zero so the altitude value will not be stored continuously in memory (RAM or EEPROM).</p>					

Table 3-31 Message 1219 (user-entered altitude input)

3.5.2.10 Message 1220 (application platform control).

This message allows the user to adjust the receiver's dynamics based on the type of

application in which the receiver is being used. Storage for the Platform parameter requires EEPROM. The contents of the 'application platform control' message are described in Table 3-32

Message ID: 1220					
Rate: as required (maximum rate is 1 Hz)					
Message length: 8 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6	Sequence number (Note 1)	I		0 to 32767	
7	Platform	UI		0 = default 1 = static 2 = pedestrian 3 = marine (lakes) 4 = marine (sea level) 5 = land (auto) 6 = air	
8	Data checksum				
Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.					

Table 3-32 Message 1220 (application platform control)

3.5.2.11 Message 1221 (nav configuration).

This message allows the user to control various features in the navigation processing. The held altitude disable bit controls the use of stored GPS-based altitude to aid the receiver when the vertical geometry deteriorates. The ground track smoothing bit controls the use of satellite range bias estimates to minimise the position shifts resulting from SA and constellation changes. The position pinning bit controls the use of a horizontal speed test to pin the position reported by the receiver and eliminate the wander associated with SA when static.

Ground track smoothing and position pinning are not used when DGPS corrections are in use. The contents of the 'nav configuration' message are described in Table 3-33.

3.5.2.12 Message 1300 (perform built-in test command).

This message instructs the receiver to immediately execute its Built-In Test (BIT). Results of the BIT are available in the BIT results message. The contents of the 'perform built-in test command' message are described in Table 3-34.

Message ID: 1221				
Rate: as required (maximum rate is 1 Hz)				
Message length: 15 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6	Sequence number (Note 1)	I		0 to 32 767
Nav configuration word (7.0-7.15)				
7.0	Held altitude disable (default = enabled)	Bit		0 = enabled 1 = disabled
7.1	Ground track smoothing disable (default = enabled)	Bit		0 = enabled 1 = disabled
7.2	Position pinning disable (default = enabled)	Bit		0 = enabled 1 = disabled
7.3	Disable low quality measurements (Note 2)	Bit		0 = enabled 1 = disabled
7.4	Enable jamming detect	Bit		0 = enabled 1 = disabled
7.5-7.15	Reserved (must be zeroed out)	Bit		0
8-14	Reserved (must be zeroed out)			
15	Data checksum			
<p>Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.</p> <p>Note 2: When this bit is set, the receiver will only use "perfect" measurements (ie measurements without any errors in tracking status or data). If the bit is not set, the system uses measurements that, while not perfect, are still good enough to use under SPS conditions.</p>				

Table 3-33 Message 1221 (nav configuration)

Message ID: 1300				
Rate: as required (maximum rate approximately 0.1 Hz)				
Message length: 8 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6	Sequence number (Note 1)	I		0 to 32 767
7	Reserved			
8	Data checksum			
<p>Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.</p>				

Table 3-34 Message 1300 (perform built-in test command)

3.5.2.13 Message 1303 (restart command).

This message commands a full restart each time it is received.

The contents of the 'restart command' message are described in Table 3-35.

Message ID: 1303					
Rate: as required (maximum rate approximately 0.2 Hz)					
Message length: 8 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6	Sequence number (Note 1)	I		0 to 32767	
Invalidation control (7.0-7.15)					
7.0	Invalidate RAM (Note 2)	Bit		0 to 1	
7.1	Invalidate EEPROM (Note 3)	Bit		0 to 1	
7.2	Invalidate RTC (Note 4)	Bit		0 to 1	
7.3-7.14	Reserved				
7.15	Force cold start (Note 5)	Bit		0 to 1	
8	Data checksum				
<p>Note 1: the sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.</p> <p>Note 2: 1 = invalidate all RAM address space before restart</p> <p>Note 3: 1 = invalidate all data in the EEPROM device (if present) before restart</p> <p>Note 4: 1 = invalidate all data in the RTC device (if present) before restart</p> <p>Note 5: 1 = force a cold start reset by clearing RAM and ignoring, but not clearing, the stored position in EEPROM. This provides cold start testing with the valid time. If cold start testing without time is desired, then the invalidate RTC bit (7.2) should also be set.</p>					

Table 3-35 Message 1303 (restart command)

3.5.2.14 Message 1310 (frequency standard input parameters).

This message defines the temperature polynomial, coefficients, and scale factors used by the receiver's frequency standard compensation model. The contents of the 'frequency standard input parameters' message are described in Table 3-36.

Note: Message 1310 is primarily used to input key parameters from GPS systems without non-volatile storage. This is why the format of output Message 1110 is exactly the same. In other words, the output message is used to capture data while the input message is used to restore data.

Message ID: 1310					
Rate: as required (maximum rate 1 Hz)					
Message length: 20 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6	Sequence number (Note 1)	I		0 to 32767	
7	Frequency standard issue number (Note 2)	UI		0 to 65535	
Temperature characteristic					
8	C0 (ageing and calibration offset) (Note 3)	I	s/s	0 to $\pm 2^{-14}$	2^{-29}
9	C1 (linear term) (Note 3)	I	s/s/°C	0 to $\pm 2^{-20}$	2^{-35}
10	C2 (second order term) (Note 3)	I	s/s/(°C) ²	0 to $\pm 2^{-26}$	2^{-41}
11	C3 (third order term) (Note 3)	I	s/s/(°C) ³	0 to $\pm 2^{-32}$	2^{-47}
12	TINF (inflection point) (Note 3)	I	°C	0 to ± 100	0.01
Temperature dynamics					
13	D0 (Note 4)	I			
14	D1 (Note 4)	I			
Temperature sensor calibration					
15	TREF(calibration reference temperature) (Note 5)	I	°C	0 to ± 100	0.01
16	T0 (temperature sensor reading at TREF) (Note 5)	UI	counts	0 to 65535	1
17	S0 (temperature sensor scale factor) (Note 5)	I	°C/count	0 to ± 23	2^{-18}
Uncertainty coefficients					
18	U0 (Note 6)	I	s/s	0 to $\pm 2^{-14}$	2^{-29}
19	U1 (Note 6)	I	s/s/°C	0 to $\pm 2^{-20}$	2^{-35}
20	Data checksum				
<p>Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.</p> <p>Note 2: Unique identification of each update. This allows a different set of data to be in use while newer data are only stored to EEPROM. The issue number is preserved from run to run if non-volatile storage is available.</p> <p>Note 3: Defines a cubic in (T – TINF). Over a range of TINF+65 degrees C, each term can produce from 0.002 to 60 ppm, approximately.</p> <p>Note 4: *** TBD ***. These parameters will be used to compensate temperature dynamics transients.</p> <p>Note 5: These parameters define the temperature sensor scaling according to the equation: $T = TREF + (TFILT - T0) S0$</p> <p>Note 6: Defines a linear equation in (T – TINF)'. Over a range of TINF +65°C, each term can produce from 0.002 to 60 ppm, approximately.</p>					

Table 3-36 Message 1310 (frequency standard input parameters)

3.5.2.15 Message 1317 (power management control).

This message controls the use of power management in the receiver. The contents of the 'power management control' message are described in Table 3-37.

Note: Message 1317 is primarily used to input key parameters from GPS systems without non-volatile storage. This is why the format of output message 1117 is exactly the same. In other words, the output message is used to capture data while the input message is used to restore data.

Message ID: 1317				
Rate: As required - maximum rate 1 Hz				
Message Length: 8 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6	Sequence number (Note 1)	I		0 to 32767
7	Power management on duty cycle (Note 2)	I	s	0 = off 1 to 4 = on
8	Data checksum			
<p>Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.</p> <p>Note 2: In power management mode, the RF power may be switched off to reduce power consumption. The digital circuitry may be gated off and the processor idled when not needed. This field gives the measurement engine permission to turn off the RF for the minimum off time in seconds.</p>				

Table 3-37 Message 1317 (power management control)

3.5.2.16 Message 1330 (serial port communication parameters).

This message allows the user to set the communication parameters for the receiver's

two serial ports. The contents of the 'serial port communication parameters' message are described in Table 3-38.

Message ID: 1330				
Rate: As required (maximum rate 1 Hz)				
Message Length: 20 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6	Sequence number (Note 1)	I		0 to 32 767
Port control/validity data				
7.0	Port 1 data valid	Bit		1 = data valid
7.1	Port 2 data valid	Bit		1 = data valid
7.2-7.15	Reserved			
8	Port 1 character width	UI		0 = 7 bits, 1 = 8 bits
9	Port 1 stop bits	UI		0 = 1, 1 =2
10	Port 1 parity	UI		0 = no parity 1 = odd parity 2 = even parity
11	Port 1 bits per second (bps) Rate	UI		0 = custom 1 = 300 2 = 600 3 = 1200 4 = 2400 5 = 4800 6 = 9600 7 = 19200 8 = 38400 9 = 57600 10 = 76800 11 = 115200
12	Port 1 pre-scale (Note 2)	UI		0 to 255
13	Port 1 post-scale (Note 2)	UI		0 to 7
14	Port 2 character width	Bit		0 = 7 bits, 1 = 8 bits
15	Port 2 stop bits	bit		0 = 1, 1 =2
16	Port 2 parity	Bit		0 = no parity 1 = odd parity 2 = even parity
17	Port 2 bps rate	Bit		0 = custom 1 = 300 2 = 600 3 = 1200 4 = 2400 5 = 4800 6 = 9600 7 = 19200 8 = 38400 9 = 57600 10 = 76800 11 = 115200
18	Port 2 pre-scale (Note 2)	UI		0 to 255
19	Port 2 post-scale (Note 2)	UI		0 to 7
Note 1: The sequence number is a count that indicates if the data in a particular binary message has been updated or changed since the last message input.				
Note 2: Pre-scale/post-scale parameters are used to set custom bps rates (bps rate = 'CPU clock/(16 x pre-scale x 2post-scale)				

Table 3-38 Message 1330 (serial port communication parameters)

3.5.2.17 Message 1331 (message protocol control)

This message allows the user to set the message format protocol which will be used to communicate information to and from the receiver through the host serial I/O port. Currently, the available protocols are binary (with fixed-point numbers) and NMEA-0183. Storage for the protocol type parameter requires EEPROM. The contents of the

'message protocol control' message are described in Table 3-39.

3.5.2.18 Message 1350 (factory calibration input).

This message is used to inform the system about the quality of the frequency standard being used. The contents of the 'factory calibration input' message are described in Table 3-40

Message ID: 1331				
Rate: As required (maximum rate 1 Hz)				
Message Length: 9 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6	Sequence number (Note 1)	I		0 to 32767
7	Reserved (must be zeroed out)	I		
8	Protocol type (Note 2)	I		0 = binary 1 = NMEA 2 = RTCM SC-104
9	Data checksum			
Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.				
Note 2: RTCM SC-104 is not a valid protocol for the host data stream.				

Table 3-39 Message 1331 (message protocol control)

Message ID: 1350					
Rate: As required (maximum rate 1 Hz)					
Message Length: 10					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6	Sequence number (Note 1)	I		0 to 32767	
7	Oscillator temperature (Note 2)	I	°C	-40 to +85	0.01
8-9	Oscillator frequency error	I	ppm	0 to ±51	0.01
10	Data checksum				
Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.					
Note 2: Externally supplied temperature measurement. An external temperature input causes the internal temperature sensor to be ignored as a source of temperature data.					

Table 3-40 Message 1350 (factory calibration input)

3.5.2.19 Message 1351 (raw DGPS RTCM SC-104 data)

This input message contains DGPS RTCM SC-104 data. The message is provided for backwards

compatibility with the earlier MicroTracker GPS receiver and may be used in lieu of the auxiliary port data. The contents of the 'raw DGPS RTCM SC-104 data' message are described in Table 3-41.

Message ID: 1351				
Rate: As required. The maximum allowable rate is once every 100 ms (Note 1)				
Message Length: Varies with message				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6	Sequence number (Note 2)	I		0 to 32767
7 to n-1	Any valid RTCM-104 raw data in multiples of 16 bits, not to exceed 32 16-bit words (Note 3)			
n	Data checksum (Note 1)			
<p>Note 1: 'n' must be less than or equal to 39. No more than 32 receiver 16-bit words of RTCM data should be delivered to the receiver with anyone message. Word description, number of words, header 4, header checksum 1, reserved (sequence number) 1, RTCM data <32, data checksum 1----- (max number of words <39).</p> <p>Note 2: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.</p> <p>Note 3: Raw demodulated data must conform to the '6 of 8' format described in the RTCM SC-1 04 standard. The data must also be packed into one or more 16-bit words and should be ordered chronologically from earliest to latest. Specifically, Word 7 should represent the earliest data and Word n-1 should represent the latest.</p> <p>Within each word, the most significant bit (bit 15) should represent the latest received bit and the least significant bit (bit 0) should represent the earliest received bit. (Note that according to RTCM '6 of 8' format, bits 6 and 14 should be set marking (1) and bits 7 and 15 should be set spacing (0) for each word.) The intent of this bit ordering is to allow the user to pass on the raw RTCM data without modification.</p>				

Table 3-41 Message 1351 (raw DGPS RTCM SC-104 data)

3.5.2.20 Message 1360 (frequency standard table input data).

This message allows the user to input the parameters and table data used in the receiver's frequency standard compensation model. It is intended that this message will be used in conjunction with message 1160 to retrieve and restore this information for external storage. The

contents of the 'frequency standard table input data' message are described in Table 3-42.

3.5.2.21 Message 1380 (flash reprogram).

This message is used only in the Jupiter flash board to force the receiver into the re-program flash mode. The contents of the 'flash re-program' message are described in Table 3-43.

Message ID: 1360					
Rate: As required - maximum rate 1 Hz					
Message Length: 268 words					
Word No.	Name	Type	Units	Range	Resolution
1-4	Message header				
5	Header checksum				
6	Sequence number (Note 1)	I		0 to 32767	
7	Table frequency offset (Note 2)	I	ppm	0 to ±51	0.15
8.0	Table frequency offset valid (Note 3)	Bit		1 = valid	
8.1-8.15	Reserved				
9	Offset error estimate (Note 4)	I	ppm	0 to ±51	0.002
10	Aging rate estimate (Note 5)	I	ppm/yr	0 to ±5	0.0002
11	last rate update week (Note 6)	I	weeks	0 to 32767	1
12-267	Frequency standard table (Note 7): LSB MSB	UI	weeks ppm	0 to 1023 0 to ±19.05	4 0.15
268	Data checksum				
<p>Note 1: The sequence number is a count that indicates whether the data in a particular binary message has been updated or changed since the last message input.</p> <p>Note 2: Each value of frequency error in the table shares this common offset value.</p> <p>Note 3: Flag to indicate that the offset has not been established.</p> <p>Note 4: Filtered estimate of accumulated error in the table offset value.</p> <p>Note 5: Filtered estimate of the current ageing rate.</p> <p>Note 6: Whole week number of the last update of the ageing rate.</p> <p>Note 7: LSB = the approximate time of last table entry update. MSB = the frequency error at each table temperature, less the table offset.</p>					

Table 3-42 Message 1360 (frequency standard table input data)

Message ID: 1380				
Rate: As required				
Message Length: 7 words				
Word No.	Name	Type	Units	Range
1-4	Message header			
5	Header checksum			
6	Request flag	Boolean		0 = false nonzero = true
7	Data checksum			
Note: This message does not provide the sequence number as word 6.				

Table 3-43 Message 1380 (flash re-program)

3.6 Jupiter NMEA data messages

This section describes the NMEA data messages of the Jupiter GPS receiver. All of the output and input NMEA messages are listed in Table 3-44 together with their corresponding message IDs. Power-up default messages are also identified.

NMEA mode is selected according to the logic described in the appropriate 'Jupiter' receiver data sheet. NMEA messages are transmitted and received across the host port serial I/O interface (RS-232) with the following default communications parameters: 4800 bps, no parity, 8 data bits, 1 stop bit. This interface conforms with the NMEA-0183, version 2.01, specification.

3.6.1 NMEA output message descriptions

3.6.1.1 Navman proprietary Built-In Test (BIT) results

This proprietary message provides detailed test results when a BIT is commanded. Non-zero device failure status indicates failure. The contents of the 'BIT' message are described in Table 3-45. Sample message:

```
$PRWIBIT,0001,0000,0000,0000,0000,0,0,15,640,01.02*75
```

Output message name	Message ID
Navman proprietary built-in test results	BIT
Navman proprietary error/status	ERR
GPS fix data (*)	GGA
GPS DOP and active satellites (*)	GSA
GPS satellites in view (*)	GSV
Navman proprietary receiver ID	RID
Recommended minimum specific GPS data (*)	RMC
Course over ground and ground speed	VTG
Navman proprietary Jupiter channel status (**)	ZCH

Input Message Name	Message ID
Navman proprietary built-in test command	IBIT
Navman proprietary log control message	ILOG
Navman proprietary receiver initialisation	INIT
Navman proprietary protocol message	IPRO
Standard query message	Q

(*) Enable by default at power-up
(**) Once at power-up/reset

Table 3-44. Jupiter NMEA data messages

Message ID: BIT				
Rate: Variable				
Fields: 11				
Field No.	Symbol	Field description	Field type	Example
	\$PRWIBIT	Start of sentence and address field (Note 1)		\$PRWIBIT
1	ROM_FAIL	ROM failure (Note 2)	hhhh	0001
2	RAM_FAIL	RAM failure (Note 2)	hhhh	0000
3	EEP_FAIL	EEPROM failure (Note 2)	hhhh	0000
4	DPR_FAIL	Dual port RAM failure (Note 2)	hhhh	0000
5	DSP_FAIL	Digital signal processor failure (Note 2)	hhhh	0000
6	RTC_FAIL	Real-time clock failure (Note 2)	hhhh	0000
7	SP1_ERR	Serial port 1 receive error count	x.x	0
8	SP2_ERR	Serial port 2 receive error count	x.x	0
9	SP1_RCV	Serial port 1 receive character count	x.x	15
10	SP2_RCV	Serial port 2 receive character count	x.x	640
11	SW_VER	Software version	x.x	01.02
	CKSUM	Checksum	*hh	*75
	<CR><LF>	Sentence terminator		<CR><LF>

Note 1: \$ = NMEA message prefix. P = proprietary message indicator, RWI = Navman Systems Inc. mnemonic, BIT = BIT results message ID.
Note 2: A value of zero indicates a test has passed. A non-zero value indicates a device failure. Missing devices are reported as failures. Therefore, the OEM's BIT pass/fail should ignore words for components that are not in the system under test. (Note: The dual port RAM failure test is currently not implemented, so field 4 will report a value of zero.

Table 3-45. BIT message (Navman proprietary built-in test results)

3.6.1.2 Navman proprietary error/status (ERR)

This message provides diagnostic information if the receiver encounters an error during execution of its firmware. The contents of the 'ERR' message are described in Table 3-46.

Sample message:

\$PRWIERR,0,0,005BC9*01

3.6.1.3 GPS fix data (GGA)

This message contains time, position, and fix related data for the Jupiter receiver. When a

navigation solution passes all validity criteria (set using the binary 'solution validity criteria' message), a GGA message is generated automatically. If any of the validity criteria are invalid for the solution, a GGA message is not generated. The contents of the 'GGA' message are described in Table 3-47.

Sample message:

\$GPGGA,222435,3339.7334,N,11751.7598,W,2,06,1.33,27.0,M,-34.4,M,7,0000*41

Message ID: ERR				
Rate: variable				
Fields: 3				
Field No.	Symbol	Field description	Field type	Example
	\$--ERR	Start of sentence and address field		\$PRWIERR
1		Class: 0 = user mode exception, 1 = executive mode exception, 2 = trap, 3 = executive error, 4 = ESR error, 5 = user error	x.x	0
2		Exception, trap, or error number	x.x	0
3		Word address of condition	hhhhh	005BC9
	CKSUM	Checksum	*hh	*01
	<CR><LF>	Sentence terminator		<CR><LF>

Table 3-46. ERR message (Navman proprietary error/status)

Message ID: GGA (while receiver is in navigation mode, see Note 1)				
Rate: variable; defaults to 1 Hz				
Fields: 14				
Field No.	Symbol	Field description	Field type	Example
	\$--GGA	Start of sentence and address field		\$GPGGA
1	POS_UTC	UTC of position (hours, minutes, seconds, decimal seconds)	hhmm.ss.ss	222435
2	LAT	Latitude	1111.11	3339.7334
3	LAT_REF	Latitude direction (N = north, S = south)	a	N
4	LON	Longitude	yyyyy.yy	11751.7598
5	LON_REF	Longitude direction (E = east, W = west)	a	W
6	GPS_QUAL	GPS quality indicator (Note 2)	x	2
7	NUM_SATS	Number of satellites in use, 00 to 12	xx	06
8	HDOP	Horizontal dilution of precision	x.x	1.33
9	ALT_MSL	Antenna altitude above/below mean sea level (geoid) (Note 3)	x.x	27.0
10	M	Units of antenna altitude (metres)	m	M
11	GEOID_SEP	Geoidal separation (Note 4)	x.x	-34.4
12	M	Units of geoidal separation (metres)	m	M
13	DGPS_AGE	Age of differential GPS data (Note 5)	x.x	7
14	STA_ID	Differential reference station ID (0000 to 1023) (Note 6)	xxxx	0000
	CKSUM	Checksum	*hh	*41
	<CR><LF>	Sentence terminator		<CR><LF>
<p>Note 1: When the navigation solution is invalid, fields 1 to 5 and 8 to 14 are null. Field 7 also has special meaning (see Note 3). Note 2: GPS quality indicator: 0 = fix not available or invalid; 1 = GPS fix; 2 = DGPS fix. Note 3: The geodetic altitude can be computed from the mean sea level altitude by adding the geoidal separation (word 11). Note 4: Geoidal separation is the difference between the WGS-84 Earth ellipsoid and mean sea level (geoid). Note 5: Time in seconds since the last SC1-04 Type 1 or Type 9 update; null field when DGPS is not used. Note 6: This field is null when DGPS is not used.</p>				

Table 3-47. GGA message (GPS fix data)

5.6.1.4 GPS satellites active and DOP (GSA) .

This message contains the Jupiter receiver's operating mode, satellites used for navigation, and DOP values. The contents of the 'GSA' message are described in Table 3-48.

Sample message:

```
$GPGSA,A,3,04,16,09,24,,,,,3.33,1.96,2.70*06
```

3.6.1.5 GPS satellites in view (GSV)

This message contains the number of satellites in view, PRN numbers, elevation, azimuth,

and Signal-to-Noise Ratio (SNR) values. Each transmission identifies up to four satellites (max); additional satellite data is sent in a second or third message. The total number of messages being transmitted and the number of the message being transmitted is indicated in the first two fields. The contents of the 'GSV' message are described in Table 3-49.

Sample message:

```
$GPGSV,2,1,07,24,60,216,50,20,47,135,47,12,40,020,47,16,36,319,46*75
```

Message ID: GSA				
Rate: variable				
Fields: 17				
Field No.	Symbol	Field description	Field type	Example
	\$_GSA	Start of sentence and address field		\$GPGSA
1	OP_MODE	Mode (Note 1)	a	A
2	FIX_MODE	Mode (Note 2)	x	3
3-14	SATN	PRNs of satellites used in solution (null for unused fields)	xx,xx,....	04, 16, 09, 24...
15	PDOP	Position dilution of precision (Note 3)	x.x	3.33
16	HDOP	Horizontal dilution of precision (Note 3)	x.x	1.96
17	VDOP	Vertical dilution of precision (Note 3)	x.x	2.70
	CKSUM	Checksum	*hh	*06
	<CR><LF>	Sentence terminator		<CR><LF>
Note 1: Mode (operating), M = manual (forced to operate in 3D mode), A = automatic (can automatically switch between 2D and 3D).				
Note 2: Mode (fix), 1 = fix not available, 2 = 2D, 3 = 3-D				
Note 3: DOPs are based on the set of satellites above the elevation mask angle, this may differ from the set used for navigation.				

Table 3-48 GSA message (GPS DOP and active satellites)

Message ID: GSV				
Rate: variable; defaults to 0.5 Hz				
Fields: 19				
Field No.	Symbol	Field description	Field type	Example
	\$_GSV	Start of sentence and address field		\$GPGSV
1	MAX_MSG	Total number of messages (1 to 3)	X	2
2	NUM_MSG	message number (1 to 3)	X	1
3	NUM_SATS	Total number of satellites in view	Xx	07
4	SAT_PRN	Satellite PRN number (Note 1)	Xx	24
5	ELEV	Elevation in degrees (90 degrees maximum) (Note 2)	Xx	60
6	AZ	Azimuth in true degrees (000 to 359) (Note 2)	Xxx	216
7	SNR	SNR (C/No) 00 to 99 dB, null when not tracking	Xx	50
8-11	...	2nd satellite PRN number, elevation, azimuth, SNR (Note 1)	xx, xx, xxx, xx	...
12-15	...	3rd satellite PRN number, elevation, azimuth, SNR (Note 1)	xx, xx, xxx, xx	...
16-19	...	4th satellite PRN number, elevation, azimuth, SNR (Note 1)	xx, xx, xxx, xx	...
	CKSUM	Checksum	*hh	*75
	<CR><LF>	Sentence terminator		<CR><LF>
Note 1: The visible satellites may include one or more that are below the horizon. Since NMEA does not account for negative elevation angles, the elevation field will be null for these satellites.				
Note 2: Azimuth and elevation are null when the satellite is in track, but a visible list is not available.				

Table 3-49 GSV message (GPS satellites in view)

3.6.1.6 Navman proprietary receiver ID (RID)

This message is output automatically at startup (after receiver initialisation is complete), it can also be requested manually. It can be used to determine when the receiver is ready to accept

serial input. The contents of the 'RID' message are described in Table 3-50.

Sample message:

\$PRWIRID,12,00.90,12/25/95,0003,*40

Message ID: RID				
Rate: variable (see above)				
Fields: 5				
Field No.	Symbol	Field description	Field type	Example
	\$_RID	Start of sentence and address field		\$PRWIRID
1	NUM_CHN	Number of channels	xx	12
2	SW_VER	Software version	x.x	00.90
3	SW_DATE	Software date	ccccccc	12/25/95
4	OPT_LST	Options list (Note 1)	hhhh	0003
5	RES	Reserved		
	CKSUM	Checksum	*hh	*40
	<CR><LF>	Sentence terminator		<CR><LF>
Note 1: The options list is a bit-encoded configuration word represented as a four-digit hexadecimal number. Bit 0 minimises ROM usage, bit 1 minimises RAM usage, bits 2-15 are reserved.				

Table 3-50. RID message (Navman proprietary receiver ID)

3.6.1.7 Recommended minimum specific GPS data (RMC)

This message contains time, date, position, course, and speed data. The fields in this message always contain data even when the receiver is not navigating. This allows user-initialised, stored, or default values to be displayed before a solution is

obtained. The contents of the 'RMC' message are described in Table 3-51.

Sample message:

```
$GPRMC,185203,A,3339.7332,N,11751.7598,W,0.000,121.7,160496,13.8,E*55
```

Message ID: RMC				
Rate: variable; defaults to 1 Hz				
Fields: 11				
Field No.	Symbol	Field description	Field type	Example
	\$__RMC	Start of sentence and address field		\$GPRMC
1	POS.UTC	UTC of position (hours, minutes, seconds, decimal seconds)	hhmmss.ss	185203
2	PAS_STAT	Position status (A = Data valid, V = Data invalid) (Note 1)	a	A
3	LAT	Latitude	1111.11	3339.7332
4	LAT_REF	Latitude direction (N = north, S = south)	a	N
5	LON	Longitude	yyyyy.yy	11751.7598
6	LON_REF	Longitude direction (E = east, W = west)	a	W
7	SPD	Speed over ground (knots)	x.x	0.000
8	HDG	Heading/track made good (degrees true)	x.x	121.7
9	DATE	Date (dd/mm/yy)	xxxxxx	160496
10	MAG_VAR	Magnetic variation (degrees)	x.x	13.8
11	MAG_REF	Magnetic variation (E = east, W = west) (Note 2)	a	E
	CKSUM	Checksum	*hh	*55
	<CR><LF>	Sentence terminator		<CR><LF>
<p>Note 1: The position status flag will be set to 'V' (data invalid) until the receiver is navigating. At that time, the flag is changed to 'A' (data valid) and the information provided in the RMC message will reflect a navigation solution.</p> <p>Note 2: Easterly variation (E) subtracts from true course. Westerly variation (W) adds to true course.</p>				

Table 3-51. RMC message (recommended minimum specific GPS data)

3.6.1.8 Course over ground and ground speed (VTG).

This message contains the course over ground (true and magnetic) and speed relative to the ground. The contents of the 'VTG' message are

described in Table 3-52.

Sample message:

\$GPVTG,291.3,T,277.3,M,0.784,N,1.452,K*4F

Message ID: VTG (while receiver is in navigation mode -- Note 1)				
Rate: Variable				
Fields: 8				
Field No.	Symbol	Field description	Field type	Example
	\$_VTG	Start of sentence and address field		\$GPVTG
1	TRU_CRS	Course over ground, degrees true	x.x	291.3
2	T	True course indicator	t	T
3	MAG_CRS	Course over ground, degrees magnetic	x.x	277.3
4	M	Magnetic course indicator	m	M
5	SPD_N	Speed over the ground (knots)	x.x	0.784
6	N	Nautical speed indicator (N = knots)	n	N
7	SPD_K	Speed (km)	x.x	1.452
8	K	Speed indicator (K = km/hr)	k	K
	CKSUM	Checksum	*hh	*4F
	<CR><LF>	Sentence terminator		<CR><LF>
Note 1: Output of this message is temporarily suppressed while the receiver is in acquisition mode.				

Table 3-52. VTG message (course over ground and ground speed)

3.6.1.9 Navman proprietary Jupiter channel status (ZCH).

This message complements the GSV message by providing satellite-to-channel mapping and a status indication for each channel. The contents of the

'ZCH' message are described in Table 3-53.

Sample message:

\$PRWIZCH,05,F,20,F,04,F,09,F,16,F,06,F,07,6,00,0,24,F,00,0,00,0,00,0*37

Message ID: ZCH				
Rate: variable; defaults to 1 Hz				
Fields: 24				
Field No.	Symbol	Field description	Field type	Example
	\$___ZCH	Start of sentence and address field		\$PRWIZCH
1-2	SAT_PRN	Channel 1 satellite PRN number (Note 1)	xx	05
2	STATUS	Channel 1 status indication (Note 1)	hh --	F
3-4	...	Channel 2 satellite PRN number and status indication	xx, hh- -	...
5-6	...	Channel 3 satellite PRN number and status indication	xx, hh- -	...
7-8	...	Channel 4 satellite PRN number and status indication	xx, hh- -	...
9-10	...	Channel 5 satellite PRN number and status indication	xx, hh- -	...
11-12	...	Channel 6 satellite PRN number and status indication	xx, hh- -	...
13-14	...	Channel 7 satellite PRN number and status indication	xx, hh- -	...
15-16	...	Channel 8 satellite PRN number and status indication	xx, hh- -	...
17-18	...	Channel 9 satellite PRN number and status indication	xx, hh- -	...
19-20	...	Channel 10 satellite PRN number and status indication	xx, hh- -	...
21-22	...	Channel 11 satellite PRN number and status indication	xx, hh- -	...
23-24	...	Channel 12 satellite PRN number and status indication	xx, hh- -	...
	CKSUM	Checksum	*hh	*37
	<CR><LF>	Sentence terminator		
<p>Note 1: Channel number (xx) is implied by position in message. Data for all 12 channels is always provided in this message. If a channel is unused, a value of 0 will appear for both channel fields. The status indication (hh__ is a one-digit, hexadecimal value which represents four bits as follows:</p> <p><y.0> Measurement of the satellite on this channel used in navigation solution. <y.1> Ephemeris available for the satellite on this channel. <y.2> Satellite on this channel is in track. <y.3> DGPS corrections available for the satellite on this channel (Note: This bit will never be set whenever the configuration of a particular Jupiter GPS receiver does not support DGPS).</p>				

Table 3-53 ZCH message (Navman proprietary Jupiter channel status)

3.6.2 NMEA input message descriptions.

This section provides details for each of the input NMEA messages.

3.6.2.1 Navman proprietary built-in test command message (IBIT).

This proprietary message instructs the receiver to immediately execute its BIT. Results of the BIT are available in the Navman proprietary BIT results message. The data field is reserved and should be left null. The contents of the 'IBIT' message are described in Table 3-54.

Sample message:

\$PRWIIBIT,

3.6.2.2 Navman proprietary log control message (ILOG).

This proprietary message controls the output of the Jupiter receiver's NMEA messages. The contents of the 'ILOG' message are described in Table 3-55.

Sample message:

\$PRWILOG,RMC,A,T,5,0

Message ID: IBIT				
Rate: as required				
Fields: 1				
Field No.	Symbol	Field description	Field type	Example
	\$PRWIIBIT	Start of sentence and address field (Note 1)		\$PRWIIBIT
1	RES	Reserved		
	CKSUM	Checksum (optional)	*hh	
	<CR><LF>	Sentence terminator		<CR><LF>
Note 1: \$ = NMEA message prefix, P = Proprietary message indicator, RWI = Navman Systems Inc. mnemonic, ILOG = BIT command message ID.				

Table 3-54 IBIT message (Navman proprietary BIT command)

Message ID: ILOG				
Rate: as required				
Fields: 5				
Field No.	Symbol	Field description	Field type	Example
	\$PRWILOG	Start of sentence and address field (Note 1)		\$PRWILOG
1	MSGJD	Approved sentence formatter of the data being requested (Note 2)	Ccc	RMC
2	ENABLE	Output enable flag (A = enable, V = disable) (Note 3)	A	A
3	TRIG	Output trigger (t = on time, u = on update) (Note 4)	A	T
4	INTERVAL	Output interval (seconds, 0 = once) (Note 4)	x.x	5
5	OFFSET	Initial output offset (seconds from minute mark) (Note 4)	x.x	0
	CKSUM	Checksum (optional)	*hh	
	<CR><IF>	Sentence terminator		<CR><IF>
Note 1: \$ = NMEA message prefix, P = proprietary message indicator, RWI = Navman Systems Inc. mnemonic, ILOG = log control message ID.				
Note 2: A special form of this field disables all output messages. Use '???' as the message ID as in the following example: \$PRWILOG,???,V,,				
Note 3: This field may be null to indicate that the previous setting should be left unchanged.				
Note 4: The TRIG, INTERVAL, and OFFSET fields may be null to indicate that the previous setting should be left unchanged.				

Table 3-55 ILOG message (Navman proprietary log control)

3.6.2.3 Navman proprietary receiver initialisation message (INIT).

This proprietary message commands the Jupiter receiver to perform a reset, modify its operating mode, or reinitialise itself using specified parameters. The contents of the 'INIT' message

are described in Table 3-56.

Sample message:

```
$PRWIINIT,V,3339.650,N,11751.680,W,64.131,
0.0,M,0.0,T,162338,190594
```

Message ID: INIT				
Rate: as required				
Fields: 14				
Field No.	Symbol	Field description	Field type	Example
	\$PRWIINIT	Start of sentence and address field (Note 1)		\$PRWIINIT
1	RESET	Software reset flag (A = reset, V = don't reset) (Note 2)	a	V
2	RES_1	Reserved		
3	RES_2	Reserved		
4	LAT	Latitude (Note 2)	IIII.II	3339.650
5	LAT_REF	Latitude direction (N = north, S = south) (Note 2)	a	N
6	LON	Longitude (Note 2)	yyyyy.yy	11751.680
7	LON_REF	Longitude direction (E = east, W = west) (Note 2)	a	W
8	ALT	Altitude (m) (Note 2)	x.x	64.131
9	SPD	Ground speed (Note 2)	x.x	0.0
10	SPD_TYP	Ground speed units (M = m/sec, N = knots, K = km/hr) (Note 2)	a	M
11	HDG	Heading (0.0 to 360.0 degrees north) (Note 2)	x.x	0.0
12	HDG_TYP	Heading type (T = true, M = magnetic) (Note 2)	a	T
13	TIME	UTC time (h, min, s) (Note 2)	hhmmss	162338
14	DATE	UTC date (Note 2)	ddmmyy	190594
	CKSUM	Checksum (optional)	*hh	
	<CR><LF>	Sentence terminator		<CR><LF>
<p>Note 1: \$ = NMEA message prefix. P = Proprietary message indicator. RWI = Navman Systems Inc. mnemonic. INIT = Initialisation message ID.</p> <p>Note 2: this function is enabled by default. Each of the fields 1 through 14 may be null to indicate that the previous setting for the data item should be left unchanged. For example, reset may be commanded without specifying the other parameters by issuing the following command: \$PRWIINIT,A,,,,,,,,,,,,,<CR><LF></p> <p>When using null fields, the following restrictions apply:</p> <ul style="list-style-type: none"> • If a supplied parameter has a corresponding unit specifier or reference indicator, it must also be supplied. • Both latitude and longitude must be provided to specify a valid horizontal position. • Both ground speed and heading must be provided to specify a valid horizontal velocity. • If a magnetic heading is specified, horizontal position (lat/lon), and UTC time and date must also be provided. • UTC time and date must be provided together. 				

Table 3-56 INIT message (Navman proprietary receiver initialisation)

3.6.2.4 Navman proprietary protocol message (IPRO).

This proprietary message allows the user to set the message format protocol which will be used to communicate information to and from the receiver through the host serial I/O port. Currently, the available protocols are binary (with fixed-point numbers) and NMEA-0183. Storage for the protocol type parameter requires EEPROM. The contents of the 'IPRO' message are described in Table 3-57.

Sample message:

\$PRWIIPRO,,RBIN

3.6.2.5 Standard query message (Q).

This message is used to request a one-time output of any of the approved NMEA messages from the Jupiter receiver. The typical response time between receipt of a query and the transmission of the requested message is approximately one second. The contents of the 'Q' message are described in Table 3-58.

Sample message:

\$LCGPQ,GSV

Message ID: IPRO				
Rate: as required				
Fields: 2				
Field No.	Symbol	Field description	Field type	Example
	\$PRWIIPRO	Start of sentence and address field (Note 1)		\$PRWIIPRO
1	RES	Reserved		
2	PRO_TYPE	Protocol type (RBIN = Navman binary))	cccc	RBIN
	CKSUM	Checksum (optional)	*hh	
	<CR><LF>	Sentence terminator		<CR><LF>
Note 1: \$ = NMEA message prefix. P = Proprietary message indicator. RWI = Navman Systems Inc. mnemonic. INIT = Initialisation message ID.				

Table 3-57. IPRO message (Navman proprietary protocol message)

Message ID: Q				
Rate: as required				
Fields: 1				
Field No.	Symbol	Field description	Field type	Example
	\$___Q	Start of sentence and address field (Note 1)		\$LCGPQ
1	MSGJD	Approved sentence formatter of the data being requested	ccc	GSV
	CKSUM	Checksum (optional)	*hh	
	<CR><LF>	Sentence terminator		<CR><LF>
Note 1: The identifier of the device from which data is being requested (refer to paragraph 5.4.4 of this chapter) must be 'GP' (GPS device) for the 'Jupiter' receiver to recognise the message; otherwise, the message will be ignored.				

Table 3-58. Q message (standard query)

4.0 Jupiter GPS receiver operation

This section presents a detailed operational description of the Jupiter series of GPS receivers. An overview is provided for the navigation and receiver support functions. Each of the receiver's internal storage devices are described as well as how each one is initialised and used to control operational configurations. This section also provides a description of start-up modes and satellite management.

4.1 Internal (on board) data sources

Internal data sources are the “built-in” information storage capabilities of the GPS receiver. The on-board receiver firmware maintains these data sources for use on a continuing basis.

4.1.1 Static Random Access Memory (SRAM)

SRAM is used to store all firmware variables manipulated by the GPS receiver. If external power has been supplied to SRAM when the main power is disconnected, this data will be available to the initialisation functions at start-up. Satellite ephemeris, last position, and frequency standard parameters are important data that helps to minimise TTFF if the data is available in SRAM.

4.1.2 Real-time clock (RTC)

Along with SRAM, an on board RTC is a valuable source of data at system start-up. If external power has been applied to the RTC when the main power is disconnected, time/date information will be available to the initialisation functions at start-up. Valid time/date is a key component used to compute satellite visibility and to minimise TTFF.

Note: A value of 'last known time' is available in SRAM. On the Jupiter board, the RTC is powered whenever SRAM is powered (see section 4.7 for more information about the RTC).

4.1.3 Electrically Erasable Programmable Read- Only Memory (EEPROM)

On board EEPROM is useful for long-term storage of data that varies somewhat over time but is, in general, fairly constant over short periods of time (weeks). Unlike SRAM and the RTC, power is not required to maintain data during 'idle' states. Important data in EEPROM that helps to minimise TTFF includes satellite almanac, last known position, and frequency standard parameters.

Note: EEPROM is used only if the required data is not available from SRAM (see section 4.7 for more information about the EEPROM).

4.1.4 Read-Only Memory (ROM)

On board ROM is only used as a data source if

SRAM and EEPROM are unavailable. Satellite almanac and frequency standard parameters can be obtained from ROM with limited usefulness.

4.2 Initialisation

4.2.1 Definition

Initialisation is defined as the set of data or actions that provide time varying information for use by the GPS receiver at start-up. The most common example is Position, Velocity, and Time (PVT) initialisation. For a GPS receiver installed in an automobile, this information is constantly changing as time progresses and the vehicle moves from location to location.

Initialisation data is required when the on board data sources are old or invalid. Serial input messages are prepared by the user and transmitted to the GPS receiver. In general, the GPS receiver is capable of 'bootstrapping' itself without any valid data sources, but TTFF times are extended.

4.2.2 Position, Velocity, Time (PVT) data

The most common form of user supplied initialisation data is position and time (velocity is normally included in this group, but it is only required for higher dynamic operations). Accurate PVT and valid almanac/ephemeris data are required to generate the current satellite visibility list and appropriate acquisition uncertainties, resulting in optimal TTFF performance.

4.2.3 Satellite ephemeris

Unlike user PVT information, satellite ephemeris data is available from every satellite that is continuously tracked (18 seconds minimum collection time). The ephemeris is maintained in SRAM. This 'over-the-air' availability means that the user does not normally have to supply ephemeris data.

4.2.4 Satellite almanac

Almanac information for all satellites is available from each tracked satellite (12.5 minute collection time for the complete set) and is maintained in the on board EEPROM and SRAM. Like ephemeris data, 'over-the-air' availability means that the user does not normally have to supply almanac data.

4.2.5 Universal Time Coordinated (UTC) and ionospheric parameters

UTC and ionospheric correction parameters are available from every tracked satellite (broadcast once every 12.5 minutes) and are maintained in the on board EEPROM and SRAM. Like almanac and ephemeris data, 'over-the-air' availability means that the user does not normally have to supply UTC and ionospheric data.

4.3 Configuration

4.3.1 Definition

Configuration is defined as the set of data or actions that provide information that is fairly constant and usually connected with installation, environmental, or user preferences. Common examples are map datums or satellite elevation mask angle. Configuration data customises or optimises the GPS receiver for use in a particular situation. In general, this data is held constant until the user decides to change it. Table 4-1 provides a brief description of all default configuration parameters.

Configuration data controls how the receiver works on a daily basis. Typically, this information is stored in EEPROM, accessed at the time of initialisation, and updated whenever the user dictates a change. The obvious benefit of this feature is that the board can be configured to work in a customised way.

The various types of configuration data are briefly described in the following paragraphs.

4.3.2 Geodetic datums

Jupiter GPS receivers provide two configuration features related to datums: datum selection and datum definition. Datum selection controls the transformation used for all navigation outputs and

inputs. Over 180 pre-defined datums are available for user configuration.

Datum definition allows the user to specify a custom datum that can be used in the same way as an element of the pre-defined set. A maximum of five user-defined datums is supported. Refer to section 4.6 (Navigation) for more details.

4.3.3 Satellite selection

Jupiter GPS receivers provide two configuration features related to satellite selection: elevation mask angle and candidate satellite specification. Satellite elevation mask angle defines the elevation angle that is used to screen satellites for inclusion in the navigation solution and Dilution of Precision (DOP) calculations. Satellites that fall between the elevation mask angle and the horizon (0 degree mask) are tracked, when possible, to gather their ephemeris data so they are ready to be used when they rise above the elevation mask. Satellite candidate specification is used to explicitly control inclusion in the visible list (satellites above horizon). By default, a satellite is a candidate until it is excluded, at which point it must be re-selected to be a candidate again. (See sections 4.6 and 4.7 for more details.)

Parameter	Value/Description
datum	WGS-84
mask angle	10 degrees
cold start control	enabled
timeout	300 ns
platform class	automotive
altitude measurement validity	mark altitude solutions valid
maximum EHPE	100 m (*)
maximum expected EVPE	150 m (*)
criterion for minimum number of satellites used for a solution	zero (*) (**)
DGPS validity	not required for a valid solution (*)
held altitude	enabled
position pinning enabled	enabled (automatically disabled when DGPS corrections are available)
ground track smoothing	enabled (only when DGPS is not available)
DGPS disable	'false' (i.e. DGPS is active if corrections are available)
host port communication parameters (Navman binary)	9600, N, 8, 1
host port communication parameters (NMEA)	4800, N, 8, 1
host port communication parameters (RTCM inout only)	9600, N, 8, 1
(*) solution validity criteria	
(**) after a 'fully determined' or successful transition to navigation	

Table 4-1 Default configuration data

4.3.4 Differential GPS (DGPS) control

Jupiter GPS DGPS operation: disable and correction timeout. When DGPS disable is asserted, the navigation solution is computed without the benefit of differential corrections even if they are available. The DGPS timeout parameter is used to specify the maximum allowable time difference between current time and the validity time of the DGPS corrections. If the timeout is exceeded, DGPS navigation solutions are unavailable until the correction time delta becomes less than the timeout (see sections 4.6 and 4.7).

4.3.5 Cold start control

A simple control that enables or disables this feature and sets the timeout for automatic transition to cold start is available (see section 4.4 for a description of this feature).

4.3.6 Solution validity criteria

This configuration feature allows the user to specify a set of conditions that must be met for a navigation solution to be reported as valid. Constraints that can be imposed on solution validity include: use of DGPS corrections, use of altitude, minimum number of satellites, maximum expected position errors (EHPE and EVPE). (See section 4.6 for a description of this feature.)

4.3.7 User-entered altitude

This configuration feature allows the user to supply a known value of altitude that can be used to improve the overall quality of the navigation solution. The most common application of this feature is to provide a mean sea level value for a boat that is used exclusively on an ocean (see section 4.6).

4.3.8 Vehicle platform select

This configuration feature allows the user to specify the type of vehicle in which the Jupiter receiver has been installed (see section 4.6).

4.3.9 Navigation control

Several navigation control features are provided by the Jupiter GPS receivers. These features are:

- groundtrack smoothing
- position pinning
- validity criteria.

(See section 4.6 for more details.)

4.3.10 Configuration straps

Configuration straps control the use of available configuration data at the time of initialisation. These straps act as metacommands that can override or complement an existing set of configuration data.

Note: These straps are only read once at

initialisation time, so a power cycle or hardware or software reset must be executed after any strap changes are made.

4.3.10.1 National Marine Electronics Association (NMEA) Select

When asserted, the host serial communication interface is configured for NMEA operation (4800-8-N-1). Configuration data related to the host port that may be available from other sources is not used. When de-asserted, operation of the host port is controlled by any available configuration data sources (SRAM, EEPROM, etc.). Details of the NMEA guarantee that the receiver is started in a known message set are contained in Section 5.0 of this document.

4.3.10.2 ROM defaults.

When asserted, all configuration and initialisation data are obtained from ROM defaults. In addition, SRAM is cleared to guarantee that the receiver is started in a known operational state. The host serial communication interface is configured for Navman binary operation (9600-8-N-1). When de-asserted (the normal operational state), configuration and initialisation data are obtained from all valid sources (SRAM, EEPROM RTC, etc.).

4.4 Start-up modes

Jupiter GPS receivers have four types of start-up modes (warm, initialised, cold, and frozen) based on the availability and source of initialisation data. Each of these modes are briefly described in the following paragraphs.

4.4.1 Warm start

This state is present when all key data (PVT, ephemeris, and frequency standard parameters) is valid and available in SRAM. Two common conditions that result in this state are a software reset ('hot' start) after continuous navigation or a return from an 'idle' period (power cycle) of a few minutes that was preceded by a period of continuous navigation.

4.4.2 Initialised start

This state is similar to warm start except that ephemeris data is not available at start-up, implying that SRAM was not powered during the "idle" state or that the data time validity has expired. Common conditions that result in this state are user-supplied PVT initialisation or continuous RTC operation with an accurate last known position available from EEPROM.

4.4.3 Cold start

This state occurs as a result of unknown position and/ or time, either of which causes an unreliable satellite visibility list. Almanac information is

used to identify previously healthy satellites and to generate “working” visible satellite lists, while frequency standard data minimises satellite acquisition uncertainties.

4.4.4 Frozen start

This state is entered if there are no valid data sources available (SRAM, RTC, EEPROM). This is considered to be a recovery mode because EEPROM should always contain valid information. An “out-of-the-box” board or a unit that has not operated for a significant amount of time (months) may approximate this state because the data in EEPROM may be valid but expired or partially complete.

4.5 Satellite management

This section describes the satellite management functions of the Jupiter family of GPS receivers.

4.5.1 Visible list generation.

A list of satellites visible to the receiver antenna is maintained whenever possible. A satellite is considered visible if its elevation in the sky is known to be above the horizon, if its almanac and ephemeris data indicate it is healthy, and if it has not been excluded by manual candidate satellite specification. Note that although a satellite is visible, its measurement is only available for use if the satellite is above the elevation mask angle.

The receiver’s channel resources are directed toward acquiring only those satellites which appear in this list except when the receiver is in cold start mode. Satellites within the list are ordered from highest to lowest elevation which, for sequential acquisition, also dictates the order in which acquisition attempts are made.

Receiver position and current time are required to compute satellite positions from orbital data. If position and/ or time is not considered to be well known (i.e. their expected errors are large), then the list is extended below the horizon and is filled to the maximum of 12 satellites. If DGPS corrections are available, the satellites represented in the corrections are used to set the list membership instead, since they also represent satellites visible to a nearby transmitting DGPS base station.

New visible satellite lists are generated by events that could cause a change in satellite list membership or could indicate a significant change in a satellite position relative to the antenna. These events include receipt of an elevation mask angle or candidate satellite specification command, downloading of a new satellite almanac, and changes in satellite health status reflected in new

almanac or ephemeris data.

In the case where DGPS corrections are used to establish list membership, a change in the set of satellites reflected in the corrections also causes a new list to be generated. During initial acquisition, a new list is generated when the receiver makes step adjustments to position and time. In the absence of these events, the visible satellite list is updated every 30 seconds. The visible satellite list is output in the Visible Satellites message (binary Message 1003)

4.5.1.1 Dilution Of Precision (DOP)

Geometric Dilution of Precision (GDOP) is a measure of the quality of a satellite constellation geometry. GDOP reflects the influence of satellite geometry on the accuracy of user position and time estimates. The best geometry is that which produces the lowest GDOP value. GDOP acts as a multiplier of the error in position and time estimates due to other sources.

GDOP is a composite measure. It can be separated into:

- Position Dilution of Precision (PDOP)

PDOP reflects the effects of geometry on three-dimensional position estimates

- Time Dilution of Precision (TDOP)

TDOP reflects geometric effects on time estimates. The relationship can be expressed as:

$$GDOP = \sqrt{(PDOP)^2 + (TDOP)^2}$$

In turn, PDOP can be separated into horizontal and vertical components:

- Horizontal Dilution of Precision (HDOP)

- Vertical Dilution of Precision (VDOP)

These components represent the effects of satellite geometry on two-dimensional horizontal position and on vertical position (altitude) estimates, respectively.

This relationship can be expressed as:

$$PDOP = \sqrt{(HDOP)^2 + (VDOP)^2}$$

The receiver computes the best available GDOP and each of its components in the Visible Satellites message (binary Message 1003). The best available GDOP is that associated with the satellite constellation consisting of all visible satellites above the mask angle (satellites whose measurements may be used).

At least four satellites are required to estimate position and time, and therefore to compute a

GDOP. The DOP fields in message 1003 are set to maximum values when GDOP cannot be computed.

4.5.2 Acquisition modes

Two methods of satellite acquisition are used by the Jupiter GPS receiver: sequential acquisition and parallel acquisition.

4.5.2.1 Sequential acquisition

Sequential acquisition describes the acquisition of a satellite with all non-tracking channels. An example of this acquisition mode is Cold Start, in which individual satellite acquisitions are attempted one at a time using all available channels to cover the wide Doppler uncertainty. As satellites are acquired, they stay in track on one channel with the remaining channels available for the next acquisition. Sequential acquisition is always used to acquire the first satellite. The receiver will automatically transition to parallel acquisition after the first satellite is acquired during a Warm Start or an Initialised Start.

4.5.2.2 Parallel acquisition

Parallel acquisition describes the acquisition of a satellite with a single non tracking channel. An example of this acquisition mode occurs after the first satellite is acquired in Warm Start, in which all of the visible satellites are assigned a channel and acquisitions are attempted simultaneously. Note that even though a single channel is being used, a large Doppler uncertainty can still be covered with extended search time.

4.5.2.3 Adaptive threshold-based signal detection

To extend the weak signal reception capability of the receiver, an adaptive noise threshold-based detection scheme has been implemented in the receiver software. With this approach, a variable detection threshold is computed from the average cross-correlation value of the received signal with a Pseudo-Random Noise (PRN) code. This PRN code is similar in structure to the GPS satellite PRN codes but uses a PRN ID that is not assigned to any of the GPS satellites. The computation of the received C/No power is also based on the cross-correlation value as determined above.

This scheme lowers the average detection threshold for weak signals, thus improving the receiver's ability to acquire and track satellites under these conditions. Conversely, this scheme sets a higher threshold when strong signals are received. This method results in more reliable acquisition of satellites and a corresponding reduction in TTFF over a wider variation of GPS signal strength conditions.

4.5.2.4 Overall search process

Figure 4-1 depicts the overall search process as

it interacts with the visible satellite list generation described in section 4.5.1. Sequential or parallel acquisition is selected based on channel availability and the required frequency search range (the number of Doppler bins) for each satellite.

4.5.3 Data collection

Sub frame data collection is a continuous process once a satellite is in track. This technique guarantees that current ephemeris and almanac information are always available to an operating GPS receiver (making identification of unhealthy satellites easy).

4.5.3.1 Ephemeris

Ephemeris data is gathered and maintained on a per satellite basis. For continuously tracked satellites (no blockage), it will take between 18 and 36 seconds to gather the data set. Once gathered, it is used to compute high accuracy satellite position, velocity, and acceleration (PVA) states for navigation and re-acquisition processes.

Note that this data is only maintained in SRAM due to its limited time validity.

4.5.3.2 Almanac

Almanac data is gathered and maintained on a per satellite basis. For continuously tracked satellites (no blockage), it will take a minimum of 12.5 minutes to gather the complete data set for all satellites. The primary function of almanac data is to provide approximate satellite PVA states for the acquisition process.

Note that this data is maintained in EEPROM due to its validity over an extended time range (weeks)

4.5.3.3 UTC and ionospheric corrections.

This data is gathered and maintained independently of the satellite from which it was obtained (one set is used for all). For continuously tracked satellites (no blockage), it will take a minimum of 12.5 minutes to gather an updated data set.

UTC corrections are used to compute the exact time offset between GPS and UTC time. Ionospheric corrections are used by the navigation process to compensate for the effects of the satellite signal passing through the Earth's ionosphere.

Note that this data is maintained in EEPROM due to its validity over an extended time range (a few weeks).

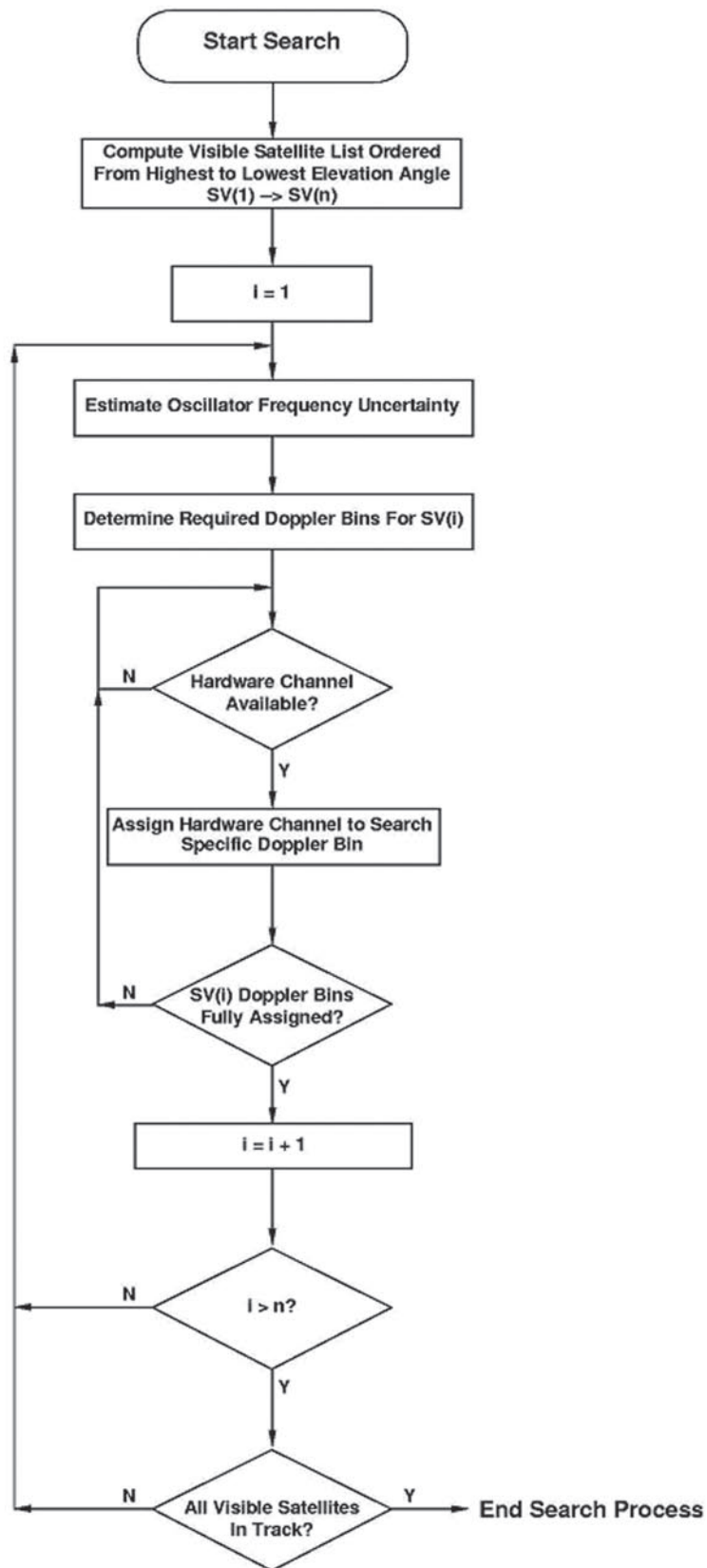


Figure 4-1 Jupiter search process

4.6 Navigation

This section describes the operation of the navigation software in the GPS receiver. It defines many of the features of the navigation system with emphasis on those that the OEM can control.

The navigation software initialises and maintains a state vector which is used to report time, position, and velocity to the user. The navigation software uses pseudo-range, integrated carrier phase, and Doppler measurements from the satellites, and external altitude inputs if available. An eight-state Kalman filter estimates position, velocity, and clock errors.

The OEM has substantial control over the operation of the navigation system to customise it for a specific application.

4.6.1 Geodetic datums

Geodetic parameters are used in both input and output messages. The receiver reports position as a set of geodetic parameters (latitude, longitude and altitude) in the geodetic position status output message (binary Message 1000). Geodetic parameters are also reported in the GPS fix data message (NMEA Message GGA), with the substitution of Mean Sea Level (MSL) altitude for geodetic altitude, and in the recommended minimum specific GPS data message (NMEA Message RMC) as latitude longitude. The receiver expects geodetic parameters as part of the geodetic position and velocity initialisation input message (binary Message 1200).

Whether geodetic parameters are used as input or output data, they are always referenced to the currently selected geodetic datum. Each geodetic datum is defined by five parameters:

The semi-major axis.

Flattening of the reference ellipsoid.

Delta X component of the WGS-84 datum origin offset.

Delta Y component of the WGS-84 datum origin offset.

Delta Z component of the WGS-84 datum origin offset.

The receiver has 189 pre-defined user datums selectable by the OEM. These datums, together with their identification codes, are listed in Appendix E of this document. All of the pre-defined datums are taken from the US Government document, Department of Defense World Geodetic System 1984.

4.6.1.1 User selection of geodetic datums

The default datum is WGS-84 (defined as datum code zero for the receiver). Other datums are selected using the Map Datum Select message (binary Message 1211). The selected code is reported back in the position status output message 1000 or 1001.

For example, if the receiver was in Navman binary mode and the OEM wanted to use a previously recorded position to initialise the receiver, and then get reported positions in WGS-84, the OEM would send three messages to the receiver as follows:

- 1 Send a 'map datum select' message (binary message (1211) with the desired datum code (the new datum code is reported back in message 1000 and/or 1001 if either or both messages have been enabled).

- 2 Send a 'geodetic position and velocity initialisation' message (binary Message 1200) with the correct latitude, longitude, and altitude.

- 3 Finally, send another message 1211 with the datum code 0 to set the datum back to WGS-84.

The selected datum is always stored in EEPROM, so that it is saved during power-off and reset cycles. The Navman binary Map Datum Select message must be used to change the geodetic datum; the datum cannot be changed when in NMEA mode. NMEA outputs will use the last datum selected in binary mode or WGS-84 if a datum selection has never been made.

4.6.1.2 User defined datums

Besides the 189 pre-defined datums, the OEM can define five custom datums for a specific application. Each datum is defined by the five parameters described in section 4.6.1 and the new datum definition is sent to the receiver using the User-Defined Datum Definition message (binary Message 1210).

There are five custom datum codes to choose from, 300 to 304. All user-defined datums are stored in EEPROM. Once the datum is stored, it is selected using the Navman binary Map Datum Select message in the same manner as the pre-defined datums. If a custom datum is stored and later re-defined, the existing datum will be overwritten.

4.6.2 Platform class

The Jupiter GPS receiver supports three platform classes:

- pedestrian (low dynamics)
- automotive (medium dynamics)
- aircraft (high dynamics)

The platform class is set by the OEM to optimise navigation processing for the dynamics of the specific platform that is carrying the receiver. The class is used to set process noise parameters, velocity decay time constants, and speed and altitude limits.

The default platform class is automotive. The OEM sets the platform class using the Application Platform Control message (binary Message 1220). The platform class is stored in EEPROM, so it is retained when power is turned off.

4.6.2.1 Pedestrian

This platform class is used when the receiver is mobile in a low dynamic environment. An example would be a hand-held GPS receiver used for hiking.

4.6.2.2 Automotive

This platform class is for moderate dynamic environments where altitude is not constant. A common example would be a car, truck, or motorcycle.

4.6.2.3 Aircraft.

This platform class is for high dynamic environments where altitude may change rapidly.

4.6.3 Navigation cycle

The navigation software nominally executes once per second. During each execution, the navigation state is propagated forward to the current time and updated with any available measurements. The navigation solution is then provided to the serial interface for output in the selected message set (either Navman binary or NMEA).

Note: NMEA may be slightly delayed compared to the binary data.

4.6.3.1 State propagation

User state propagation over the measurement update interval, nominally one second, is by dead reckoning with constant tangent plane velocity. The tangent plane is defined by the current position and the selected datum. This means that if the vertical velocity is zero, the state propagation will be at constant altitude in the user-selected datum. For Pedestrian, Automotive, and Aircraft platforms, user state propagation is in three dimensions.

Once the receiver has been navigating and a velocity has been established by the Kalman filter,

it will be used to propagate the state forward in the absence of further measurements for a limited time period, until the estimated errors in the propagated velocity have reached certain limits. Once these limits are reached, Pedestrian (low dynamics), Automotive (medium dynamics), Aircraft (high dynamics), the velocity estimate is considered less reliable and is decayed exponentially with platform class dependent time constants.

4.6.3.2 Measurement processing

Once four satellites are available above the elevation mask angle with ephemeris data and sufficiently good geometry, the Kalman filter begins to process the measurements. The Kalman filter processes two measurements for each satellite, the integrated carrier phase measurement (also known as carrier-smoothed pseudo-range) and the Doppler, or range rate, measurement.

4.6.3.3 Altitude processing

The receiver uses altitude aiding if a source is available and the Expected Vertical Position Error (EVPE) exceeds a threshold. The sources available for aiding, in the order of preference for use, are:

- 1 user-entered altitude.
- 2 held altitude. ROM altitude (acquisition only).
- 3 ROM altitude (acquisition only)

User-entered altitude

The 'user-entered altitude input' message (binary Message 1219) is used to supply an altitude to the receiver. The altitude can be specified as instantaneous, valid until cleared from RAM, or valid until cleared from EEPROM. Instantaneous altitude is valid for one navigation cycle only. This altitude input type is used when there is a continuous source of external altitude data.

Held altitude

Held altitude is stored in the receiver when the navigation solution is valid. The held altitude is stored with a variance that grows from the last time it was updated to reflect the age and growing uncertainty of the altitude estimate.

Use of held altitude is normally a significant performance boost in an urban environment with heavy blockage and it is enabled by default. A held altitude value is discarded if the estimated climb rate magnitude exceeds 1 m/s. The OEM can disable the use of held altitude using the 'nav configuration' message (binary Message 1221).

4.6.3.4 Position pinning

When the receiver is not using DGPS, satellite measurements include time varying range errors.

These errors induce velocities in the receiver's state estimate even if the receiver is motionless. The magnitude of these velocities depends on the geometry and number of satellites in track. Typical values are between one-half and two metres per second. The position estimate of the receiver will vary within a circle of approximately 100 m (the 2Drms position error specified in the GPS SPS Signal Specification).

This varying of the position estimate while the receiver is static is undesirable for users who display their position on a map or for those with similar applications. The receiver's proprietary navigation software is capable of "pinning" the position output when the estimated velocity is low and the navigation solution is of good quality. This prevents the varying behaviour of the solution in static situations, but introduces some risk that actual platform motion will be mistaken for deliberate SA induced error.

By default, the position pinning feature of the Jupiter GPS receiver is enabled. The OEM can turn it off using the 'nav configuration' message (binary Message 1221).

4.6.3.5 Ground track smoothing.

Without the use of DGPS, satellite measurements are corrupted by SA and do not generate a consistent estimate for receiver position. Typical range errors are on the order of 30 m. The receiver processes all satellites above the mask angle to minimise the effects of the range error.

Changes occur in the set of satellites being processed because of blockage, and the rising and setting of satellites. When a change occurs, the position estimate formed from averaging these errors is shifted. These shifts can be substantial, typically 10 m to 20 m, but up to 100 m or more in bad geometry.

The receiver has a proprietary compensation technique for these constellation switch effects which maintains a smooth estimate of the platform's ground-track and altitude. This smoothing is accomplished without any loss of dynamic response.

However, this method is not required and is automatically disabled when DGPS is available. Without DGPS, the method is enabled by default. Most users should leave it enabled. One reason for disabling it would be to compare the solution with a point solution from another receiver or a solution calculated off-line.

Ground-track smoothing can be disabled using the 'nav configuration' message (binary

Message 1221). The configuration word is stored in EEPROM, so the setting for ground-track smoothing will be retained through power-off and reset cycles.

4.6.4 Solution validity

The validity of navigation solution outputs is determined by user-defined criteria. The OEM can specify which criteria to apply for the particular application. There are five possible criteria used to validate a solution:

- 1 Was an altitude measurement used?
- 2 Was DGPS used?
- 3 How many satellite measurements were used?
- 4 What is the Expected Horizontal Position Error (EHPE)?
- 5 What is the Expected Vertical Position Error (EVPE)?

The OEM cannot change the validity criteria in NMEA mode. These criteria can be set using only the binary 'solution validity criteria' message (Message 1217) and they are retained through power-off and reset cycles in EEPROM.

4.6.4.1 Altitude measurement validity criterion

The altitude measurement validity criterion allows the OEM to specify if solutions that make use of an altitude measurement should be marked valid. Altitude is not used in the solution unless it is necessary because of deteriorating EVPE or untracked satellites. When it is required, the OEM may wish this to be an indication that the solution is invalid for purposes of the specific application. The default is that solutions using altitude measurements may be marked valid

4.6.4.2 DGPS used validity criterion

The DGPS used validity criterion indicates an invalid navigation solution if DGPS is unavailable after it has been required. The system default is that DGPS is not required for a valid solution.

4.6.4.3 Number of satellites used validity criterion

The number of satellites used validity criterion indicates an invalid navigation solution if the minimum number of satellites required to be in the solution is not met. The default for this test is zero.

A solution may be reported as valid with no measurements used so long as the EHPE and EVPE criteria pass and a Kalman filter solution has been previously computed. The reason the default is set to zero is to allow the receiver to coast through brief outages without declaring the solution invalid (e.g. for example, under a freeway overpass).

If the measurements are lost for a long time, the EHPE and EVPE will grow until they surpass their thresholds and the solution fails the validity test for that reason. Some applications require a solution to be marked invalid unless it uses three, four, or more satellites. The OEM can set any of these thresholds by sending a binary 'solution validity criteria' message (Message 1217) with the number of satellites required

4.6.4.4. Maximum EHPE validity criterion

The EHPE is the one sigma horizontal position error estimate for the solution. The validity criterion default is 10 m. The meaning of the reported EHPE depends on whether or not DGPS is in use. If DGPS is in use the EHPE is the estimated one-sigma error in absolute position accuracy. When DGPS is not in use, the EHPE and EVPE are reported with the effects of the satellite User Equivalent Range Error (UERE) excluded. This excludes SA induced error from the EHPE and EVPE.

So in SPS navigation, the EHPE and EVPE serve as convergence indicators for the Kalman filter, not as absolute accuracy limits for the reported position. The EHPE validity threshold can be set by the OEM in the binary 'solution validity criteria' message (message 1217).

4.6.4.5 Maximum EVPE validity criterion

The EVPE is the one sigma vertical position error estimate for the solution. The default is 25 m. The operation and meaning of this criterion is analogous to the EHPE criterion in section 4.6.4.4. The threshold can be set in the binary 'solution validity criteria' message (message 1217).

4.6.5 Mean Sea Level (MSL)

MSL is a geoid, or surface of equal gravitational potential. The height of the MSL geoid above or below the reference ellipsoid (WGS-84 by default) is called the geoidal separation. Positive geoidal separation means that the geoid is above the ellipsoid.

Values for the geoidal separation are computed at any receiver position by interpolating on the table of geoidal separation values provided in the U.S. Government document, Department of Defense World Geodetic System 1984.

Altitude or height computation is referenced to the ellipsoid and is referred to as geodetic altitude. Altitude referenced to the geoid (usually referred to as altitude MSL) can be computed as the geodetic altitude minus the geoid separation.

4.6.6 Magnetic variation

The magnetic variation model used in the receiver

is derived from the full International Geomagnetic Reference Field (IGRF) 95 magnetic model. Documentation, tabular data, and test programs for the IGRF 95 magnetic model can be obtained from the National Oceanic and Atmospheric Administration (NOAA) National Geophysical Data Centre (NGDC) web site (<http://julius.ngdc.noaa.gov/seg/potfld/geomag.html>).

The magnetic variation is used to convert true heading to magnetic heading. It is output in binary Message 1000. To convert the true course provided in binary Message 1000 to magnetic heading, the magnetic variation is added to the true course.

4.7 Support functions

This section describes the support functions of the GPS receiver.

4.7.1 Serial communication interfaces

Jupiter GPS receivers provide two bi-directional serial communication interfaces: the host and auxiliary ports (see Section 3)

4.7.1.1 The host port

The Host port is the primary interface to the controlling application and provides all the services for initialising and configuring the system as well as for the reporting of the navigation solution and receiver status.

By default, the Host port is configured for 9600 baud, no parity, 8 data bits, and 1 stop bit. The Navman binary communications protocol is the default selection for the Host port.

The default settings (configuration and protocol) can be overridden with the use of the NMEA Select control line of the interface. When this line is asserted, the configuration defaults to 4800 baud, no parity, 8 data bits, and 1 stop bit, and the communications protocol defaults to NMEA. Note that the NMEA Select line will override any previously stored selections for the Host port configuration and communication settings.

While using the Navman binary communications protocol on the Host port, a number of application specific parameters can be configured to customise the receiver for a specific application. The ability to freely switch between Navman binary and NMEA modes provides full capability to all users.

Host port output messages can be configured using the log control messages supported in both Navman binary and NMEA message protocols. Changes to the port configuration settings,

communications protocol, and message controls are stored in non-volatile EEPROM.

4.7.1.2 The auxiliary port

The auxiliary port is used exclusively for the receipt of differential corrections in RTCM SC-104 serial message format.

By default, the auxiliary port is configured for 9600 baud, no parity, 8 data bits, and 1 stop bit. There is no data output from this port.

4.7.2 EEPROM services

The EEPROM services provide for the non-volatile storage and retrieval of system configuration parameters and data that vary, but are generally fairly constant for short periods of time (a few weeks).

The configuration and operational data stored in EEPROM is only read during system initialisation if the complimentary SRAM data is invalid. When data is stored in EEPROM, a checksum is stored with it to validate the data when it is read. If the data read from EEPROM during initialisation is invalid, default values from ROM will be used to initialise the system.

EEPROM data blocks are updated/refreshed when the corresponding system data changes significantly. The qualification of a significant change varies for each data block. In the case of user configurable data items (datum selection, user-defined datums, platform class, communication parameters, etc.), simply receiving new inputs is all that is required for the data to be refreshed in the EEPROM.

In the case of slowly changing data (position, almanac, frequency standard data, etc.), additional constraints of distance moved, change in value, and/or elapsed time are imposed on the EEPROM

update. The various parameters and data maintained in the Jupiter receiver's EEPROM are listed in Table 4-2.

4.7.3 RTC services

The RTC services provide for the storage of time/ date data, maintained while the system is in an "idle" state. As long as external power is provided to the RTC device, it will keep the time/ date data current, providing the system with accurate time initialisation as needed.

The time/ date data is only read from the RTC during system initialisation. When the time/ date data is stored in the RTC, a snapshot of the data is stored with a checksum in the RAM space of the RTC device (RTC- RAM). The snapshot data in the RTC-RAM is used to determine if the RTC was kept alive, and therefore if the time/ date data is valid. If the clock data is not valid at system initialisation, the "last known time" stored in SRAM will be used if it is available, otherwise time will be invalid.

The time/ date data is updated in the RTC periodically while the system is in its Kalman filter navigation mode.

4.7.4 Differential GPS (DGPS)

DGPS techniques can be used to eliminate errors introduced by Selective Availability (SA) and other error sources. DGPS requires one GPS receiver to be located at a precisely surveyed location. This receiver, often referred to as a 'base station' or 'reference station', calculates corrections to the measured pseudo-range and delta-range measurements from each of the satellites it is tracking.

These corrections are then broadcast over a communications link to remote GPS receivers in the field which apply these corrections to their

Configuration data	Satellite management parameters	Navigation data
Serial port configuration (both ports)	UTC and ionosphere model parameters	last known position
solution validity criteria	frequency standard data	user-entered altitude
selected datum	almanac data	
platform class		
cold start control		
satellite elevation Mask Angle		
satellite candidate List		
differential GPS control		
default serial output messages		
user defined datums		
navigation control		

Table 4-2 Parameters and data maintained in EEPROM

measurements before computing a position solution. This technique effectively eliminates much of the error due to SA as well as errors due to unmodelled satellite clock errors, satellite ephemeris errors, and atmospheric delays. This 'improved' solution is present in all output messages.

With a few minor exceptions outlined below, DGPS is enabled by default, but may be disabled by the OEM. Because SA changes with time, the corrections deteriorate with time as well. Therefore, DGPS operation will only occur when enough current DGPS corrections are available.

The Jupiter receiver accepts RTCM SC-104 format DGPS correction messages directly on the auxiliary serial port. The receiver also accepts DGPS corrections data formatted as a binary data input message (Message 1351) over its primary serial port. (Detailed information on the format of this message is provided in Section 3.5.2.19.)

4.7.4.1 The RTCM protocol

The Jupiter will accept 6-of-8 RTCM SC-104 data directly from the auxiliary serial port. No external formatting is required and the receiver handles all parsing and verification of the data. The user needs only to verify the integrity of the data sent to the receiver to ensure that high bit errors are not present in the detected RTCM raw data stream.

The user should be aware that RTCM SC-104 data will be used only if, for every 30-bit word, the syndrome (6-bit parity) exactly matches the one which should occur on the basis of the 24-bit data seen in each word. No attempt will be made to correct single bit errors; any syndrome mismatch will cause rejection of that data word and rejection of the message in which it exists.

The receiver will parse the incoming data bits and decode all of the RTCM SC-104 messages. Those messages required for DGPS operation will be used to fill in the DGPS database within the receiver. Those messages which are not used will be discarded.

4.7.4.2 The RTCM message types

The receiver accepts DGPS correction data as a subset of the 64 RTCM SC-104 messages found in Table 4-2 of the RTCM SC-104 Version 2.1 standard. Though the receiver will accept and decode all RTCM messages, not all messages are necessary for DGPS operation.

The Data Sheet for each of the Jupiter GPS receivers shows which of the messages defined in the RTCM standard are used by the receiver to form a DGPS position solution. Refer to the

standard for more detailed descriptions of these and other RTCM SC-104 messages.

Type 1 message

Type 1 messages contain pseudo-range and pseudo-range rate corrections for a complete set of visible satellites. Currently, this is the most common type of message transmitted by commercial RTCM providers and base stations.

Type 2 message

Type 2 messages contain delta corrections and are transmitted by reference stations to help receivers during ephemeris cutovers. These Table 4-2. Parameters And Data Maintained In EEPROM messages are used by the field receiver in conjunction with Type 1 or Type 9 messages until both the reference station and field receiver are operating with the same set of ephemeris.

Type 9 message

Type 9 messages have the same format as Type 1 messages, but usually only contain corrections for a subset of the visible constellation. These messages are typically transmitted at a higher rate than the Type 1 messages. Beacons, such as those operated by the U.S. Coast Guard, are currently the primary source for these corrections, but they are also available from some commercial service providers and base stations.

4.7.4.3 Compliance with RTCM SC-104 requirements

The Radio Technical Commission for Maritime Services (RTCM) has a special committee numbered 104 (SC-104). Its charter is to create recommended standards for the transmission of DGPS correction data.

4.7.4.4 DGPS initialisation and configuration.

At power-on, the receiver initialises its internal DGPS database to indicate that no valid DGPS data is available. If the user requests the Differential GPS Status message (binary Message 1005), the message will indicate that no corrections have been processed. Some of the position status messages (binary messages 1000 and 1001, and NMEA message GGA) will also indicate that the receiver is not computing a DGPS solution.

As sufficient valid RTCM data is passed to the receiver, it will automatically produce DGPS solutions. Other than supplying RTCM data and ensuring that DGPS operation is not disabled, no action is required on the part of the user to cause DGPS operation.

The receiver will compute DGPS solutions whenever all of the following conditions are satisfied:

Ephemeris data has been collected by the receiver for at least four satellites.

DGPS corrections have been received for at least the same four satellites, and these corrections are not older than the time limit specified in the Differential GPS Control message (binary Message 1214)

The Issue Of Data Ephemeris (IODE) is the same for both the receiver-collected ephemeris and the RTCM SC-104 corrections.

All of the applicable satellites have good health or have been declared healthy for DGPS purposes by the RTCM SC-104 source.

The User Differential Range Error (UDRE) reported by the RTCM SC-104 source is equal to or less than 8 m for all four satellites.

The RTCM SC-104 source declares itself to be in good health.

The user has not turned DGPS operation off.

4.7.4.5 Disabling DGPS operation

The user may disable DGPS operation through the Differential GPS Control message (binary Message 1214). When disabled the receiver will not use DGPS information to compute a position solution nor will the information be erased.

During the time that DGPS operation is disabled, and DGPS solutions are not being computed, RTCM processing continues as long as RTCM messages are being sent to the receiver. The data contained within these messages will be used to update the receiver's internal DGPS database. As soon as the DGPS function is enabled, the most current data will be used to compute a position solution.

4.7.4.6 DGPS reset

The user may also "reset" the DGPS process at any time using the Differential GPS Control message (binary Message 1214). When this is done, the DGPS data currently stored in the receiver is invalidated or replaced by its default values. This discontinues DGPS service until new RTCM SC-104 and ephemeris data is collected.

A DGPS reset is different from the type of reset initiated by power-on or an initialisation message system reset. During a DGPS reset, 'DGPS disable' and 'correction timeout' are unaffected. If values have been previously entered for these words, these same values will be in effect both before and after the DGPS reset. If new valid entries for these words are received within a DGPS control message that also contains a reset, then the new values will be in effect after the reset. However, after a DGPS reset all other DGPS

parameters will be set to their default values.

4.7.4.7 DGPS status request

The user may request that the status of DGPS operation be provided. When requested, the DGPS status message (binary Message 1005) provides information on the state of each of the corrections being processed. In the event that DGPS solutions are not available, the status message also provides enough diagnostic data for the user to determine why they are not being computed.

4.7.5 Built-In Test (BIT)

The receiver can be commanded to execute a BIT at any time while in Navman binary mode. The receiver performs the test and returns the results in the corresponding output message.

A BIT is commanded by sending a binary 'perform built-in test command' message (Message 1300). Such a command will interrupt normal receiver operations and result in a system reset.

Output messages that are processed by the serial I/O hardware when the BIT command is received are output, but subsequent output messages are suspended until after the BIT cycle is complete. When the BIT is complete, the receiver is reset and normal operation resumes. This means that the BIT results may not be the first received output message after a BIT command.

4.7.5.1 Interpreting BIT results

A device failure indicator in the 'BIT results' message is valid for all devices installed on the board. The failure words defined in Message 1100 will be zero if the device is working as expected and non-zero if an error was detected.

ROM failure

The ROM Failure word in Message 1100 indicates the result of a ROM (program memory) checksum test. A failed status means that the ROM chip may be defective.

RAM failure

The RAM failure word in Message 1100 indicates the results of a non-destructive pattern test and an address line integrity test. A failed status means that the RAM chip(s) may be defective.

EEPROM failure

There are no explicit tests of the EEPROM device in response to message 1100. However, the receiver maintains and reports a status of what parameters have been written to EEPROM. When a data block has been written and cannot be successfully read back from the device, a failure will be reported. A failure will also be reported if the device does not respond to an attempt to

access it. A failed status means that the EEPROM chip may be defective.

Digital Signal Processor (DSP)

The DSP failure word in message 1100 indicates the results of the DSP tests. A failed status indicates that one or more of the DSP tests failed and that the DSP chip may be defective.

RTC

The RTC failure word in message 1100 indicates the results of a time rollover test of the RTC. A failed status indicates that the RTC test failed and that the RTC chip may be defective.

PORT 1 (host port) and PORT 2 (aux port) error and received byte counts

There are no explicit tests for the two serial communications ports. However, a count of bytes received with error and a count of bytes received without error for each port are maintained and reported in Message 1100. These words provide a measure of the reliability of the communications interface. If the count of bytes received with error is large, the interface may be defective or the port configuration may be incorrect.

Appendix A: Acronyms, abbreviations, and glossary

This appendix provides a list of all acronyms, abbreviations, and selected terms used in this document, together with their associated meaning.

2D: Two Dimensional.

2Drms: Two Dimensional root mean square.

3D: Three Dimensional.

3Drms: Three Dimensional root mean square.

AAMP: Advanced Architecture Micro-Processor.

A/D: Analog/Digital.

Almanac: a set of orbital parameters that allows calculation of approximate GPS satellite positions and velocities. The almanac is used by a GPS receiver to determine satellite visibility and as an aid during acquisition of GPS satellite signals. The almanac is a subset of satellite ephemeris data and is updated weekly by GPS Control.

Altitude hold: a technique that allows navigation using measurements from three GPS satellites plus an independent value of altitude.

Altitude hold enable command: this message allows the application processor to enable or disable the 'altitude hold' feature.

Altitude hold mode: a navigation mode during which a value of altitude is processed by the Kalman filter as if it were a range measurement from a satellite at the Earth's centre (WGS-84 reference ellipsoid centre).

AP: Application Processor. The processor connected to the Jupiter GPS receiver port which controls the receiver with command messages and uses data from output messages.

ASCII: American Standard Code for Information Interchange.

ATO: Acquisition Time-Out.

Auto hold: The receiver will use the last altitude calculated in 3D navigation as the current value of held altitude when entering 'altitude hold' 2D navigation. It will continue to use this value throughout this altitude hold event unless an 'amended altitude' command is received from the application processor. The 3D calculated altitude used in this way is called an 'auto hold' altitude.

B: Boolean.

Baud: (See bps.)

BIT: Built-In Test.

Block I satellite: satellites designed and built to

support GPS development and testing. A total of 10 Block I satellites were successfully launched between February 1978 and October 1989.

Block II satellite: satellites designed and built to support GPS 'Space Segment' operation. A total of 28 Block II satellites had been built and launched as of August 1995.

Block IIR satellite: satellites designed to replace Block II satellites.

bps: bits per second (sometimes referred to as baud rate)

C: Celsius.

C/A: Code Coarse/Acquisition Code. A spread spectrum direct sequence code that is used primarily by commercial GPS receivers to determine the range to the transmitting GPS satellite.

CEP: Circular Error Probable. The radius of a circle, centred at the user's true location, that contains 50 % of the individual position measurements made using a particular navigation system.

Clock error: the uncompensated difference between synchronous GPS system time and time best known within the GPS receiver.

CMOS: Complimentary Metal Oxide Semiconductor.

C/No: Carrier-to-Noise density ratio. Also, Channel Signal-To-Noise.

COG: Course Over Ground.

Cold start: a condition in which the GPS receiver can arrive at a navigation solution without initial position, time, current ephemeris, and almanac data.

Control segment: the master control station and the globally dispersed monitor stations used to manage the GPS satellites, determine their precise orbital parameters, and synchronise their clocks.

dB: Decibel.

DB-9: 9-pin D-subminiature connector.

DB-25: 25-pin D-subminiature connector.

dBic: Decibel-isotropic-Circular (measure of power relative to an isotropic antenna with circular polarisation).

dBm: Decibel- milliwatt (measure of power relative to one milliwatt).

dBW: Decibel-Watt (measure of power relative to one watt).

DC: Direct Current.

DGPS: Differential GPS. A technique to improve

GPS accuracy that uses pseudo-range errors recorded at a known location to improve the measurements made by other GPS receivers within the same general geographic area.

DI: Double Precision Integer.

Doppler aiding: a signal processing strategy, which uses a measured doppler shift to help a receiver smoothly track the GPS signal to allow a more precise velocity and position measurement.

DoD: Department of Defense.

DOP: Dilution of Precision (see GDOP, HDOP, PDOP, TDOP, and VDOP).

DOS: Disk Operating System.

DSP: Digital Signal Processor.

DTR: Data Terminal Ready.

ECEF: Earth-Centred Earth-Fixed. A Cartesian coordinate system with its origin located at the centre of the Earth. The coordinate system used by GPS to describe three-dimensional location. For the WGS-84 reference ellipsoid, ECEF coordinates have the Z-axis aligned with the Earth's spin axis, the X-axis through the intersection of the prime meridian and the equator and the Y-axis is rotated 90 degrees east of the X-axis about the Z-axis.

EEPROM: Electrically Erasable Programmable Read-Only Memory.

AFP: Extended Floating Point.

EHPE: Expected Horizontal Position Error.

EMC: Electromagnetic Compatibility

EMI: Electromagnetic Interference.

Ephemeris: a set of satellite orbital parameters that is used by a GPS receiver to calculate precise GPS satellite positions and velocities. The ephemeris is used to determine the navigation solution and is updated frequently to maintain the accuracy of GPS receivers.

EPROM: Erasable Programmable Read Only Memory.

ESD: Electrostatic Discharge.

EVPE: Expected Vertical Position Error.

FOM: Figure Of Merit.

FP: Floating Point.

FRP: Federal Radio-navigation Plan. The U.S. Government document which contains the official policy on the commercial use of GPS.

GaAs: Gallium Arsenide.

GDOP: Geometric Dilution of Precision. A factor used to describe the effect of the satellite geometry on the position and time accuracy of the

GPS receiver solution. The lower the value of the GDOP parameter, the less the error in the position solution. Related indicators include PDOP, HDOP, TDOP, and VDOP.

GMT: Greenwich Mean Time.

GPS: Global Positioning System. A space-based radio positioning system which provides suitably equipped users with accurate position, velocity, and time data. When fully operational, GPS will provide this data free of direct user charge worldwide, continuously, and under all weather conditions. The GPS constellation will consist of 24 orbiting satellites, four equally spaced around each of six different orbital planes.

GPSRE: GPS Receiver Engine.

GPS Time: the number of seconds since Saturday/Sunday midnight UTC, with time zero being this midnight. Used with GPS week to determine a specific point in GPS time.

GPS Week: the number of weeks since January 6, 1980, with week zero being the week of January 6, 1980. Used with GPS Time to determine a specific point in GPS time.

HDOP: Horizontal Dilution of Precision. A measure of how much the geometry of the satellites affects the position estimate (computed from the satellite range measurements) in the horizontal (East, North) plane.

Held altitude: the altitude value that will be sent to the Kalman filter as a measurement when in Altitude Hold Mode. It is an Auto Hold Altitude unless an Amended Altitude is supplied by the application processor.

HDOP: Horizontal Dilution of Precision

Hz: Hertz.

IF: Intermediate Frequency.

IGRF: International Geomagnetic Reference Field.

I/O: Input/output.

ICODE: Issue Of Data Ephemeris.

JPO: Joint Program Office. An office within the U.S. Air Force Systems Command, Space Systems Division. The JPO is responsible for managing the development and production aspects of the GPS system and is staffed by representatives from each branch of the U.S. Military, the U.S. Department of Transportation, Defense Mapping Agency, NATO member nations, and Australia.

Kalman Filter: Sequential estimation filter which combines measurements of satellite range and range rate to determine the position, velocity, and time at the GPS receiver antenna.

km: Kilometre.

L1 Band: the 1575.42 MHz GPS carrier frequency which contains the C/A code, P-code, and navigation messages used by commercial GPS receivers.

L2 Band: a secondary GPS carrier, containing only P-code, used primarily to calculate signal delays caused by the ionosphere. The L2 frequency is 1227.60 MHz.

LD/LR: Line Driver/Line Receiver.

LED: Light Emitting Diode.

LPTS: Low Power Time Source.

LSB: Least Significant Bit.

m/s: metres per second (units of velocity).

m/s/s: metres per second per second (units of acceleration).

m/s/s/s: metres per second per second per second (units of impulse or 'jerk').

Mask angle: The minimum GPS satellite elevation angle permitted by a particular GPS receiver design.

Measurement error variance: The square of the standard deviation of a measurement quantity. The standard deviation is representative of the error typically expected in a measured value of that quantity.

MFI: Multi-Function Interface.

MHz: Megahertz.

MR: Master Reset.

MSB: Most Significant Bit.

MSL: Mean Sea Level.

MTBF: Mean Time Between Failure.

Multipath errors: GPS positioning errors caused by the interaction of the GPS satellite signal and its reflections.

mV: Milli-Volt.

mW: Milli-Watt.

NF: Noise Factor (or Noise Figure).

NMEA: National Marine Electronics Association.

Obscuration: term used to describe periods of time when a GPS receiver's line-of-sight to GPS satellites is blocked by natural or man-made objects.

OEM: Original Equipment Manufacturer.

Over-determined solution: the solution of a system of equations containing more equations than unknowns. The GPS receiver computes, when possible, an over-determined solution using

the measurements from all GPS satellites it can track, instead of the four necessary for a three-dimensional position solution.

P-Code Precision Code: a spread spectrum direct sequence code that is used primarily by military GPS receivers to determine the range to the transmitting GPS satellite.

Parallel receiver: a receiver that monitors four or more satellites simultaneously.

PC: Personal Computer.

PCMCIA: Personal Computer Memory Card International Association.

PDOP: Position Dilution of Precision. A measure of how much the error in the position estimate produced from satellite range measurements is amplified by a poor arrangement of the satellites with respect to the receiver antenna.

Pi (or π): the mathematical constant having a value of approximately 3.14159.

P-P: Peak-to-Peak.

PPS: Pulse Per Second.

Note: PPS can also stand for Precise Positioning Service. The GPS positioning, velocity, and time service which will be available on a continuous, worldwide basis to users authorised by the DoD.

PRN: Pseudo-random Noise Number. The identity of the GPS satellites as determined by a GPS receiver. Since all GPS satellites must transmit on the same frequency, they are distinguished by their pseudo-random noise codes.

PRR: Pseudo-Range Rate.

Pseudo-range: the calculated range from the GPS receiver to the satellite determined by measuring the phase shift of the PRN code received from the satellite with the internally generated PRN code from the receiver. Because of atmospheric and timing effects, this time is not exact. Therefore, it is called a pseudo-range instead of a true range.

PSF: Post Select Filter.

PVT: Position, velocity, and time.

RAM: Random Access Memory.

Receiver channels: a GPS receiver specification which indicates the number of independent hardware signal processing channels included in the receiver design.

RF: Radio Frequency.

RFI: Radio Frequency Interference.

ROM: Read-Only Memory.

RTC: Real-Time Clock.

RTCA: Radio Technical Commission for Aeronautics.

RTCM: Radio Technical Commission for Maritime Services.

SA: Selective Availability. The method used by the DoD to control access to the full accuracy achievable with the C/A code.

Satellite elevation: the angle of the satellite above the horizon.

SEP: Spherical Error Probable. The radius of a sphere, centred at the user's true location, that contains 50 percent of the individual three-dimensional position measurements made using a particular navigation system.

Sequential Receiver: a GPS receiver in which the number of satellite signals to be tracked exceeds the number of available hardware channels. Sequential receivers periodically reassign hardware channels to particular satellite signals in a predetermined sequence.

SNR: Signal-To-Noise Ratio (expressed in decibels).

SOG: Speed Over Ground.

SPS: Standard Positioning Service. A positioning service available to all GPS users on a continuous, worldwide basis with no direct charge. SPS uses the C/A code to provide a minimum dynamic and static positioning capability.

SRAM: Static Random Access Memory.

Stand-by SRAM: portion of the SRAM that is powered by a "keep-alive" power supply when prime power is removed to preserve important data and allow faster entry into the Navigation Mode when prime power is restored. All of the SRAM in the receiver is "keep-alive" SRAM.

SV: Space Vehicle. Also Satellite Vehicle.

TDOP: Time Dilution of Precision. A measure of how much the geometry of the satellites affects the time estimate computed from the satellite range measurements.

Three dimensional coverage (hours): the number of hours-per-day with four or more satellites visible. Four visible satellites are required to determine location and altitude.

Three dimensional navigation: Navigation mode in which altitude and horizontal position are determined from satellite range measurements.

Time mark pulse: a one pulse per second (IPPS) output synchronised to UTC when the receiver is in its Navigation Mode.

TOW: Time Of Week (see GPS time).

TTFF: Time-To-First-Fix. The actual time required by a GPS receiver to achieve a position solution. This specification will vary with the operating state of the receiver, the length of time since the last position fix, the location of the last fix, and the specific receiver design.

TTL: Transistor-Transistor Logic

Two dimensional coverage (hours): the number of hours-per-day with three or more satellites visible. Three visible satellites can be used to determine location if the GPS receiver is designed to accept an external altitude input (Altitude Hold).

Two dimensional navigation: Navigation mode in which a fixed value of altitude is used for one or more position calculations while horizontal (2D) position can vary freely based on satellite range measurements.

UDRE: User Differential Range Error. A measure of error in range measurement to each satellite as seen by the receiver.

USERE: User Equivalent Range Error.

Update Rate: the GPS receiver specification which indicates the solution rate provided by the receiver when operating normally.

U.S. Air Force Space Command: the U.S. Air Force agency responsible for the operation of the GPS Space and Control Segments.

UTC: Universal Time Coordinated. This time system uses the second defined true angular rotation of the Earth measured as if the Earth rotated about its conventional terrestrial pole. However, UTC is adjusted only in increments of one second. The time zone of UTC is that of Greenwich Mean Time (GMT).

VCO: Voltage Controlled Oscillator.

VDOP: Vertical Dilution of Precision. A measure of how much the geometry of the satellites affects the position estimate (computed from the satellite range measurements) in the vertical (perpendicular to the plane of the user) direction.

VSWR: Voltage Standing Wave Ratio.

WGS-84 World Geodetic System (1984): a mathematical ellipsoid designed to fit the shape of the entire Earth. It is often used as a reference on a worldwide basis, while other ellipsoids are used locally to provide a better fit to the Earth in a local region. GPS uses the centre of the WGS-84 ellipsoid as the centre of the GPS ECEF reference frame.

Appendix B: References

This appendix provides a list of documents that may help a user of Navman's GPS receivers to learn more about the way the GPS can be used. Not all of these documents have been referred to in the text of this document.

1. Global Position System Standard Positioning Service Signal Specification, United States Department of Defense.
2. Standard For Interfacing Marine Electronic Devices, NMEA 0183, National Marine Electronics Association.
3. RTCM Recommended Standards for Differential NAVSTAR GPS Service, Radio Technical Commission for Maritime Services.
4. Principle of Operation of NAVSTAR and System Characteristics, Milliken and Zoller, Global Positioning System, Vol 1, 1980, pp. 3-14.
5. Department of Defense World Geodetic System 1984, DMA TR 8350.2.
6. Internet web site for the National Geophysical Data Centre (NGDC): "<http://julius.ngdc.noaa.gov/seq/potfld/geomag.html>"

APPENDIX C: NAVSTAR GPS operation

NAVSTAR GPS is a space-based satellite radio navigation system developed by the U.S. Department of Defense (DoD). GPS receivers provide land, marine, and airborne users with continuous 3D position, velocity, and time data. This information is available free of direct charge to an unlimited number of users. The system operates under all weather conditions, 24 hours a day, anywhere on Earth. There are three major segments:

- space segment
- control segment
- user segment

The space segment

This segment consists of a nominal constellation of 24 operational satellites (including 3 spares). These satellites have been placed in 6 orbital planes (see Figure C-1) about 20 200 km (10 900 miles) above the Earth's surface. The satellites are in circular orbits with a 12-hour orbital period and inclination angle of 55 degrees. This orientation normally provides a GPS user with a



Figure C-1 NAVSTAR GPS operational satellite constellation

minimum of 5 satellites in view from any point on Earth at any time.

Each satellite continuously broadcasts an RF signal at a centre frequency of 1575.42 MHz (L1 band). This signal is modulated by a 10.23 MHz clock rate precise ranging signal and by a 1.023 MHz clock rate coarse acquisition (C/A) code ranging signal. Each of these two binary signals has been formed by a precision code (p-code) or a C/A code which is modulo-2 added to 50 bps navigation data.

This navigation data, which is computed and controlled by the GPS Control Segment, includes the satellite's time, its clock correction and ephemeris parameters, almanacs, and health status for all GPS satellites. From this information, the user computes the satellite's precise position and clock offset. Currently, the DoD encrypts the P-code ranging signal and thus denies access to the Precise Positioning Service (PPS) by unauthorised users. The Standard Positioning Service (SPS) uses the C/A code ranging signal and is intended for general public use.

The control segment

This segment consists of a master control station, located in Colorado Springs, and a number of monitor stations at various locations around the world. Each monitor station tracks all the GPS satellites in view and passes the signal measurement data back to the master control station, where computations are performed to determine precise satellite ephemeris and satellite clock errors. The master control station generates the upload of user navigation data for each satellite. This data is subsequently re-broadcast by the satellite as part of its navigation data message.

The user segment

This segment is the collection of all GPS receivers and their application support equipment such

as antennas and processors. This equipment allows users to receive, decode, and process the information necessary to obtain accurate position, velocity, and timing measurements. This data is used by the receiver's support equipment for specific application requirements. GPS supports a wide variety of applications including navigation, surveying, and time transfer. Receivers may be used in a stand-alone mode or integrated with other systems to enhance the overall system performance.

GPS System operation

How A GPS Receiver Determines Position

A GPS receiver determines its geographic position by measuring the ranges (the distance between a satellite with known coordinates in space and the receiver's antenna) of several satellites and computing the geometric intersection of these ranges.

To determine a range, the receiver measures the time required for the GPS signal to travel from the satellite to the receiver antenna. The timing code generated by each satellite is compared to an identical code generated by the receiver. The receiver's code is shifted until it matches the satellite's code. The resulting time shift is multiplied

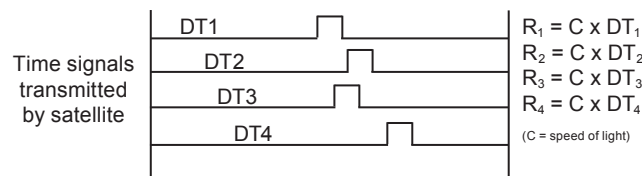
by the speed of light to arrive at the apparent range measurement.

Since the resulting range measurement contains propagation delays due to atmospheric effects, and satellite and receiver clock errors, it is referred to as a 'pseudorange'. Changes in each of these pseudo-ranges over a short period of time are also measured and processed by the receiver. These measurements, referred to as 'delta-pseudoranges', are used to compute velocity.

A minimum of four pseudo-range measurements are required by the receiver to mathematically determine time and the three components of position (latitude, longitude, and altitude). The equations used for these calculations are shown in Figure C-2. The solution of these equations may be visualised as the geometric intersection of four ranges from four known satellite locations.

Figure C-3 illustrates 'triangulation', one way to envision the navigation process. For ease of understanding, it is assumed that the user clock is synchronous.

After the four range equations are solved, the receiver has estimates of its position and time.



Pseudo ranges

$$R_1 = CDt_1$$

$$R_2 = CDt_1$$

$$R_3 = CDt_1$$

$$R_4 = CDt_1$$

Position equations

$$(X_1 - U_x)^2 + (Y_1 - U_y)^2 + (Z_1 - U_z)^2 = (R_1 - C_B)^2$$

$$(X_2 - U_x)^2 + (Y_2 - U_y)^2 + (Z_2 - U_z)^2 = (R_2 - C_B)^2$$

$$(X_3 - U_x)^2 + (Y_3 - U_y)^2 + (Z_3 - U_z)^2 = (R_3 - C_B)^2$$

$$(X_4 - U_x)^2 + (Y_4 - U_y)^2 + (Z_4 - U_z)^2 = (R_4 - C_B)^2$$

R_i = pseudo range (i = 1,2,3,4)

- Pseudo range includes actual distance between satellite and user plus satellite clock bias, user clock bias, atmospheric delays, and receiver noise.
- Satellite clock bias and atmospheric delays are compensated for by incorporation of deterministic corrections prior to inclusion in nav solution.

X_i, Y_i, Z_i = satellite position (i= 1,2,3,4)

- Satellite position broadcast in navigation 50 Hz message.

Receiver solves for:

- U_x, U_y, U_z = user position
- C_B = user clock bias

Figure C-2 Range processing equations GPS system operation

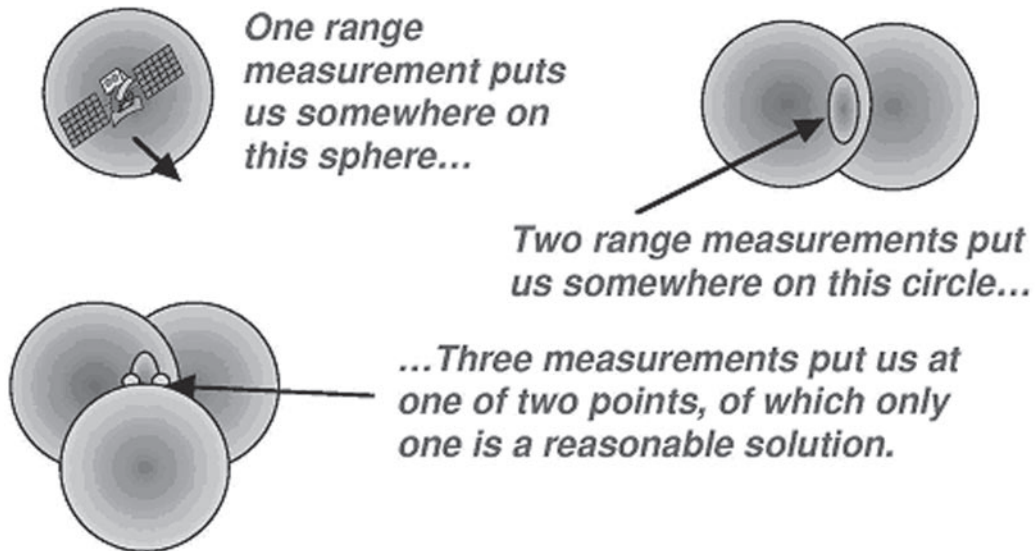


Figure C-3 Satellite ranging intersections

Similar equations are then used to calculate velocity using relative velocities instead of pseudo-ranges. The position, velocity, and time data is generally computed once a second.

If one of these parameters, such as altitude, is known, only three satellite pseudo-range measurements are needed for the receiver to determine its position and time. In this case, only three satellites need to be tracked.

GPS accuracy

GPS accuracy has a statistical distribution which is dependent on two important factors. The expected accuracy will vary with the error in the range measurements as well as the geometry or relative positions of the satellites and the user.

Dilution of precision

The Geometric Dilution of Precision (GDOP) indicates how much the geometric relationship of the tracked satellites affects the estimate of the receiver's position, velocity, and time.

Four other DOP components indicate how the geometry specifically affects errors in horizontal position (HDOP), vertical position (VDOP), position (PDOP), and time (TDOP).

DOPs are computed based on the spatial relationships of the lines of sight between the satellites and the user. The motion of the satellites relative to each other and the user causes the DOPs to vary constantly. For the same range measurement errors, lower DOPs relate to more accurate estimates.

The errors in the range measurements used to solve for position may be magnified by poor geometry. The least amount of error results when the lines of sight have the greatest angular separation between them (see Figure C-4).

For example, if two lines of sight are necessary to establish a user position, the least amount of error is present when the lines cross at right angles.

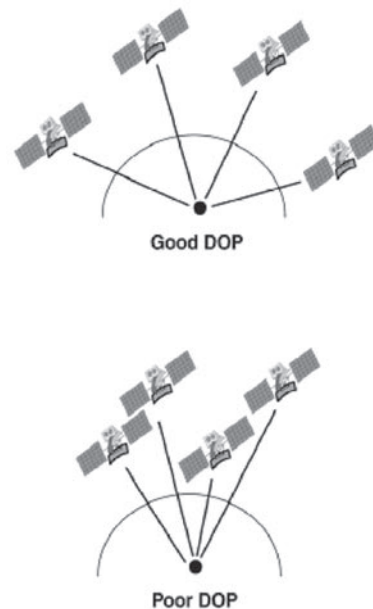


Figure C-4 Geometric dilution of precision

Range Measurement Error

The error in the range measurement is dependent on one of two levels of GPS accuracy to which the user has access. PPS is the most accurate, but is

reserved for use by the DoD and certain authorised users. SPS is less accurate and intended for general public use. This is the level of accuracy used by the Jupiter family of GPS receivers.

The SPS signal can be intentionally degraded to a certain extent by a process known as Selective Availability (SA). SA is used to limit access to the full accuracy of SPS in the interest of D.S. national security.

Differential GPS (DGPS) Description

The following general description of DGPS is from the document RTCM Recommended Standards For Differential NAVSTAR GPS Service. Refer to that document for more specific details of DGPS operations (see Appendix B).

Differential operation of the GPS offers the possibility of accuracies from 1 m to 10 m for dynamic, navigation applications. DGPS operation requires a reference receiver to be placed at a known, surveyed-in point. By comparing the known location with that predicted by the GPS, corrections are determined. These corrections are then broadcast to nearby users who use them to improve their position solutions.

Sources of bias error

The differential technique works if the main errors are bias errors due to causes outside the receiver. This is the case for GPS. The major sources of error are the following:

SA errors: artificial errors introduced at the satellites for security reasons. Pseudorange errors of this type are about 30 m, 1-sigma. PPS users have the capability to eliminate them entirely.

Ionospheric delays: signal propagation group delay, which is typically 20 to 30 m during the day and 3 to 6 m at night.

Tropospheric delays: signal propagation delays caused by the lower atmosphere. While the delays are as much as 30 m at low satellite elevation angles, they are quite consistent and modellable. Variations in the index of refraction can cause differences (between reference station and user) in signal delays from 1 to 3 m for low-lying satellites.

Ephemeris error: differences between the actual satellite location and the location predicted by the satellite orbital data. Normally these are quite small, less than 3 m, but they could be more than 30 m under SA.

Satellite clock errors: differences between the satellite clock time and that predicted by the satellite data. The oscillator that times the

satellite signal is free-running; the GPS ground control station monitors it and establishes corrections that are sent up to the satellite to set the data message. The user reads the data and adjusts the signal timing accordingly. Satellite clock errors are completely compensated by differential operation as long as both reference and user receivers are employing the same satellite data. Ephemeris errors, unless they are quite large (30 m or more) are similarly compensated by differential operation. SA errors that affect the timing of the signals are also compensated by differential operation, except that the corrections lose their validity after a period of time.

For users near the reference station, the respective signal paths to the satellites are sufficiently close that compensation is almost complete. As the separation increases between user and reference station, the different ionospheric and tropospheric paths to the satellites may be sufficiently far apart that the atmospheric heterogeneities cause the delays to vary. The extent of the difference constitutes an error in the DGPS measurement, called 'spatial decorrelation'. This type of error will be greater at larger 'user-to-reference station' separations.

Required DGPS Equipment

The equipment consists of a GPS receiver with antenna, a data processor, a data link receiver with antenna, and interfacing equipment as illustrated in Figure C-5. The data processor applies the corrections received from the reference station to the pseudoranges measured by the sensor.

Application of DGPS Corrections

For each satellite employed by the user's receiver, the correction obtained from the reference station (message type 1 or 9) is added to the pseudorange measurement. The correction itself is derived from the range and range-rate, adjusted to account for the time elapsed between the time of reception of the correction and the time of the user pseudo-range measurement, as follows:

$$PRC(t) = PRC(t_0) + RRC \times [t - t_0]$$

where:

PRC(t) is the correction to be applied

PRC(t₀) is the range correction from the message RRC is the range-rate correction from the message

(t₀) is the time reference of the correction

(t) is the time associated with the pseudo-range measurement.

Occasionally a type 2 message is sent interspersed among the correction messages, which provides a secondary correction. This is done to allow a user to operate with old (up to two hours) satellite ephemeris and satellite clock data while the reference station is operating with most recent data. This correction, called the 'delta correction' is added to the normal correction for that satellite. The reference station will usually decode the satellite data before the user does since it is constantly monitoring the data.

Data Link

The data link, which communicates the corrections from the reference station to the user receiver, can take a number of forms and operate at any of several frequencies. The chief requirement is that the messages be communicated reliably at a data rate of at least 50 bps (continuous transmission). Figure C-5 shows the user data link functions. In its simplest form, the data link continuously carries the DGPS data message without interruption at a constant data rate of at least 50 bps. However, it is transparent to the GPS receiver whether the data

is transmitted continuously or in bursts, or whether protocol overhead is added.

For example, each message (or multiple messages, or any fraction of a message) could be transmitted as a short burst at 2400 bps, along with a data link protocol preamble, parity, and even error correction bits. This would be stripped off at the receiver end and the differential correction bits would be stored in the buffer, to be transferred to the receiver at will. DGPS broadcasts intended for general public use require that the data link be a standard, published design.

For non-public use, however, the reference station, data link and receivers could be part of an integrated DGPS system. In such a case, the data might be encrypted to limit the service to paying customers. The format allows for such operation. At the minimum rate of 50 bps, there is considerable robustness in the data link. The corrections are broadcast frequently enough so that the loss of as many as three consecutive corrections can be tolerated and still provide 5 m accuracy.

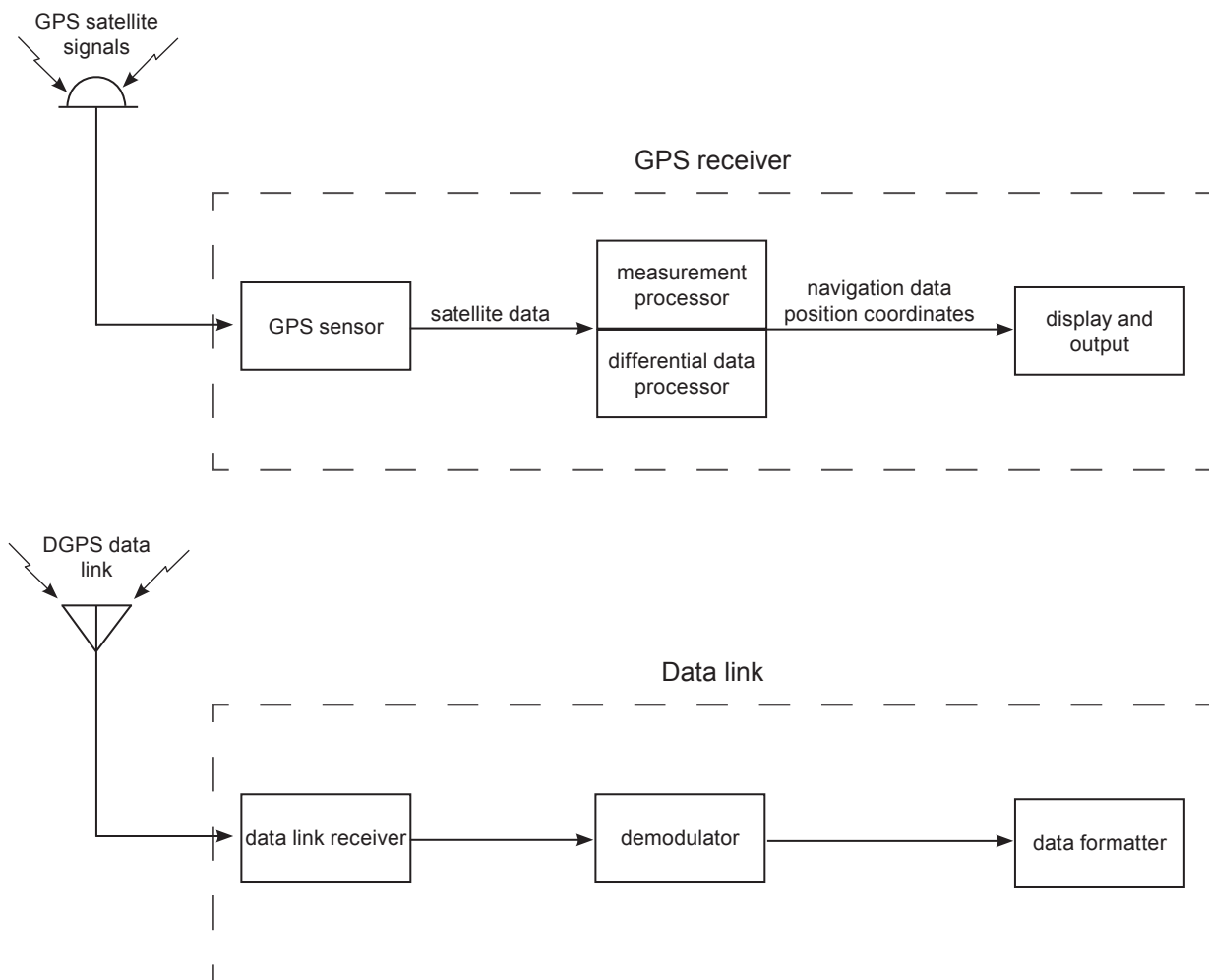


Figure C-5 User equipment block diagram

APPENDIX D: Frequently Asked Questions (FAQ)

This appendix provides answers to frequently asked questions about GPS in general and about the Jupiter series of GPS receivers, it is intended to supplement the operational description provided in section 4.0 of this document.

1. How far and under what conditions can a passive antenna track before it is necessary to change it to an active antenna?

There is no simple answer to this question. Navman generally recommends limiting cable loss to 3 dB between the antenna and the receiver board. If attenuation exceeds this value there may be degraded signal acquisition and navigation accuracy performance. GPS satellites transmit more power than their specification requires, but that margin is allocated to the 3 dB cable loss. The safest approach is to use an active antenna unless the antenna and receiver engine are co-located.

2. Can the Jupiter receiver operate efficiently in an urban location with tall structures and buildings?

Yes. By using 12 parallel channels, Jupiter receivers maintain continuous tracking of all visible satellites and produce an over-determined solution, minimising the effects of signal blockage and giving optimal performance in dense urban environments.

3. Is there any danger to the receiver when switching is done between active and passive antennas?

Yes. If pre-amp power is supplied to an active antenna and then connected to a passive antenna there is a high probability of damage since the passive antenna often presents a short circuit to ground at DC. This then shorts out the pre-amp power line and destroys the bias-tee network on the receiver.

4. What is the criteria for choosing satellites for navigation if more than four are visible?

The Jupiter receiver continuously tracks all visible satellites. The measurements from these satellites are used in an over-determined solution to provide the most robust performance that is possible.

5. What is the accuracy of GPS with selective availability turned on? How is the accuracy affected by DGPS?

The U.S. Government guarantees that horizontal accuracy will be less than 100 m (95% of the time) and less than 300 m (99.99% of the time). Accuracy with DGPS is primarily a function of the quality and latency of the corrections used.

6. What is the difference between the two models for position determination used in GPS: WGS 84 and Earth-Centred-Earth-Fixed (ECEF)?

ECEF refers to a Cartesian (rectangular) coordinate system (x,y,z,) whose centre is at the middle of the Earth; one axis goes through the North Pole, one through the Greenwich meridian at the equator, and the third passes through the equator 90 degrees offset from the second. This system rotates with the Earth. GPS satellites broadcast their location in this coordinate system.

WGS-84 contains a mathematical model of the Earth's surface (spheroid) which is accepted worldwide. However, the model does have some limitations. For example, 0 m altitude may differ from mean sea level in this model by up to ~100 m. Position in WGS-84 is specified in latitude and longitude and by the altitude above the WGS-84 spheroid (Earth surface model).

7. What are the addresses for U.S. FM DGPS service providers?

- ACCQPOINT Communications Corp. 2737, Campus Drive, Irvine, CA 92715, (800) 995-3477
- Differential Corrections Inc. (DCI) 10121 Miller Avenue, Cupertino, CA 95014, (408) 446-8350

8. Does the Jupiter receiver provide an over-determined solution?

Jupiter receivers provide all-in-view parallel tracking of all visible satellites. In SPS mode all valid measurements are used to produce an over-determined navigation solution to minimise position excursions arising from SA and loss of signals. In DGPS all valid measurements with valid DGPS corrections are used in an over-determined solution. For example, if 8 satellites are in track, all producing valid measurements, and DGPS corrections are available for 7 of the 8, then 7 DGPS corrected measurements will be used in the over-determined DGPS solution.

9. How is heading data at low speeds derived? Shouldn't the heading be derived from Doppler data rather than position differences?

Navman receivers compute velocity from the carrier loop Doppler information. Heading angle is then computed from east and north velocity as the arc-tangent (V_e/V_n). When on, SA induces an error on the GPS clock and thus the carrier Doppler information and pseudo-range is corrupted, but the carrier data is a better source of velocity information than position differences. The worst heading error at 5 m/s is 1.1 degrees when SA is off or DGPS is on. All heading determination techniques using GPS velocities have large uncertainties at small velocities when the velocity approaches the magnitude of the inherent noise.

APPENDIX E: Reference ellipsoids and datum tables for Jupiter and NavCore receivers

Reference Ellipsoids

The following data is taken from DoD World Geodetic System 1984, DMA TR 8350.2-B, 1 Dec 1987, Second Printing. Includes 1 Sept 1991 updates.

REFERENCE ELLIPSOIDS			
No.	Name	Semi-Major Axis	Inverse Flattening
1	Airy	6377563.396000	299.324965
2	Modified Airy	6377340.189000	299.324965
3	Australian National	6378160.000000	298.250000
4	Bessel 1841	6377397.155000	299.152813
5	Clarke 1866	6378206.400000	294.978698
6	Clarke 1880	6378249.145000	293.465000
7	Everest 1830	6377276.345000	300.801700
8	Everest 1948	6377304.063000	300.801700
9	Fischer 1960	6378166.000000	298.300000
10	Modified Fischer 1960	6378155.000000	298.300000
11	Fischer 1968	6378150.000000	298.300000
12	GRS 1980	6378137.000000	298.257222
13	Helmert 1906	6378200.000000	298.300000
14	Hough	6378270.000000	297.000000
15	International	6378388.000000	297.000000
16	Krassovsky	6378245.000000	298.300000
17	South American 1969	6378160.000000	298.250000
18	WGS 60	6378165.000000	298.300000
19	WGS 66	6378145.000000	298.250000
20	WGS72	6378135.000000	298.260000
21	WGS 84	6378137.000000	298.257224
22	Bessel 1841 (Namibia)	6377483.865000	299.152813
23	Everest 1956	6377301.243000	300.801700
24	Everest 1969	6377295.664000	300.801700
25	Everest (Sabah & Sarawak)	6377298.556000	300.801700
26	SGS 85	6378136.000000	298.257000

The following lists of datums, maintained and selectable through the LABMON development software, apply to Navman's Jupiter Series of GPS receivers.

ROM Datums					
Code	Name	EII	dx	dy	dz
0	WGS 84 – Default	21	0	0	0
1	Adindan - MEAN FOR Ethiopia, Sudan	6	-166	-15	204
2	Adindan - Burkina Faso	6	-118	-14	218
3	Adindan - Cameroon	6	-134	-2	210
4	Adindan - Ethiopia	6	-165	-11	206
5	Adindan - Mali	6	-123	-20	220
6	Adindan - Senegal	6	-128	-18	224
7	Adindan - Sudan	6	-161	-14	205
8	Afgooye - Somalia	16	-43	-163	45
9	Ain el Abd 1970 - Bahrain	15	-150	-251	-2
10	Ain el Abd 1970 - Saudi Arabia	15	-143	-236	7
11	Anna 1 Astro 1965 - Cocos Islands	3	-491	-22	435
12	Antigua Island Astro 1943 Antigua (Leeward Islands)	6	-270	13	62
13	Arc 1950 MEAN FOR Botswana, Lesotho, Malawi, Swaziland, Zaire, Zambia, Zimbabwe	6	-143	-90	-294
14	Arc 1950 - Botswana	6	-138	-105	-289
15	Arc 1950 - Burundi	6	-153	-5	-292
16	Arc 1950 - Lesotho	6	-125	-108	-295
17	Arc 1950 - Malawi	6	-161	-73	-317
18	Arc 1950 - Swaziland	6	-134	-105	-295
19	Arc 1950 - Zaire	6	-169	-19	-278
20	Arc 1950 - Zambia	6	-147	-74	-283
21	Arc 1950 - Zimbabwe	6	-142	-96	-293
22	Arc 1960 - MEAN FOR Kenya, Tanzania	6	-160	-6	-302
23	Ascension Island 1958 Ascension Island	15	-191	103	51
24	Astro Beacon E 1945 - Iwo Jima	15	145	75	-272
25	Astro DOS 71/4 - St Helena Island	15	-320	550	-494
26	Astro Tern Island (FRIG) 1961 Tern Island	15	114	-116	-333
27	Astronomical Station 1952 Marcus Island	15	124	-234	-25
28	Australian Geodetic 1966 Australia & Tasmania	3	-133	-48	148
29	Australian Geodetic 1984 Australia & Tasmania	3	-134	-48	149
30	Ayabelle Lighthouse - Djibouti	6	-79	-129	145
31	Bellevue (IGN) Efate & Erromango Islands	15	-127	-769	472
32	Bermuda 1957 - Bermuda	5	-73	213	296
33	Bissau - Guinea-Bissau	15	-173	253	27
34	Bogota Observatory - Colombia	15	307	304	-318
35	Bukit Rimpah Indonesia (Bangka & Belitung Islands)	4	-384	664	-48
36	Camp Area Astro Antarctica (McMurdo Camp Area)	15	-104	-129	239
37	Campo Inchauspe - Argentina	15	-148	136	90

Code	Name	EII	dx	dy	dz
38	Canton Astro 1966 - Phoenix Islands	15	298	304	-375
39	Cape - South Africa	6	-136	108	-292
40	Cape Canaveral - Bahamas, Florida	5	-2	151	181
41	Carthage - Tunisia	6	-263	6	431
42	Chatham Island Astro 1971 New Zealand (Chatham Island)	15	175	-38	113
43	Chua Astro - Paraguay	15	-134	229	-29
44	Corrego Alegre - Brazil	15	-206	172	-6
45	Dabola - Guinea	6	-83	37	124
46	Djakarta (Batavia) Indonesia (Sumatra)	4	-377	681	-50
47	DOS 1968 New Georgia Islands (Gizo Island)	15	230	-199	-752
48	Easter Island 1967 - Easter Island	15	211	147	111
49	European 1950 MEAN FOR Austria, Belgium, Denmark, Finland, France, West Germany, Gibraltar, Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland	15	-87	-98	-121
50	European 1950 MEAN FOR Austria, Denmark, France, West Germany, Netherlands, Switzerland	15	-87	-96	-120
51	European 1950 MEAN FOR Iraq, Israel, Jordan, Lebanon, Kuwait, Saudi Arabia, Syria	15	-103	-106	-141
52	European 1950 - Cyprus	15	-104	-101	-140
53	European 1950 - Egypt	15	-130	-117	-151
54	European 1950 England, Channel Islands, Ireland, Scotland, Shetland Islands	15	-86	-96	-120
55	European 1950 - Finland, Norway	15	-87	-95	-120
56	European 1950 - Greece	15	-84	-95	-130
57	European 1950 - Iran	15	-117	-132	-164
58	European 1950 - Italy (Sardinia)	15	-97	-103	-120
59	European 1950 - Italy (Sicily)	15	-97	-88	-135
60	European 1950 - Malta	15	-107	-88	-149
61	European 1950 - Portugal, Spain	15	-84	-107	-120
62	European 1979 MEAN FOR Austria, Finland, Netherlands, Norway, Spain, Sweden, Switzerland	15	-86	-98	-119
63	Fort Thomas 1955 Nevis, St. Kitts (Leeward Islands)	6	-7	215	225
64	Gan 1970 - Republic of Maldives	15	-133	-321	50
65	Geodetic Datum 1949 - New Zealand	15	84	-22	209
66	Graciosa Base SW 1948 Azores (Faial, Graciosa, Pico, Sao Jorge, Terceira)	15	-104	167	-38
67	Guam 1963 - Guam	5	-100	-248	259
68	Gunung Segara - Indonesia (Kalimantan)	4	-403	684	41
69	GUX 1 Astro - Guadalcanal Island	15	252	-209	-751
70	Herat North - Afghanistan	15	-333	-222	114
71	Hjorsey 1955 - Iceland	15	-73	46	-86
72	Hong Kong 1963 - Hong Kong	15	-156	-271	-189
73	Hu-Tzu-Shan - Taiwan	15	-637	-549	-203

Code	Name	EII	dx	dy	dz
74	Indian - Bangladesh	7	282	726	254
75	Indian - India, Nepal	23	295	736	257
76	Indian 1954 - Thailand, Vietnam	7	218	816	297
77	Indian 1975 - Thailand	7	209	818	290
78	Ireland 1965 - Ireland	2	506	-122	611
79	ISTS 061 Astro 1968 South Georgia Islands	15	-794	119	-298
80	ISTS 073 Astro 1969 - Diego Garcia	15	208	-435	-229
81	Johnston Island 1961 - Johnston Island	15	189	-79	-202
82	Kandawala - Sri Lanka	7	-97	787	86
83	Kerguelen Island 1949 Kerguelen Island	15	145	-187	103
84	Kertau 1948 - West Malaysia & Singapore	8	-11	851	5
85	Kusaie Astro 1951 - Caroline Islands	15	647	1777	-1124
86	L. C. 5 Astro 1961 - Cayman Brac Island	5	42	124	147
87	Leigon - Ghana	6	-130	29	364
88	Liberia 1964 - Liberia	6	-90	40	88
89	Luzon Philippines (Excluding Mindanao)	5	-133	-77	-51
90	Luzon - Philippines (Mindanao)	5	-133	-79	-72
91	Mahe 1971 - Mahe Island	6	41	-220	-134
92	Massawa - Ethiopia (Eritrea)	4	639	405	60
93	Merchich - Morocco	6	31	146	47
94	Midway Astro 1961 - Midway Islands	15	912	-58	1227
95	Minna - Cameroon	6	-81	-84	115
96	Minna - Nigeria	6	-92	-93	122
97	Montserrat Island Astro 1958 Montserrat (Leeward Islands)	6	174	359	365
98	M'Poraloko - Gabon	6	-74	-130	42
99	Nahrwan - Oman (Masirah Island)	6	-247	-148	369
100	Nahrwan - Saudi Arabia	6	-243	-192	477
101	Nahrwan - United Arab Emirates	6	-249	-156	381
102	Naparima BWI - Trinidad & Tobago	15	-10	375	165
103	North American 1927 MEAN FOR Antigua, Barbados, Barbuda, Caicos Islands, Cuba, Dominican Republic, Grand Cayman, Jamaica, Turks Islands	5	-3	142	183
104	North American 1927 MEAN FOR Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua	5	0	125	194
105	North American 1927 - MEAN FOR Canada	5	-10	158	187
106	North American 1927 - MEAN FOR CONUS	5	-8	160	176
107	North American 1927 MEAN FOR CONUS (East of Mississippi River) including Louisiana, Missouri, Minnesota	5	-9	161	179
108	North American 1927 MEAN FOR CONUS (West of Mississippi River)	5	-8	159	175
109	North American 1927 - Alaska	5	-5	135	172
110	North American 1927 Bahamas (Except San Salvador Island)	5	-4	154	178
111	North American 1927 Bahamas (San Salvador Island)	5	1	140	165

Code	Name	EII	dx	dy	dz
112	North American 1927 Canada (Alberta, British Columbia)	5	-7	162	188
113	North American 1927 Canada (Manitoba, Ontario)	5	-9	157	184
114	North American 1927 Canada (New Brunswick, Newfoundland, Nova Scotia, Quebec)	5	-22	160	190
115	North American 1927 Canada (Northwest Territories, Saskatchewan)	5	4	159	188
116	North American 1927 - Canada (Yukon)	5	-7	139	181
117	North American 1927 - Canal Zone	5	0	125	201
118	North American 1927 - Cuba	5	-9	152	178
119	North American 1927 Greenland (Hayes Peninsula)	5	11	114	195
120	North American 1927 - Mexico	5	-12	130	190
121	North American 1983 Alaska, Canada, CONUS	12	0	0	0
122	North American 1983 Central America, Mexico	12	0	0	0
123	Observatorio Metreeo 1939 Azores (Corvo & Bores Islands)	15	-425	-169	81
124	Old Egyptian 1907 - Egypt	13	-130	110	-13
125	Old Hawaiian MEAN FOR Hawaii, Kauai, Maui, Oahu	5	61	-285	-181
126	Old Hawaiian - Hawaii	5	89	-279	-183
127	Old Hawaiian - Kauai	5	45	-290	-172
128	Old Hawaiian - Maui	5	65	-290	-190
129	Old Hawaiian - Oahu	5	58	-283	-182
130	Oman - Oman	6	-346	-1	224
131	Ord. Survey G. Britain 1936 MEAN FOR England, Isle of Man, Scotland, Shetland Islands, Wales	1	375	-111	431
132	Ord. Survey G. Britain 1936 - England	1	371	-112	434
133	Ord. Survey G. Britain 1936 England, Isle of Man, Wales	1	371	-111	434
134	Ord. Survey G. Britain 1936 Scotland, Shetland Islands	1	384	-111	425
135	Ord. Survey G. Britain 1936 - Wales	1	370	-108	434
136	Pico de las Nieves - Canary Islands	15	-307	-92	127
137	Pitcairn Astro 1967 - Pitcairn Island	15	185	165	42
138	Point 58 MEAN FOR Burkina Faso & Niger	6	-106	-129	165
139	Pointe Noire 1948 - Congo	6	-148	51	-291
140	Porto Santo 1936 Porto Santo, Madeira Islands	15	-499	-249	314
141	Provisional S. American 1956 MEAN FOR Bolivia, Chile, Colombia, Ecuador, Guyana, Peru, V Venezuela	15	-288	175	-376
142	Provisional S. American 1956 - Bolivia	15	-270	188	-388
143	Provisional S. American 1956 Chile (Northern, Near 19°S)	15	-270	183	-390
144	Provisional S. American 1956 Chile (Southern, Near 43°S)	15	-305	243	-442

Code	Name	EII	dx	dy	dz
145	Provisional S. American 1956 - Colombia	15	-282	169	-371
146	Provisional S. American 1956 - Ecuador	15	-278	171	-367
147	Provisional S. American 1956 - Guyana	15	-298	159	-369
148	Provisional S. American 1956 - Peru	15	-279	175	-379
149	Provisional S. American 1956 Venezuela	15	-295	173	-371
150	Provisional S. Chilean 1963 Chile (South, Near 53°S) (Hito XVIII)	15	16	196	93
151	Puerto Rico Puerto Rico, Virgin Islands	5	11	72	-101
152	Qatar National- Qatar	15	-128	-283	22
153	Qornoq - Greenland (South)	15	164	138	-189
154	Reunion - Mascarene Islands	15	94	-948	-1262
155	Rome 1940 - Italy (Sardinia)	15	-225	-65	9
156	Santo (DOS) 1965 Espirito Santo Island	15	170	42	84
157	Sao Braz Azores (Sao Miguel, Santa Maria Islands)	15	-203	141	53
158	Sapper Hill 1943 - East Falkland Island	15	-355	21	72
159	Schwarzeck - Namibia	22	616	97	-251
160	Selvagem Grande - Salvage Islands	15	-289	-124	60
161	SGS 85 - Soviet Geodetic System 1985	26	3	9	-9
162	South American 1969 MEAN FOR Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Trinidad & Tobago, Venezuela	17	-57	1	-41
163	South American 1969 - Argentina	17	-62	-1	-37
164	South American 1969 - Bolivia	17	-61	2	-48
165	South American 1969 - Brazil	17	-60	-2	-41
166	South American 1969 - Chile	17	-75	-1	-44
167	South American 1969 - Colombia	17	-44	6	-36
168	South American 1969 - Ecuador	17	-48	3	-44
169	South American 1969 Ecuador (Baltra, Galapagos)	17	-47	27	-42
170	South American 1969 - Guyana	17	-53	3	-47
171	South American 1969 - Paraguay	17	-61	2	-33
172	South American 1969 - Peru	17	-58	0	-44
173	South American 1969 - Trinidad & Tobago	17	-45	12	-33
174	South American 1969 - Venezue1a	17	-45	8	-33
175	South Asia - Singapore	10	7	-10	-26
176	Tananarive Observatory 1925 Madagascar	15	-189	-242	-91
177	Timbalai 1948 Brunei, East Malaysia (Sabah, Sarawak)	25	-679	669	-48
178	Tokyo - MEAN FOR Japan, Korea, Okinawa	4	-148	507	685
179	Tokyo - Japan	4	-148	507	685
180	Tokyo - Korea	4	-146	507	687
181	Tokyo - Okinawa	4	-158	507	676
182	Tristan Astro 1968 - Tristan da Cunha	15	-632	438	-609
183	Viti Levu 1916, Fiji (Viti Levu Island)	6	51	391	-36
184	Wake-Eniwetok 1960 - Marshall Islands	14	102	52	-38
185	Wake Island Astro 1952 - Wake Atoll	15	276	-57	149
186	WGS 1972 - Global Definition	20	0	0	0
187	Yacare - Uruguay	15	-155	171	37
188	Zanderij - Suriname	15	-265	120	-358

0	WGS-84 (Default)	49	Mahe 1971
1	Adindan	50	Marco Astro
2	AFG	51	Massawa
3	AIN EL ABD 1970	52	Merchich
4	Anna 1 Astro 1965	53	Midway Astro 1961
5	ARC 1950	54	Minna
6	ARC 1960	55	Nahrwan Masirah Island
7	Ascension Island 1958	56	Narhwan United Arab Emirates
8	Astro Beacon "E"	57	Nahrwan Saudia Arabia
9	Astro B4 SOR. ATOLL	58	Namibia
10	Astro POS 71/4	59	Naparima, BWI
11	Astronomic Station 1952	60	NAD-27 Conus
12	Australian Geodetic 1966	61	NAD-27 Alaska
13	Australian Geodetic 1984	62	NAD-27 Bahamas
14	Bellevue (IGN)	63	NAD-27 San Salvador Island
15	Bermuda 1957	64	NAD-27 Canada
16	Bogota Observatory	65	NAD-27 Canal Zone
17	Campo Inchauspe	66	NAD-27 Caribbean
18	Canton Island 1966	67	NAD-27 Central America
19	Cape	68	NAD-27 Cuba
20	Cape Canaveral	69	NAD-27 Greenland
21	Carthage	70	NAD-27 Mexico
22	Chatham 1971	71	North America 1983
23	Chua Astro	72	Observatorio 1966
24	Corrogo Alegre	73	Old Egyptian 1960
25	Djakarta (Batavia)	74	Old Hawaiian
26	DOS 1968	75	Oman
27	Easter Island 1967	76	Ordinance Survey of Great Britain
28	European 1950	77	Pi co de las Nieves
29	European 1979	78	Pitcairn Astro 1967
30	Gandajika Base	79	Provisional South Chilean 1963
31	Geodetic Datum 1949	80	Provisional South American 1956
32	Guam 1963	81	Puerto Rico
33	GUX 1 Astro	82	Qatar National
34	Hjorsey 1955	83	Qornoq
35	Hong Kong 1963	84	Rome 1940
36	Indian Thailand	85	Santa Braz
37	Indian Bangladesh	86	Santo (DOS)
38	Ireland 1965	87	Sapper Hill
39	ISTS 073 Astro 1969	88	South American 1969
40	Johnston Island 1962	89	South Asia
41	Kandawala	90	Southeast Base
42	Kerguelen Island	91	Southwest Base
43	Kertau 1948	92	Timbalai 1948
44	La Reunion	93	Tokyo
45	L.C. 5 Astro	94	Tristan Astro 1968
46	Liberia 1964	95	Viti Levu 1916
47	Luzon	96	Wake-Eniwetok 1960
48	Mindanao Island	97	Zanderij

Table E-1 NavCore datums, maintained and selectable through the LABMON development software

APPENDIX F: 2 x 10 pin field connector information

This appendix contains ordering information for the 2 x 10 pin field connector.

Note: The Pico modules have a different 2 x 10 pin field connector to the one described below. Please see the appropriate data sheet for details

PCB sockets

3M part number 20way 150220-6002-TB Digikey
part number 3M1020-ND

IDC ribbon cable sockets

AMP (Tyco) part number 20w 111626-4 Digikey
part number ASA20K-ND

APPENDIX G: RG-142 and RG-316 Specifications

This appendix provides technical specifications for the RG-316 antenna cable used with the Jupiter GPS receiver.

Typical Specification for RG-316:

I. Electrical Characteristics:

Nominal impedance 50 Ω
Nominal inductance 0.065 micro-h/ft
Nominal capacitance (conductor to shield) 29.0 pf/ft
Nominal velocity of propagation 69.5%
Nominal delay 1.48 pf/ft
Nominal attenuation 1500 Mhz
57.9 dB/100 ft
Nominal shield dc resistance at 20°C:
6.5 Ω /1000 ft
Nominal conductor dc resistance at 20°C:
33.0 Ω /1000 ft
Continuous working voltage 900 V RMS

II. Physical Characteristics:

Nominal weight 10 lbs/1000 ft
Minimum bending radius 1.0 inch
Temperature rating -70 to +200°C
Type shield and percent coverage silver coated copper
Inner braid, 96%
Outer braid, 96%
Maximum pulling tension 2lbs
Insulation material TFE Teflon*
Jacket material brown tint FEP Teflon*
Conductor diameter 0.020 inches nominal
Core diameter 0.58 inches nominal
Outside dimensions 0.96 inches nominal
Applicable specifications MIL-C-17F (M17/113-RG316)

*Teflon is a trademark of DuPont

*Teflon is a trademark of DuPont

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