

Zodiac GPS Receiver Family Designer's Guide



Order No. GPS-33
December 16, 1996

Information to the user

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1 INTRODUCTION

Rockwell's Zodiac family 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. While the body of this Designer's Guide provides information common to the entire Zodiac family, specific technical information for a particular board product can be found in the appendixes.

Each of these receivers continuously tracks all satellites in view and provides accurate satellite positioning data. They are designed for high performance and maximum flexibility in a wide range of OEM configurations including handhelds, panel mounts, sensors, and in-vehicle automotive products. The highly integrated digital receivers incorporate two custom Rockwell devices including the Rockwell Zodiac chip set: the "Gemini/Pisces" MonoPac™ and the "Scorpio" Digital Signal Processor (DSP). The combination of custom devices minimizes the receivers' size to about 28 square centimeters and satisfies harsh industrial requirements.

1.1 Product Overview

1.1.1 Description. The Rockwell Zodiac family of GPS receivers (the "Jupiter" model is shown in Figure 1-1) decodes and processes signals from all visible GPS satellites. These satellites, in various orbits around the Earth, broadcast radio frequency (RF) ranging codes and navigation data messages. The Zodiac receivers use all available signals to produce a highly accurate and robust

navigation solution that can be used in a wide variety of end product applications.

The Zodiac receivers are packaged on 28 square centimeter printed circuit boards intended for harsh industrial applications. The receivers require conditioned DC power and a GPS signal from a passive or active antenna. To provide the

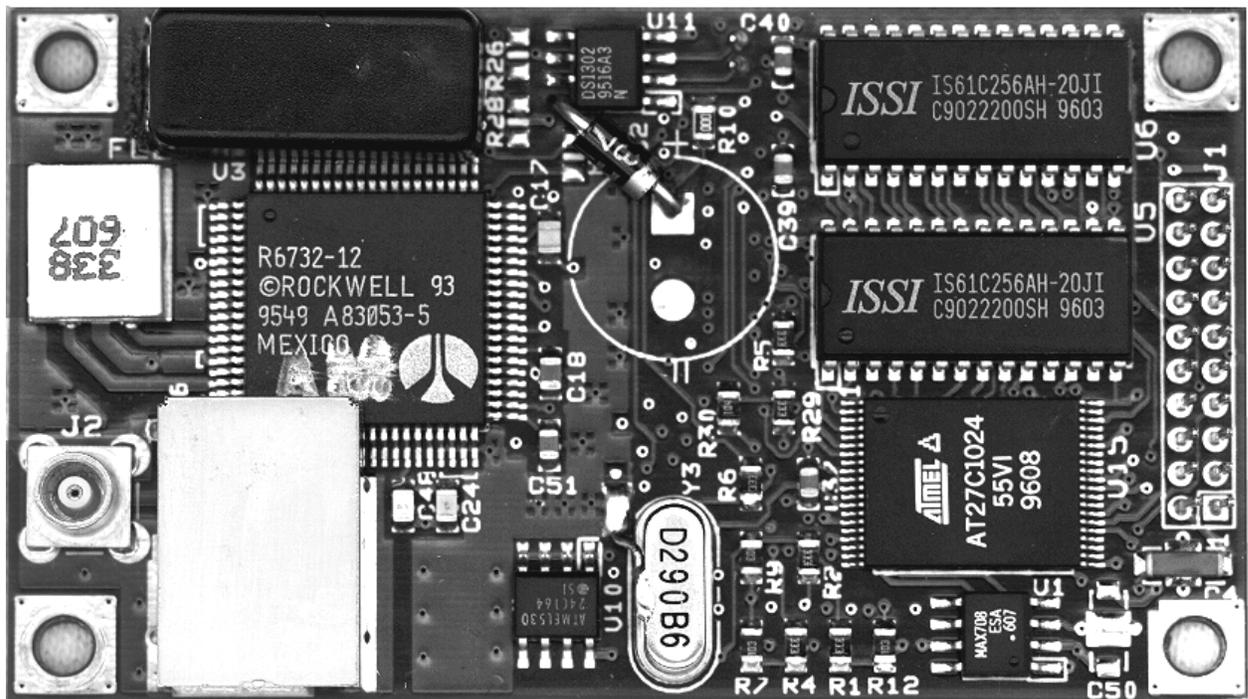


Figure 1-1. The Rockwell "Jupiter" GPS Receiver (Top View Shown Approximately 4x Actual Size)

lowest total system cost with minimal power consumption, each of the receivers provide only those components that are required for the majority of applications. For instance, if a passive antenna can be used in close physical proximity to the receiver, no preamplifier is required.

The all-in-view tracking of the Zodiac receiver family provides robust performance in applications that require high vehicle dynamics and in applications that operate in areas of high signal blockage such as dense urban centers. The receivers continuously track all visible GPS satellites and use all the measurements to produce an overdetermined, smoothed navigation solution. This solution is relatively immune to the position jumps induced by blockage that can occur in other receivers with fewer channels.

The 12-channel architecture provides rapid Time-To-First-Fix (TTFF) under all startup conditions. While the best TTFF performance is achieved when time of day and current position estimates are provided to the receiver, the flexible Zodiac signal acquisition system takes advantage of all available information to provide a rapid TTFF. Acquisition is guaranteed under all initialization conditions as long as visible satellites are not obscured.

To minimize TTFF following a power down, each of the Zodiac 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 prime power. The use of external voltage assures the shortest possible TTFF following a short power down. The OEM may extend the operation of the RTC by providing standby 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 Zodiac family supports two dimensional (2-D) operation when less than four satellites are available or when required by operating

conditions. Altitude information required for 2-D operation is determined by the receiver or may be provided by the OEM.

The Zodiac 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 Rockwell 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 dramatically improved accuracies over standard GPS.

A complete description of the serial data interface for the entire Zodiac family of GPS receivers is contained in this Designer's Guide.

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

1.1.2 Receiver Architecture. Figure 1-2 illustrates the internal architecture of the Zodiac receivers. Each receiver is designed around two custom Rockwell devices that contain most of the required GPS functionality. The "Gemini/Pisces" MonoPac™ contains all the RF downconversion and amplification circuitry, and presents sampled data to the "Scorpio" device. The "Scorpio" device contains an integral microprocessor and all GPS specific signal processing hardware. 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 Zodiac receiver with an applications processor that drives peripheral devices such as a display and keyboard. The interface between the applications processor and the Zodiac receiver is through the serial data interface.

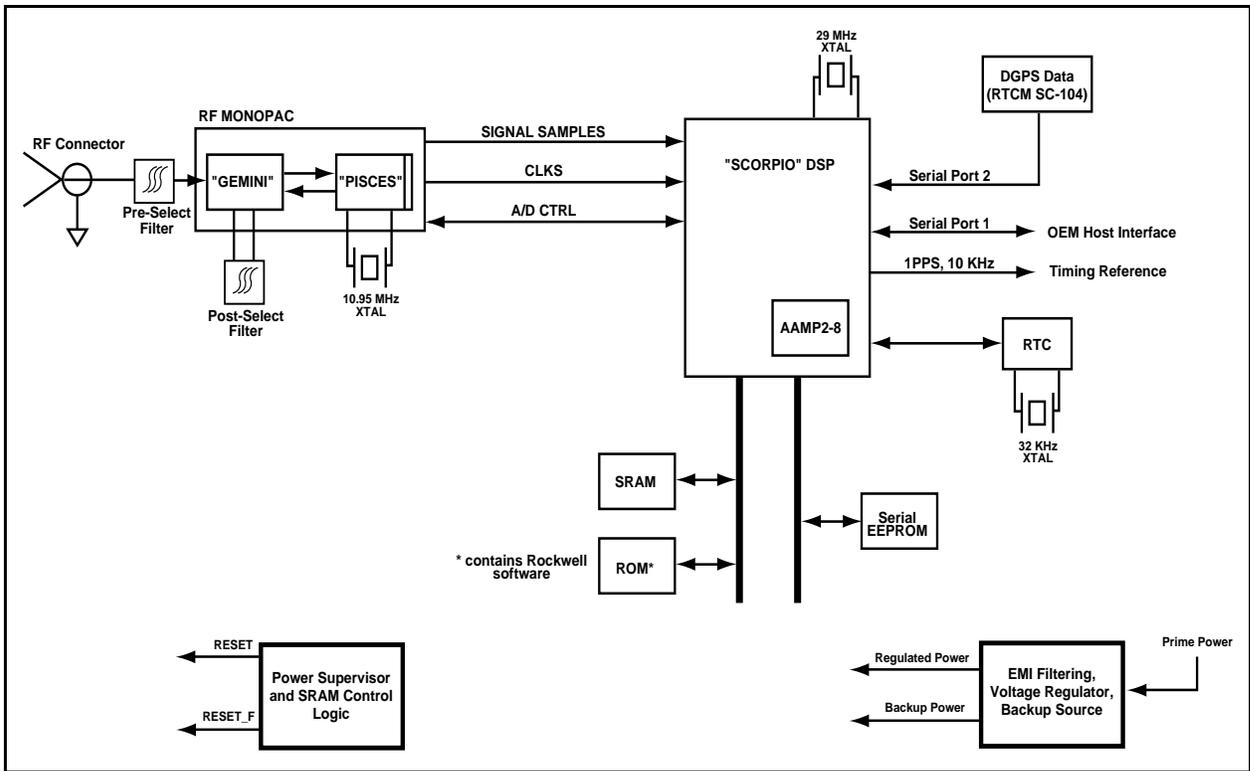


Figure 1-2. Internal Zodiac Architecture

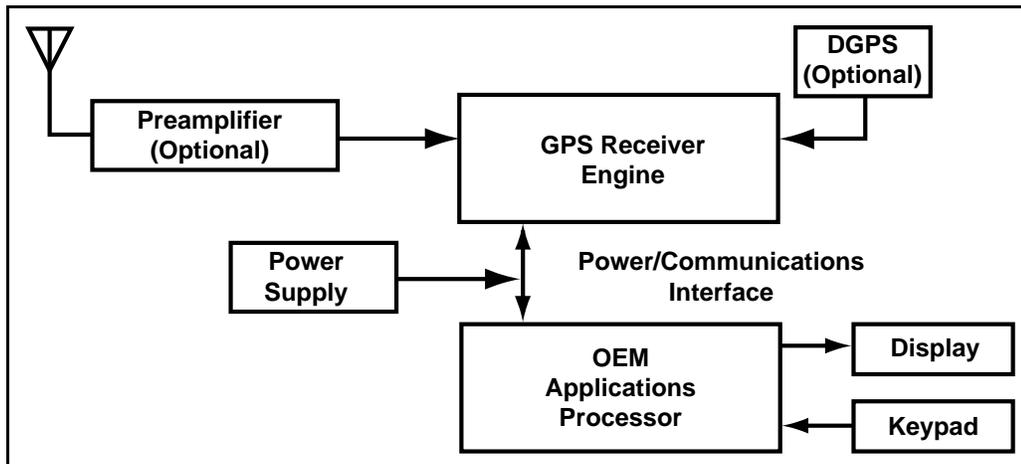


Figure 1-3. Possible Zodiac/OEM Architecture

1.2 Features

The Zodiac family of GPS receivers offers the following physical, operational, and support features:

- OEM product development is fully supported through applications engineering.
- One of the smallest, most compact GPS receiver footprints measuring 2.800" x 1.575" x 0.480" (approximately 70 x 40 x 12 mm).
- Twelve parallel satellite tracking channels.
- Supports NMEA-0183 data protocol.
- Direct, differential RTCM SC-104 data capability dramatically improves positioning accuracy. Available in both Rockwell binary and NMEA host modes.
- Static navigation enhancements to minimize wander due to SA.
- Designed for passive or active antennas for lowest system cost.
- Maximum navigation accuracy achievable with the Standard Positioning Service (SPS).
- Enhanced TTFF upon power-up when in a "Keep-Alive" power condition before start-up.
- Meets rigid 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 initialization data is entered by the user).
- Maximum operational flexibility and configurability via user commands.
- Ability to accept externally supplied initialization data.
- Three-Satellite Navigation startup from acquisition.
- User selectable satellites.
- User selectable visible satellite mask angle.
- Standard microminiature coaxial RF jack receptacle.
- Standard 2x10 pin-field I/O connector.

2 DEVELOPMENT KIT SETUP AND OPERATION

The Rockwell Zodiac™ Development Kit is designed to facilitate evaluation of Rockwell's "Jupiter" Global Positioning System (GPS) receiver engine based on the Zodiac chip set. The receiver can be used in both static and mobile operations for evaluation purposes.

The Development Kit implements the receiver control operation and input/output (I/O) functions of the GPS receiver using an IBM-AT compatible personal computer (PC), a serial port, external antenna, and power supply. The GPS receiver is contained in a housing with I/O connectors, status LEDs, and configuration DIP switches as shown in Figure 2-1.

This section explains how to configure the Development Kit and the receiver, and how to set up the test equipment.

LABMON, the GPS monitor and controller software, is provided with the Development Kit to communicate with the receiver. This software runs on the PC and allows the user to control the receiver and to display the receiver output message data. Externally supplied Radio Technical Commission for Maritime Services (RTCM SC-104) data can also be logged using a second PC serial port if desired. The LABMON software source code is included to provide a reference for similar Original Equipment Manufacturer (OEM) code implementations. Refer to Section 3 for details on how to use LABMON.

2.1 Equipment Supplied

The Development Kit contains the following items as depicted in Figure 2-2:

1. "Jupiter" receiver, power supply, voltage regulators, and RS-232 drivers in housing.
2. Active patch antenna with male SMA connector.
3. Two RS-232 cables with female DB-9 connectors at both ends.
4. 120V AC, 60 Hz/12 VDC power adapter.
5. 12 VDC automotive power adapter.
6. "Jupiter" GPS Receiver Data Sheet.
7. Zodiac GPS Receiver Family Designer's Guide.
8. Zodiac LABMON software on a 3.5-inch diskette.

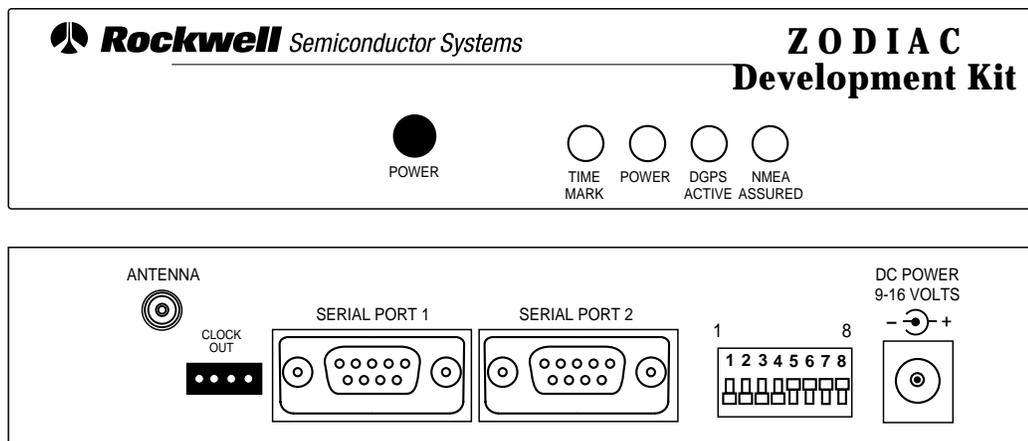


Figure 2-1. Front (Top) And Rear (Below) Panels Of The Development Kit

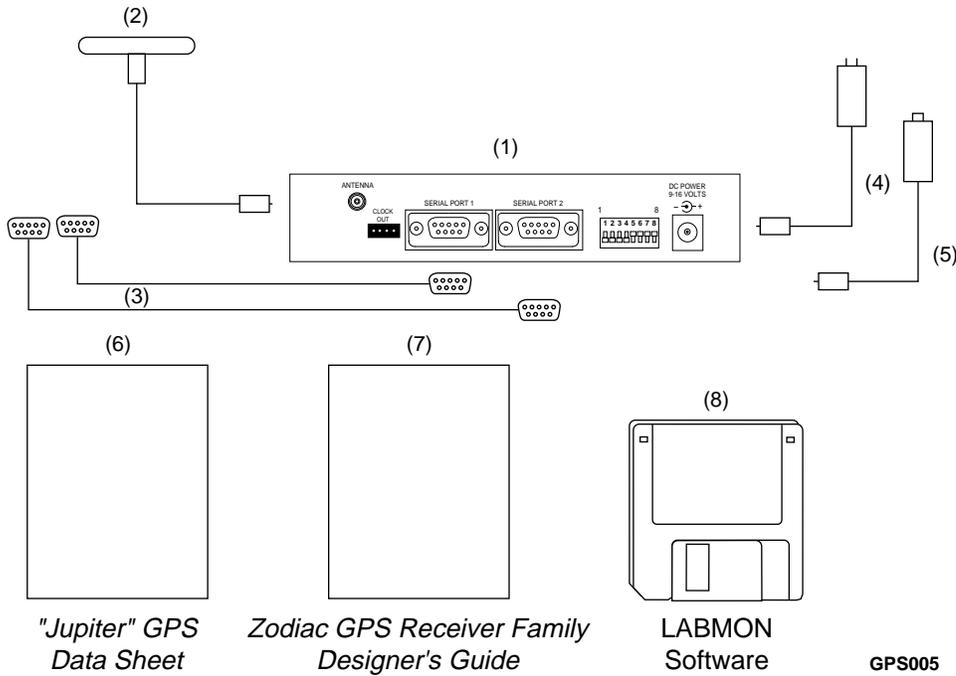


Figure 2-2. Development Kit Components

2.2 Equipment Needed

The following OEM supplied equipment is also required, as a minimum, to test the "Jupiter" GPS receiver:

1. IBM-AT compatible PC processor with at least one available serial port, a 3.5-inch diskette drive, at least 640 KB RAM and DOS version 3.0 or greater.
2. Color monitor with VGA or EGA, or monochrome monitor with VGA (no monochrome with EGA).
3. RTCM data source (required only if the differential capability is being tested).
4. Cabling to connect the RTCM data source to the second PC serial port and the receiver's Auxiliary port for simultaneous RTCM SC-104 data collection and DGPS operation. A ribbon cable with three connectors is recommended.

A laptop or portable PC is highly recommended since it allows the receiver to be easily evaluated in an outdoor environment where GPS signals are more accessible.

2.3 Description of The Development Kit

The Development Kit features dual RS-232 level serial data I/O ports, selectable bias voltages for active GPS antennas, port configurations, message protocols, and flexible internal "Keep-Alive" back-up power modes for both the Static Random-Access Memory (SRAM) and the low power time source.

The kit also includes the necessary circuitry to convert the receiver's Complimentary Metal Oxide Semiconductor (CMOS) level output to RS-232 level, serial data I/O. The two serial data ports are RS-232, 9-pin D-Subminiature connectors.

2.3.1 Host Serial Port. The Host serial port, labelled Serial Port 1, is used to send and receive both binary and National Marine Electronics Association (NMEA-0183) initialization and configuration data messages.

2.3.2 Auxiliary Serial Port. The Auxiliary serial port, labelled Serial Port 2, is dedicated to the reception of RTCM SC-104 Differential GPS (DGPS) correction messages. No data is output from the receiver through the Auxiliary port.

2.3.3 Auxiliary Test Connector. An auxiliary output connector, labelled Clock Out, on the Development Kit allows the OEM processor to access the 1 pulse-per-second (1 PPS) time mark and 10 KHz time mark signals. The signals available at the auxiliary test connector are buffered CMOS level outputs driven by a 74LS04 CMOS inverting buffer device.

2.3.4 DC Power Regulation. The kit also includes the necessary circuitry to regulate the DC power input and to provide the necessary supply voltages to the receiver.

The Development Kit board contains jumper blocks which allow the OEM to insert a current measuring device inline with the primary and Real-Time Clock (RTC) power lines to the receiver to monitor power usage under various conditions. To isolate the receiver from the Development Kit, an electronic bus switch is used. This switch is controlled externally by a DIP switch on the kit. The bus switch also

provides control over the bus voltage level. A jumper block is provided to select the interface voltage level to be used.

DC power for the Development Kit is provided by either an AC/DC converter or automobile adapter. The AC/DC converter operates from a nominal 120 VAC @ 60 Hz input and provides a 12 VDC @ 500 mA out. For mobile operation, an automotive adapter intended for use in 12V vehicles is provided. Four front panel LEDs provide the Development Kit's basic status indicators. A momentary pushbutton switch is provided on the Development Kit board to generate a master reset signal to the receiver.

2.3.5 Interface Cables. Ribbon cables are provided to interface between the Development Kit and the customer's PC, and between the Development Kit and a DGPS receiver. These cables are terminated at both ends with female connectors to match the male connectors on the Development Kit and the PC.

2.3.6 The Active Antenna. A magnetic mount, active antenna is supplied with the kit. An 8-foot long RF cable (RG-316) is provided for the antenna with the proper connector already terminated. The nominal measured attenuation of the cable with connector is approximately 3 dB. The supplied active antenna should be biased at +5 VDC, but a different active antenna with a bias of either +5 or +12 VDC may be used. Switches located on the back panel of the Development Kit are used to select the proper bias.

CAUTION: Make certain the antenna power switches are properly set before connecting the antenna. An antenna designed for +5 VDC operation will be damaged if connected to a +12 VDC source.

2.3.7 On/Off And Reset Switches. A pushbutton ON/OFF power switch is provided to control primary power to the "Jupiter" board. A pushbutton reset switch is also provided on the Development Kit circuit board to generate a receiver system hardware reset. This reset switch

is not accessible unless the cover is removed from the Development Kit.

There is also a provision to supply external backup power to the SRAM and RTC devices after primary power has been removed from the board. This feature provides the receiver with a "hot start" capability by maintaining last position, current time, and satellite ephemeris data in SRAM.

2.4 Configuring The Development Kit

CAUTION: If the Development Kit cover is removed during configuration, proper Electrostatic Discharge (ESD) precautions should be observed when handling the unit to prevent possible damage to circuits. Failure to observe these precautions may result in permanent damage to the unit.

The Development Kit should be correctly configured before it is connected to the PC and powered up.

2.4.1 Configuration Devices. The "Jupiter" board is configured using a bank of eight dip switches, three jumper blocks, and a single, two-position jumper switch block. The relative position of each configuration device on the "Jupiter" board, as well as the auxiliary I/O connector, is shown in Figure 2-3.

The primary configuration switches, located on the rear of the Development Kit, are illustrated in Figure 2-4. They are shown in their normal default positions.

CAUTION: The antenna bias may be set to either 0, +5, or +12 VDC for an active antenna. The switches must be set correctly to avoid possible damage to the unit. The active antenna supplied with the Development Kit must be set to +5 VDC only. If a passive antenna is used, be sure to set the antenna bias to 0 volts VDC. Remember

The supply of an external backup voltage to the SRAM and RTC is accomplished by properly configuring a jumper block and a configuration DIP switch. This external backup power is maintained to the SRAM and RTC unless it is disabled using the DIP switches, by removing the appropriate jumper on the kit, or by removing +12 VDC power to the kit.

to set the Development Kit's power switch to OFF or remove power from the unit before changing these switches.

Switch 1 is reserved and should be set to the OFF position.

Switch 2 is used to select the receiver's output message protocol. If switch 2 is set to the ON position, the receiver's output message format will be set to NMEA-0183 with Host port settings of 4800 bps, no parity, 8 data bits, and 1 stop bit. If switch 2 is set to the OFF position, the receiver's output message format and communication parameters are determined by the configuration of switch 3 as follows:

- If switch 3 is ON when switch 2 is OFF, ROM defaults are used and the receiver will output Rockwell binary format messages with Host port settings of 9600 bps, no parity, 8 data bits, and 1 stop bit.
- If switch 3 is OFF when switch 2 is off, the receiver's output protocol, communication parameters, and initialization parameters will be determined from data stored in SRAM or EEPROM (whichever is valid). That is, the receiver recalls the settings from its last operating session.

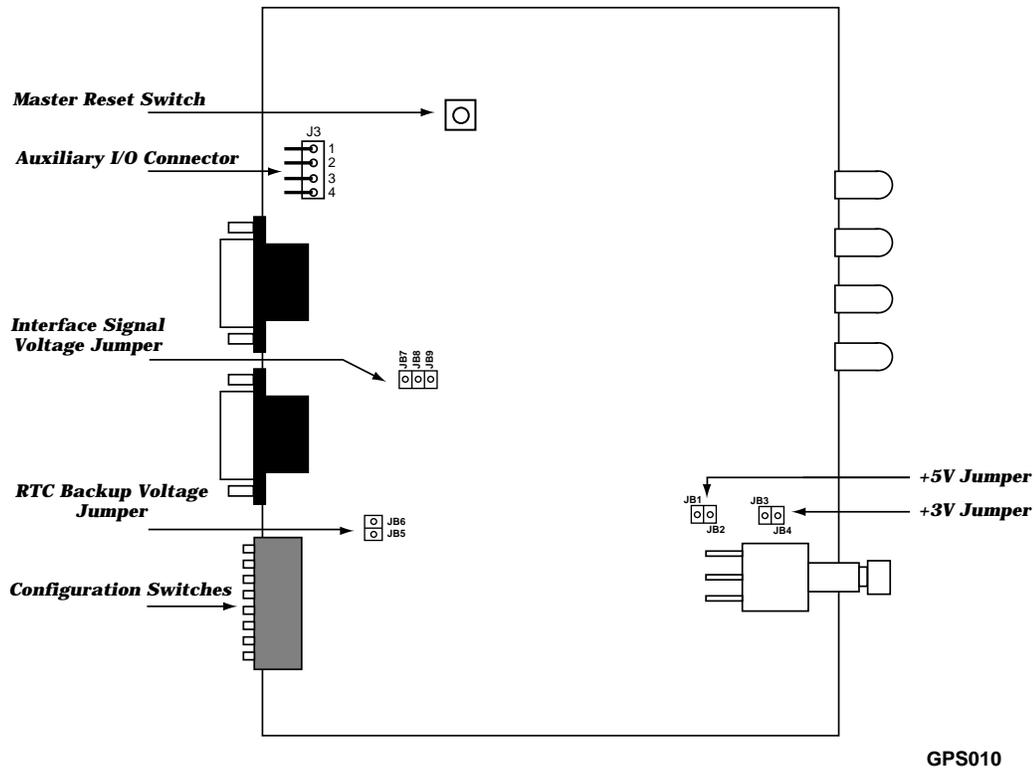


Figure 2-3. "Jupiter" Board With Location Of Configuration Devices

Switch/Function:	ON:	OFF:
1 Reserved	N/A	N/A
2 Host Port Protocol	NMEA Assured	Rockwell Binary or NMEA depending on Switch 3
3 EEPROM Enable/Disable	EEPROM Disable	EEPROM Enabled
4 Reserved	N/A	N/A
5 I/O Control	Enable I/O signals	Disable I/O signals
6 RTC Control	RTC Backup Power Enabled	RTC Backup Power Removed
7 Preamp Voltage Select	Apply +5 VDC to Active Antenna	Apply +12 VDC to Active Antenna
8 Preamp Power Enable	Preamp Power On for Active Antenna	Preamp Power Off For Passive Antenna

GPS015

Figure 2-4. Development Kit Configuration Switches

Switch 3 is used to enable or disable the Electrically Erasable Programmable Read-Only Memory (EEPROM). When switch 3 is ON, EEPROM is disabled and ROM defaults such as message format, host port communication settings, and receiver default message set are used. When switch 3 is off, user-configurable settings stored in EEPROM are used. This switch should normally be OFF to use data such as clock parameters, last position, and receiver configuration from EEPROM.

NOTE: Be advised that if the Development Kit is operated with switch 3 in the ON position (EEPROM disabled), then each power cycle or reset of the receiver may result in a longer Time-To-First-Fix (TTFF). This is because the receiver will use the default initialization parameters stored in ROM rather than more current initialization parameters that may be available in SRAM or EEPROM.

Switch 3 must be in the Off position for the receiver to output the results of a commanded Built-In Test (BIT).

Switch 4 is reserved and should be set to the OFF position.

Switch 5 is used to control the I/O signals to the receiver. Set switch 5 ON to enable and OFF to completely disable the receiver's I/O signals.

Switch 6 is used to control whether the Development Kit will supply SRAM and RTC backup power when the receiver has been switched off. Set switch 6 ON to supply backup power and OFF to remove backup power. When switch 6 is ON, SRAM and RTC back-up power is supplied to the receiver as long as the Development Kit is receiving +12 VDC power from the supplied AC/DC adapter or car adapter.

Switch 7 is used to select the voltage applied to an active antenna when switch 8 is in the ON position. Set switch 7 to ON to apply +5 VDC and to OFF to apply +12 VDC (only +5 VDC should be applied when the active antenna supplied with the Development Kit is used).

Switch 8 is used to select between an active and a passive antenna. Set switch 8 to OFF for a

passive antenna and to ON for an active antenna. The ON setting allows DC voltage (selected by switch 7) to be applied to the center conductor of the RF cable.

2.4.2 RTC Backup Voltage Jumper. A jumper block on the Development Kit, with pins labeled **JB5** and **JB6**, may be used to disable the backup power to the receiver's SRAM and RTC from the kit. Remove the jumper to disable the backup power; leave the jumper in place to supply voltage to the SRAM and RTC even when primary power has been removed from the receiver.

To supply a backup voltage from an external source, remove the jumper and connect the voltage source to pin JB6. Additional information on backup power requirements can be found elsewhere in this Designer's Guide.

2.4.3 +5V and +3V Jumpers. Two additional jumper blocks are provided to enable +3.3 VDC or +5 VDC primary power. To enable the +5 VDC primary power to the receiver interface connector, the jumper should be in place over the pins labeled **JB1** and **JB2** on the circuit board.

To supply the primary voltage from an external source, remove the jumper from pins **JB1** and **JB2** and connect the voltage source to pin **JB2**. Additional information on power requirements can be found elsewhere in this Designer's Guide.

2.4.4 Interface Signal Voltage Jumper. A switch jumper block is provided to select either +3.3 VDC or +5 VDC for the receiver's I/O interface. The three-pin jumper block is labeled **JB7**, **JB8**, and **JB9** on the circuit board. When the +5 VDC "Jupiter" board is operated with the Development Kit, the jumper should be over pins labeled **JB7** and **JB8**.

2.4.5 Auxiliary I/O Connector. There is a 4-pin AUX I/O connector on the Development Kit as shown in Figure 2-5. This connector is a Molex 70553 series right-angle pin header. The connector provides access to the buffered 10 KHz UTC signal and the one pulse-per-second timing signal. These may be used by the OEM's processor for synchronization.

The pin assignments are as follows:

1. K10. Buffered 10 KHz UTC output frequency reference signal. This is a synchronous 10 KHz output clock with a 50 \pm 5 percent duty cycle.
2. TM (inverted version of the Time Mark pulse). This is a 1 pulse-per-second (1 PPS) CMOS output signal buffered through a 74LS04 device.
3. No connect.
4. GROUND.

For further information on the characteristics of these signals, consult the "Jupiter" receiver Data Sheet included with this Development Kit.

CAUTION: Do not connect an antenna and apply power to the Development Kit before reviewing this entire section and checking the antenna bias switch settings. The settings must be correct before power is applied to the receiver.

When connected, a passive antenna provides a low resistance path. Therefore, an abnormally high current will occur in the supply circuits of the "Jupiter" board if the switches are set for an active type. Although the preamp power supply internal to the Development Kit is current-limited to 65 milliamps, this feature will only prevent damage to the receiver, itself, but not necessarily to the Development Kit or antenna.

Failure to observe these precautions may result in permanent damage to the unit and/or the antenna.

2.4.6 Positioning The RF Antenna. Since GPS is a line of sight system, the antenna can only receive signals from visible satellites. Therefore, a location for the test equipment should be selected so that the GPS antenna is placed where the view of the sky is least obstructed for optimal reception of the satellite signals.

NOTE: GPS signals are severely attenuated or totally obscured by the roofs or walls of wood, metal, brick, or stucco buildings. The signals are also attenuated by coated glass found in many office structures. The Development Kit should be taken outside or to the roof of a building to effectively evaluate receiver performance. With stationary evaluations, care should also be taken to keep the antenna away from the side of a building since GPS signals can reflect off of metal or coated glass. These reflections have a longer path than direct signals and can cause multi-path errors.

2.4.7 Connecting an RTCM Differential Source. The Development Kit, PC, and the RTCM SC-104 differential correction source are connected as shown in Figure 2-6. If RTCM SC-104 data needs to be logged at the same time it is sent to the receiver, the OEM must supply a cable with three connectors to connect the RTCM correction source to the Development Kit's Auxiliary port and to an unused serial port on the PC. In this case, data is only logged when LABMON is invoked with filenames as command line arguments as described in Section 3 of this Designer's Guide.



GPS020

Figure 2-5. Auxiliary I/O Connector

Logging and subsequent review of RTCM correction data often proves useful to resolve performance or compatibility issues. A utility program, RTCMCHK, is contained on the LABMON disk included with the Development Kit. This software tool checks the integrity of RTCM SC-104 data sources.

Normally, the Development Kit should be set up as shown in Figure 2-6 with only the RTCM correction source connected to the receiver. If the RTCM cable is not connected to the receiver's Auxiliary port, DGPS operation will not be possible.

Note that the Development Kit may be connected to either the COM1, COM2, COM3, or COM4 serial ports and the RTCM differential correction data source connected either directly to the receiver's Auxiliary I/O port, to one of the remaining serial ports of the PC, or to both using an OEM-supplied three-connector serial cable.

2.4.8 Operating The Development Kit's GPS Receiver. To operate the "Jupiter" receiver, press the pushbutton on/off switch on the front panel of the Development Kit once. When power is applied to the receiver, the POWER LED illuminates and the TIME MARK LED flashes at a 1 Hz rate to indicate the receiver is operating.

When the NMEA protocol for the Host port is selected, the NMEA ASSURED LED illuminates. When data is received by the Auxiliary port, the DGPS ACTIVE LED illuminates. The DGPS ACTIVE LED does not indicate the integrity of the RTCM SC-104 data or the receiver mode.

Press the pushbutton switch again to remove primary DC power from the receiver.

The POWER LED on the Development Kit should indicate off before changing the configuration switch settings. The receiver operating settings will not change after re-configuration until the receiver is restarted by pressing the front panel pushbutton on/off switch.

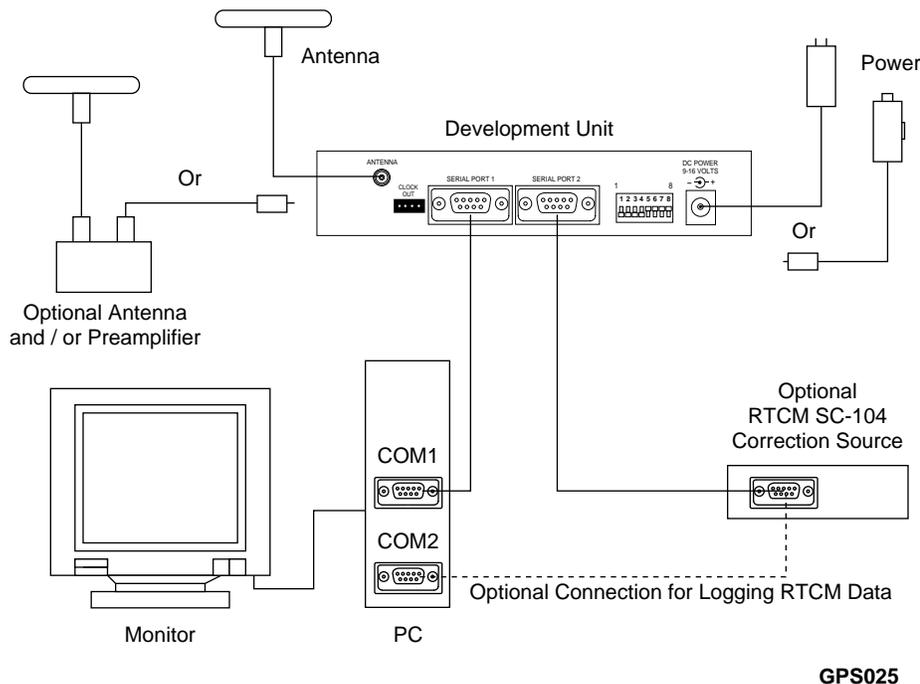


Figure 2-6. Development Kit Test Equipment Setup

3 USING LABMON

The Rockwell Zodiac™ Development Kit is designed to facilitate evaluation of Rockwell's "Jupiter" Global Positioning System (GPS) receiver engine based on the Zodiac chip set. The receiver can be used in both static and mobile operations for evaluation purposes.

This Section explains the use of the GPS monitor and controller software, referred to as LABMON, provided with the Development Kit (Refer to Section 2 of this Designer's Guide for details on how to set up and configure the Development Kit). LABMON runs on a PC and allows the user to control the receiver and to display the receiver outputs. Externally supplied Radio Technical Commission for Maritime Services (RTCM SC-104) data can also be logged using a second PC serial port. ASCII files containing the LABMON source code, included on the same diskette as the executable, provide a reference for similar Original Equipment Manufacturer (OEM) code implementations.

3.1 Introduction

The Development Kit implements the receiver control operation and input/output (I/O) functions of the GPS receiver using an IBM-AT compatible PC, a serial port, external antenna, and power supply. The GPS receiver is contained in a housing with I/O connectors, status LEDs, and configuration DIP switches.

3.1.1 LABMON Compatibility With Rockwell Receivers. There are two series of Rockwell commercial GPS receivers to date. The first was the NavCore series and the latest is the Zodiac family. The NavCore series consists of the NavCore V, MicroTracker, MicroTracker LP, NavCard, and NavCard LP receivers. The Zodiac family currently consists of the "Jupiter" board level product and the Zodiac chip set product.

LABMON 4.7 is designed primarily to support the Zodiac family of receivers. Since it is also backwardly compatible with the NavCore series of receivers, this version of LABMON may be used to monitor and control them as well.

3.1.1.1 Serial Communication Protocols. The receivers may use either a binary or NMEA-0183 type of serial interface protocol for communication. The Zodiac and NavCore receivers share a similar Rockwell binary message format, but the messages themselves have different IDs and content. To differentiate between these binary types in this document, they are referred to as Zodiac binary and NavCore binary.

The NMEA-0183 protocol consists of a number of standard messages, and also allows manufacturer specific or proprietary messages for more complete control or monitoring of receivers.

While the Zodiac and NavCore receiver NMEA-0183 protocols share a number of standard messages, the number and type of Rockwell proprietary messages differ. To differentiate between these NMEA types in this document, they are referred to as Zodiac NMEA and NavCore NMEA.

The Zodiac receiver series comes standard with both Zodiac binary and Zodiac NMEA. The type used is selected either by software command or by controlling the voltage applied to an external pin on the receiver.

The NavCore series is available with Rockwell NavCore binary and NavCore NMEA protocols depending on the model and software options. The type used is selected by controlling the voltage applied to an external pin on the receiver.

The NavCard supports only NavCore binary. The NavCard LP is available with either Rockwell NavCore binary or NavCore NMEA-0183 protocols.

To communicate with a receiver, the message protocol used by LABMON is changed to match the current message type in use by that receiver.

It is important to select the correct protocol for LABMON to operate properly. The two binary protocols are not compatible. The NMEA-0183 protocols are similar enough that standard

messages can be displayed or received properly, but not all Rockwell proprietary NMEA messages will be output or accepted.

3.2 Installing LABMON

3.2.1 Operating Environment. LABMON was designed to run using an MS-DOS/PC-DOS or compatible DOS operating system. It is also possible to run LABMON from the DOS prompt under Windows 3.x.

NOTE: Sometimes, both Windows and DOS will attempt to use the same interrupt for the serial ports and a conflict may occur. If problems are encountered running LABMON under Windows, exit to DOS to run LABMON.

If a mouse driver is installed on a serial port used by LABMON, serial data may be prevented from reaching LABMON. The mouse driver should be removed if LABMON does not function properly.

While LABMON can be run from the 3.5-inch diskette, copying the program and associated files to a hard disk and retaining the diskette as a backup is recommended.

The current version of LABMON can be used to operate the Zodiac family of receivers and is also compatible with the MicroTracker/MicroTracker LP, NavCore V, and PCMCIA NavCard/NavCard LP receivers. However, some of the keys and commands used to enable certain features of the current hardware configuration may not be supported by these receivers.

3.2.2 DOS Installation. To install LABMON for use with DOS, do the following:

1. Create a directory on the PC's hard drive and copy all the LABMON disk files to it.
2. Edit your AUTOEXEC.BAT file to include this directory as part of the path.
3. Remove the LABMON disk and save it as a backup.
4. Reboot the PC to update the path.

3.2.3 Windows 3.x Installation. To install LABMON for use with Windows 3.x, do the following:

1. Perform steps 1 through 4 as for DOS installation above.
2. Start Windows, select the Program Manager, and select New under the File menu.
3. Click on the Program Item within the dialog box which appears and click on OK to exit the dialog box.
4. Enter "LABMON" for the Description.
5. Enter "LABMON" for the Command Line.
6. Enter the full path to the LABMON directory or use Browse to set the Working Directory (i.e., C:\LABMON).
7. To select the program icon, click on Change Icon. Then, enter the full path or use Browse to select the LABMON.ICO file located in the LABMON installation directory and click on OK twice to exit the dialog boxes.

3.2.4 Windows 95 Installation. To install LABMON for use with Windows 95, do the following:

1. Create a directory on the PC's hard drive and copy all the LABMON disk files to it.
2. Remove the LABMON disk and save it as a backup.
3. Create a "shortcut" to the LABMON executable (see the Win95 manual or use the Win95 on-line Help feature).

3.3 Configuring LABMON

3.3.1 The LABMON.CFG File. Using function keys or certain <Alt>/function key combinations, LABMON can be configured for the message protocol mode (binary or NMEA), display datum, the UTC time offset, speed units, display colors, reference position, and filtering parameters. This is the easiest way to change the configuration settings.

These parameters can also be changed by editing the LABMON.CFG file. If difficulties are encountered processing the settings, the LABMON.CFG file should be examined to see if extraneous or incorrect information has corrupted it. This file may be deleted since the program will automatically reconstruct it with defaults which can then be modified.

LABMON checks for the presence of the LABMON.CFG file when the program is invoked and reads parameters from the file if it is present. If the LABMON.CFG file is not present, default configuration parameters are used, and a LABMON.CFG file containing the following lines is created in the local directory:

```
DATA TYPE 4
DATUM NUMBER 0
UTC OFFSET 7
SPD UNITS 0
COLORS 10 15 0 14 15 10
LAT 33.661446 LON - 117.861252
ALT - 8.716304
FILTERS STATMASK FFFF FOM 5
QUALITY 1 SATS 3 PDOP 6.000000
HDOP 6.000000 VDOP 6.000000
```

NOTE: Although the latitude, longitude, altitude, and filter parameters are shown on more than one line above, they must all appear on the same line in the configuration file.

3.3.1.1 DATA TYPE Parameter. This parameter determines the desired message protocol mode, binary or NMEA. Use 1 for Rockwell NavCore binary, 2 for NavCore NMEA-0183, 4 for Rockwell

Zodiac binary, and 8 for Zodiac NMEA-0183. This is done using the <Alt>F2 keys.

3.3.1.2 DATUM NUMBER Parameter. The datum number for display of position output is no longer set from within the configuration file when using the Zodiac family of GPS receivers. Instead, use the Ctrl-<F6> keys to enter any of the datum numbers shown in Appendix E of this Designer's Guide.

The Zodiac family supports many datums internally while the NavCore series of receivers supported only WGS-84 with the desired transformation being performed by LABMON. LABMON 4.7 ignores the datum number contained in the LABMON.CFG file when processing Zodiac data. The inclusion of the datum number in the configuration file is for backward compatibility of LABMON with Rockwell NavCore GPS receivers.

When using LABMON 4.7 with one of these earlier receivers, the datum number may either be changed in the configuration file (using an appropriate text editor) or by using the Ctrl-<F6> keys to enter any of the datums shown in Appendix E.

3.3.1.3 UTC OFFSET Parameter. The UTC time offset between local time and UTC should be set to UTC minus local time. The time zones in the United States, for example, have positive time offsets. This time is added to the PC time and used as the default for receiver initialization. It is important to verify and correct, if necessary, the PC time for correct initialization when using the defaults provided by LABMON. This is done using the F1 key.

3.3.1.4 SPD UNITS Parameter. This parameter configures the speed units displayed in the SPD field on the LABMON display. Unless modified in the LABMON.CFG file (since there are no keys or key combinations that will do this), the speed units will default to meters per second (m/s). The setting for speed units in the LABMON.CFG file should be set to 0 for m/s, 1 for miles per hour (mph), or 2 for kilometers per hour (kph).

3.3.1.5 COLORS Parameters. Screen colors are changed using the <Alt>-Function key combinations shown on the screen menu.

3.3.1.6 LAT, LON, ALT Parameters. The receiver's reference position can be changed using the <Alt>F3 keys. When this position is changed, the LAT, LON, and ALT parameters in the LABMON.CFG file are changed. The new location becomes the default reference position (the start-up location).

3.3.1.7 FILTERS Parameters. The data filtering parameters STATMASK, FOM, QUALITY, SATS, PDOP, HDOP, and VDOP should be set to the desired criteria for solution evaluation using the <F> key. The parameters used depend on the message protocol in use.

When the criteria are not all met, the FILTER ON indicator is shown on the display screen and if data is being extracted into a text file for post processing, the data is not written to the file. When the criteria are all met, the indicator is not displayed and the data is extracted and written to the file. This allows filtering or screening of outputs that are computed under conditions which do not meet the user's criteria for solution quality.

NOTE: The filter does not prevent any data from being written to the log file when recording data.

3.3.2 The LABMON.INI File. LABMON can also be configured to select the COM ports it uses for serial I/O either by choosing settings from within the program or by editing the initialization file, LABMON.INI, before starting the program.

LABMON checks for the presence of the LABMON.INI file when it is invoked and reads parameters from the file if it is present. If this file is not present, default parameters are used for the GPS and RTCM ports, and a LABMON.INI file is created in the local directory. The I/O addresses and interrupts used are shown at the bottom of the screen when LABMON is first started.

The LABMON.INI file contains one line of parameters each for the GPS and for the RTCM ports. These are used to define the port number, interrupt level, baud rate, parity scheme, number of data bits, and stop bits for each. The I/O address used is the default for the port number selected.

3.3.2.1 Default Settings. The default settings for the Zodiac receiver are COM1, IRQ4, 9600 baud, no parity, 8 data bits, and 1 stop bit (if this version of LABMON is used with earlier Rockwell GPS receivers, these same settings should be used except that parity should be set to "odd").

The default parameters provided for the RTCM port are COM0 (which disables the port), IRQ3, 9600 baud, no parity, 8 data bits, and 1 stop bit. However, the user should consult the RTCM receiver hardware documentation or contact the provider of the RTCM data to determine the proper settings for the RTCM port.

The easiest way to change the GPS and RTCM port default settings is to start the program and use the <Alt>F1 keys to check or modify the port settings. Alternately, the user may edit the LABMON.INI file. If difficulties are encountered setting the ports, the user should examine the LABMON.INI file to see if extraneous or incorrect information has corrupted it (this file may be deleted since the program will automatically reconstruct it).

The LABMON.INI file initially contains the following lines which provide default values for the GPS port and the RTCM port:

```
GPS   COM1  IRQ4  9600  n  8  1
RTCM  COM0  IRQ3  9600  n  8  1
```

The port parameters may be changed using either lower or uppercase letters, separated by spaces. The syntax for the configuration commands is as follows:

```
[Port][COMn][IRQm][Baud][Parity][Dat
aBits][StopBits]
```

NOTE: Although these configuration commands are shown on two lines above, they must all appear on the same line in the initialization file.

Only the following configuration values are currently allowed:

Port	GPS for the GPS port RTCM for the RTCM port
COMn	n = 1, 2, 3, or 4 (to open the port) n = 0 (to ignore the port)
IRQm	m = 3, 4, 5, or 7

Baud	300, 600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 76800, or 115200
Parity	n, o, e (None, Odd, or Even)
DataBits	6, 7, or 8
StopBits	1 or 2

The modified settings are saved in the LABMON.INI file.

3.4 Using Differential RTCM Data

3.4.1 Differential RTCM Data and Zodiac GPS Receivers.

When using differential corrections with a Zodiac receiver, the data is directly input using the Zodiac's Auxiliary port. The baud rate, parity, and number of data and stop bits required by the source needs to be determined and the source protocol established using Message 1330 (Serial Port Communication Parameters).

The source is then connected using either a straight-through cable or a null-modem cable. The required cable type may be different than that recommended by the provider of the specific correction source.

To change the Auxiliary port parameters, the receiver must be using Zodiac binary protocol. The protocol may be changed to Zodiac NMEA after setting port parameters.

Normally, RTCM data is sent directly to the Auxiliary port of the receiver. In the event that RTCM data needs to be recorded for analysis, a cable with three connectors may be used to send data to both the receiver's Auxiliary port and a second PC serial port. The user must then set the parameters for the second port to match the RTCM SC-104 source protocol as described in Section 3.3. Refer to Section 2 of this Designer's Guide for additional details.

NOTE: An indirect DGPS data input capability is available with Zodiac GPS receivers for those applications that are limited to one serial port. Message 1351 is the Zodiac equivalent of the NavCore Message 210. Setup and operation of LABMON using this feature are identical to the

NavCore indirect RTCM input method described in the next paragraph.

3.4.2 Differential RTCM Data and NavCore GPS Receivers.

When using differential corrections with NavCore series receivers, the data may be directly input using the receiver's Auxiliary port or indirectly input with a Message 210 (Differential GPS RTCM SC-104 Data Message) using the Host port. The method used depends on the receiver type and the system configuration. The direct input method is recommended since it is the simplest.

When using direct input, the baud rate, parity, and number of data and stop bits required by the source must be established using Message 217 (Port Configuration Message) if in NavCore binary mode or using the ICOM message if in NavCore NMEA-0183 mode. The source is then connected using either a straight-through cable or a null-modem cable. The required cable type may be different than that recommended by the provider of the specific correction source.

When using indirect input of RTCM SC-104 data, the user connects the source to a second serial port on the PC. LABMON checks for the presence of RTCM SC-104 data on the second serial port and processes it when available.

The user needs to set the source protocol used by LABMON as described in Section 3.3. LABMON packages RTCM SC-104 data received from the second serial port into a series of 210 messages. When data is input directly to the receiver using the Auxiliary I/O port, the

LABMON port settings are not used and do not affect RTCM receiver operation.

Note that LABMON does not send RTCM data using Message 210 until the required number of RTCM words are received. This number can be

set by the user with the <Ctrl>F10 keys (see Section 3.8). By reducing the number of required RTCM words, the delay between reception of RTCM data by LABMON and the use of that data by the receiver can be minimized.

3.5 Starting LABMON

3.5.1 Command Line Parameters. The LABMON software can use two different command line options to record the serial data from either or both of the PC serial ports. The first option allows all data to and from the Zodiac Host port to be written to a data file. The second option records both the Host port data and the RTCM data from the Auxiliary port.

Rockwell binary Host port data and RTCM Auxiliary port data are written as raw binary files. NMEA-0183 Host port data is written as a raw ASCII text file.

LABMON determines how it records data by detecting the presence of filenames on the command line that is used to invoke it. Start up is the only opportunity where data recording may be selected. When running under DOS, the data filenames are selected on the command line. When running under Windows 3.x, either select the LABMON icon or use the Run command from the Program Manager and specify the files on the command line. When running under Windows 95, the 'Run' window under the 'Start' icon must be used so that the command line parameters can be included on the command line.

3.5.2 Starting LABMON From DOS. To run LABMON from DOS, do the following (the filenames used are examples only; others may be used):

1. Type "LABMON" for no data recording.

Or type "LABMON GPS.DAT" to record all data to and from the Host port.

Or type "LABMON GPS.DAT RTCM.RTC" to record both Host and Auxiliary port data.

3.5.3 Starting LABMON From The DOS Prompt In Windows 3.x or Windows 95. To run LABMON from Windows 3.x using the DOS prompt, do the following (the filenames used are examples only; others may be used):

1. Select the MS DOS prompt icon.
2. Type "LABMON" for no data recording.

Or type "LABMON GPS.DAT" to record all data to and from the Host port.

Or type "LABMON GPS.DAT RTCM.RTC" to record both Host and Auxiliary port data.

3. Type "EXIT" to return to Windows after quitting LABMON.

3.5.4 Starting LABMON Within Windows 3.x. To run LABMON from within Windows 3.x, do the following (the filenames used are examples only; others may be used):

1. Double-click the LABMON icon to start LABMON. (To record data, the program item Command Line field must be changed to include the GPS and/or RTCM filenames. To do this, select the LABMON icon and choose Properties from the File menu under the Windows Program Manager.)

NOTE: To display data, both the GPS message type and serial communication protocol parameters used for LABMON must be set to match those used by the receiver. If data is being received but not displayed by the receiver, a buffer overflow will result after a short time and a message will be displayed to indicate this. If the settings of the receiver are unknown and communication cannot be established, the receiver should be reset after enabling ROM defaults using the appropriate

configuration switch as described in Section 2 of this Designer's Guide.

3.5.5 Starting LABMON Within Windows 95.

To run LABMON from within Windows 95, do the following (the filenames used are examples only; others may be used):

For no data recording:

1. Start Windows, select Start, select Programs, and finally select Windows Explorer.
2. Select the LABMON folder.
3. Double click on the LABMON application file.

4. To create a Shortcut to LABMON, select the LABMON application file and drag to a location within the main screen.

To record all data to and from the Host port:

1. Start Windows, select Start, then select Run. Type "LABMON GPS.DAT" on the command line.

To record both Host and Auxiliary port data:

1. Start Windows, select Start, then select Run. Type "LABMON GPS.DAT RTCM.RTC" on the command line.

3.6 Stopping LABMON

Avoid using either Ctrl-Break or Ctrl-C to exit LABMON. LABMON replaces certain interrupt handlers that may be required by other programs during its initialization and restores them upon exiting. Therefore, any abnormal termination may affect the execution of another program. If this occurs, the PC may need to be rebooted.

To terminate the execution of LABMON software, press the <Q> key. This will stop LABMON and return the user to either the DOS prompt or to Windows.

3.7 LABMON Displays

To support the many new features available in the Zodiac family of GPS receivers, the screen display and key functions have been revised from earlier versions of LABMON. There is space provided for many new data items on the screen. Some of these items are not shown if LABMON 4.7 is used with NavCore GPS receivers.

There are two types of displays that LABMON uses to output information, the main display and the Built-In Test (BIT) display.

3.7.1 Main Display. Depending on the message protocol type used (binary or NMEA), the data labels shown on the main display change slightly to more accurately reflect the data available from that configuration. The actual label used for the data is described, together with the output message description, in Section 3.8.

The main display, shown in Figure 3-1, appears when LABMON processes Zodiac binary data. There are two portions to this display: data and menu options. Additional data is displayed behind the menu that may be viewed by pressing <N>, the No Menu key. The data portion is comprised of satellite data and status information from binary or NMEA messages.

In addition to data from the receiver, additional useful information such as the number of data bytes recorded, the number of messages sent or received, the number of checksum errors, and the number of message "no acknowledgements" is also displayed.

3.7.2 The BIT Display. The LABMON BIT display screen is different depending on whether a Zodiac GPS receiver or a NavCore GPS receiver is used.

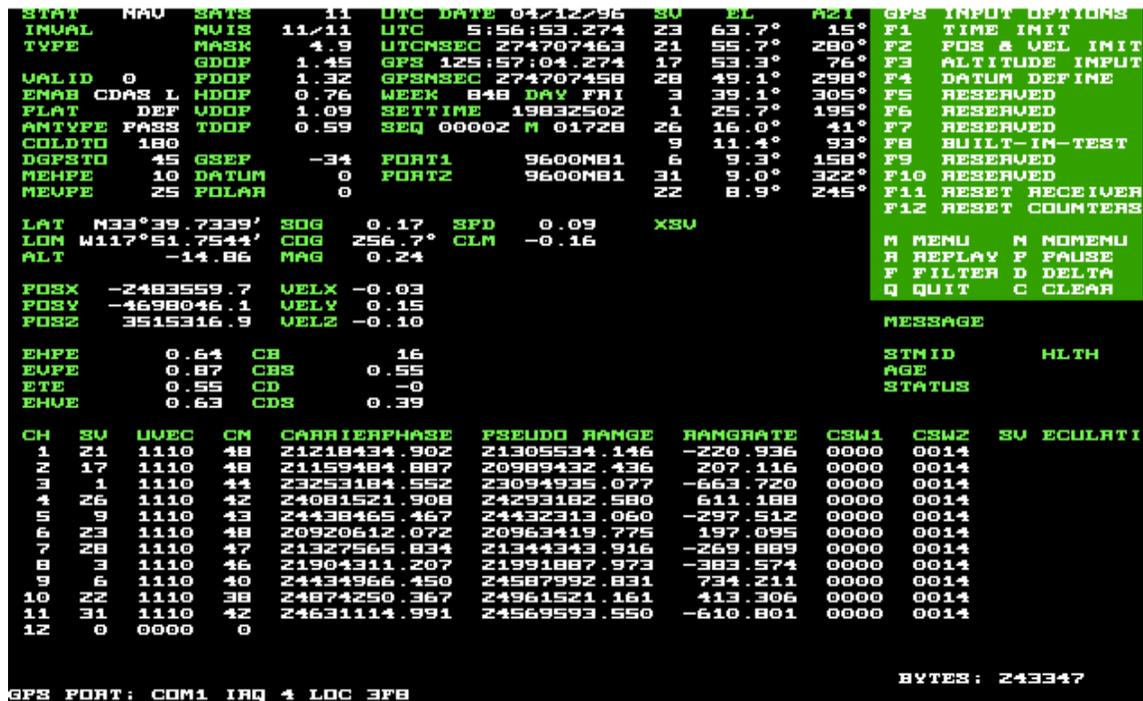


Figure 3-1. LABMON Main Display For Zodiac GPS Receivers

3.7.2.1 BIT Display For Zodiac Receivers. For Zodiac receivers, a typical LABMON BIT display is shown in Figure 3-2. This display contains information from Message 1100 (Built-In Test Results). Refer to Section 5 of this Designer's Guide for detailed information on the Zodiac BIT message.

3.7.2.2 BIT Display For NavCore Receivers. The BIT display screen for Rockwell NavCore receivers is different from the Zodiac receivers.

The BIT display for Rockwell NavCore receivers is shown in Figure 3-3. On this display, information from Message 101, Built-In Test Results, is shown.

For detailed information on the NavCore series BIT message, refer to the Designer's Guide that corresponds to the specific NavCore series GPS receiver (NavCore, MicroTracker LP, NavCard LP, etc.).

```

          ZODIAC BUILT-IN TEST RESULTS

FUNCTIONAL TEST                               FAILURES

READ-ONLY MEMORY (ROM)                       1
RANDOM ACCESS MEMORY (RAM)                    0
NON-VOLATILE STORAGE (EEPROM)                0
DUAL PORT RAM (DPRAM)                        0
DIGITAL SIGNAL PROCESSOR (DSP)               0
REAL-TIME CLOCK (RTC)                        0
SERIAL PORT 1                                0
SERIAL PORT 2                                0

SERIAL PORT 1 RECEIVE COUNT                  16
SERIAL PORT 2 RECEIVE COUNT                   0

          SOFTWARE VERSION 1.02
    
```

Figure 3-2. LABMON BIT Display For Zodiac GPS Receivers

```

          B.I.T. RESULTS

SUMMARY:  SYSTEM      ROM      LOW RAM      HIGH RAM      SPI      RAM ADDRESS
          PASS        PASS        PASS        PASS        PASS        PASS

LOW RAM = PASS      HIGH RAM = PASS      PRE_PROCESSOR RAM = PASS

          PP SELF      PP WRAP      CODE UCD      CAR UCD      CODE GEN      SIG PROC
CH1      PASS        PASS        PASS        PASS        PASS        PASS
CH2      PASS        PASS        PASS        PASS        PASS        PASS
CH3      PASS        PASS        PASS        PASS        PASS        PASS
CH4      PASS        PASS        PASS        PASS        PASS        PASS
CH5      PASS        PASS        PASS        PASS        PASS        PASS

INTERRUPT CONTROL: PASS      LOW POWER TIME SOURCE: PASS      OPTIONS REGISTER: PASS

SERIAL I/O:      TRANS ERRORS = 0      CHECKSUM ERRORS = 0
EEPROM:          PROGRAMS ERRORS = 0      CHECKSUM ERRORS = 0

LINK ID:  DGPS WITH SU MEASUREMENTS WITH POWER MANAGEMENT
SOFTWARE VERSION: 3.61

          PRESS ANY KEY TO CONTINUE
    
```

Figure 3-3. LABMON BIT Display For NavCore GPS Receivers

3.8 Receiver Output Messages

LABMON decodes and displays most of the available messages. Either Rockwell binary or NMEA messages can be in use at a time. Data from these messages is shown in various fields on the screen. Some of the data from binary messages is converted into more commonly used units of measurement (such as degrees and minutes instead of radians).

NOTE: Some of the data contained in messages is not shown on the screen due to space limitations. Data which is omitted is not needed to evaluate receiver performance.

Each of the data fields on the LABMON main display screen is listed alphabetically in Table 3-1 along with a brief description of the data item and the source of the data (i.e., the binary or NMEA messages containing that data item).

Refer to Section 5 of this Designer's Guide for detailed information on each message used by the Zodiac receiver.

For detailed information on each message used by the NavCore series of GPS receivers, refer to the Designer's Guide that corresponds to the specific receiver (NavCore, MicroTracker LP, NavCard LP, etc.).

3.9 Receiver Input Messages

LABMON makes extensive use of the keyboard function keys to control program and receiver operation. Most of the keys result in a message being sent to the receiver. The message sent depends on the message protocol in use.

When a key is pressed, there is often a prompt or series of prompts which are used to obtain the required data. These prompts may differ in content or number based on the message protocol in use. Only those that are applicable to

the current message protocol are shown. In most cases, default values, units, or allowable ranges are supplied.

Each of the function keys, singly or in combination with the <Shift>, <Ctrl>, or <Alt> keys, that are used to control program operation are listed in Table 3-2 along with their respective functionality and, where applicable, the binary and/or NMEA message that is sent.

3.10 LABMON's Menu Keys

Many of the key functions from earlier versions of LABMON have been renamed or grouped together with related functions under a single menu or key. For example, the Cold Start Enable function is now under the Cold Start key of the Solution Control menu.

The LABMON software uses several keyboard keys and the keyboard's function keys, alone or together with the <Shift>, <Ctrl>, and <Alt> keys. The functions provided by these keys allow the

user to control, and communicate with, the GPS receiver. Each key and key combination is listed in Table 3-3 together with its respective function.

While all of the key functions shown in Table 3-3 are supported in the Rockwell binary mode, all of them are not supported in the NMEA data mode. An error message is displayed if a key is pressed that is not supported by the current data mode.

Table 3-1. Output Data Shown On The Main Display Screen (1 of 4)

ITEM LABEL	DESCRIPTION	UNITS	SOURCE			
			ZODIAC		NAVCORE	
			BINARY	NMEA	BINARY	NMEA
AGE	Age of last correction	sec	1005	GGA	n/a	GGA
ALT	Height above ellipsoid (Note 1)	m	1000	ALT, GGA	103	ALT, GGA
ATO	Acquisition timeout	sec	n/a	n/a	107	n/a
AZI	Visible satellite azimuth	deg	1003	GSV	102	GSV
CARRIERPHASE	Carrier phase	m	1102	n/a	n/a	n/a
CB	Clock bias	m	1000, 1001	n/a	n/a	n/a
CBS	Clock bias standard deviation	m	1000, 1001	n/a	n/a	n/a
CD	Clock drift	m/sec	1000, 1001	n/a	n/a	n/a
CDS	Clock drift standard deviation	m/sec	1000, 1001	n/a	n/a	n/a
CH	Channel	n/a	1002	ZCH	103, 106, 111	n/a
CLM	Climb rate	m/sec	1000	n/a	n/a	n/a
CN	Carrier to noise ratio	dBHz	1002	ZCH, GSV	103	GSV
CODE	Tracking state code	n/a	n/a	n/a	111	n/a
COG	Course over ground	deg	1000	RMC	n/a	RMC, VTG
COLDTO	Cold start timeout	sec	1012	n/a	n/a	n/a
COM	Auxiliary port settings	n/a	n/a	n/a	117	n/a
CSW1	Channel status word 1	n/a	1102	n/a	n/a	n/a
CSW2	Channel status word 2	n/a	1102	n/a	n/a	n/a
DATUM	Datum in use	n/a	1012	n/a	n/a	n/a
DAY	UTC day	n/a	1000, 1001	n/a	103	ZDA
DGPSTO	DGPS correction timeout	sec	1012	n/a	n/a	n/a
ECULRTI	DGPS status bits	n/a	1005	n/a	n/a	n/a
ECULRTSI	DGPS status bits	n/a	n/a	n/a	106	DGP
EHPE	Expected horizontal position error	m	1000, 1001	n/a	106	n/a
EHVE	Expected horizontal velocity error	m/sec	1000, 1001	n/a	n/a	n/a
EL	Visible satellite elevation	deg	1003	GSV	102	GSV
ENAB	Receiver enable option bits	n/a	1012	n/a	103, 106, 107, 111	DGP
ERPFLBC	Data validity/track state bits	n/a	n/a	n/a	111	n/a

Table 3-1. Output Data Shown On The Main Display Screen (2 of 4)

ITEM LABEL	DESCRIPTION	UNITS	SOURCE			
			ZODIAC		NAVCORE	
			BINARY	NMEA	BINARY	NMEA
ETE	Expected time error	m	1000, 1001	n/a	n/a	n/a
EVPE	Expected vertical position error	m	1000, 1001	n/a	106	n/a
FIX	Fix (2-D, 3-D, or altitude fix not available)	n/a	n/a	GSA	n/a	GSA
FOM	Figure of merit	n/a	n/a	n/a	103	n/a
GDOP	Geometric Dilution of Precision	n/a	1003	n/a	103	n/a
GPSSEC	GPS seconds into week	sec	1000, 1001	n/a	102, 103, 104	n/a
GSEP	Geoidal separation	m	1000	ALT, GGA	n/a	ALT, GGA
GPSNSEC	GPS nanoseconds from epoch	nsec	1000, 1001	n/a	n/a	n/a
HDOP	Horizontal Dilution of Precision	n/a	1003	GGA, GSA	103	GGA, GSA
HLTH	DGPS station health	n/a	1005	n/a	106	DGP
INVAL	Solution invalidity bits	n/a	1000, 1001	n/a	n/a	n/a
LAT	Latitude (Note 1)	deg	1000	GGA, RMC	103	GGA, GLL, RMC
LON	Longitude (Note 1)	deg	1000	GGA, RMC	103	GGA, GLL, RMC
LPTO	Low power acquisition timeout	sec	n/a	n/a	107	n/a
M	Measurement sequence number	n/a	1000, 1001, 1002	n/a	n/a	n/a
MAG	Magnetic variation	deg	1000	RMC	n/a	RMC
MASK	Antenna elevation mask angle	deg	1012	n/a	n/a	n/a
MEHPE	Minimum expected horizontal position error	m	1012	n/a	n/a	n/a
MESSAGE	Message sent or acknowledged	n/a	n/a	n/a	n/a	n/a
MEVPE	Minimum expected vertical position error	m	1012	n/a	n/a	n/a
NVIS	Number of visible satellites	n/a	1003	GSV	102	GSV
PDOP	Position Dilution of Precision	n/a	n/a	n/a	n/a	n/a
PLAT	Platform type	n/a	1012	n/a	n/a	n/a
PMGMT	Power management status	n/a	n/a	n/a	107	n/a
POLAR	Polar navigation flag	n/a	1000	n/a	n/a	n/a
PORT1	Host port settings	n/a	1130	n/a	n/a	n/a
PORT2	Auxiliary port settings	n/a	1130	n/a	n/a	n/a
POSX	ECEF position X	m	1001	n/a	103	n/a

Table 3-1. Output Data Shown On The Main Display Screen (3 of 4)

ITEM LABEL	DESCRIPTION	UNITS	SOURCE			
			ZODIAC		NAVCORE	
			BINARY	NMEA	BINARY	NMEA
POSY	ECEF position Y	m	1001	n/a	103	n/a
POSZ	ECEF position Z	m	1001	n/a	103	n/a
PSEUDO RANGE	Pseudorange	m	1102	n/a	111	n/a
QUAL	GPS quality indicator	n/a	n/a	GGA	n/a	GGA
RANGRATE	Pseudorange rate	m/sec	1102	n/a	111	n/a
RATE	Solution update rate	sec	n/a	n/a	107	n/a
SATS	Satellite used in solution	n/a	1000, 1001	GSV	103	GSV
SEQ	Sequence number	n/a	all	n/a	n/a	n/a
SETTIME	Receiver set time	ticks	all	n/a	102, 103, 104, 107, 111	n/a
SOG	Speed over ground	knots	n/a	RMC	n/a	RMC, VTG
SPD	Speed (Note 2)	m/sec	1000	n/a	n/a	n/a
STAT	Navigation status	n/a	1000, 1001	GSA, GGA, RMC	103	GSA, GGA, RMC
STATUS	DGPS status	n/a	1005	n/a	103, 106	n/a
STNID	DGPS station ID	n/a	1005	GGA	106	GGA, DGP
SV	Satellite vehicle PRN	n/a	1002, 1003, 1005	GSA, GSV, ZCH	102, 103, 111	GSA, GSV
TDOP	Time Dilution of Precision	n/a	1003	n/a	103	n/a
TRK	Channel tracking status	n/a	n/a	n/a	103	n/a
TYPE	Solution type bits	n/a	1000, 1001	GGA, GSA	n/a	GGA, GSA
UTC	UTC seconds (Note 3)	sec	1000, 1001, 1108	GGA, RMC	n/a	GGA, GLL, RMC, ZDA
DATE	Date	n/a	1000, 1001	n/a	103	ZDA
UVEC	Channel tracking status bits	n/a	1002	ZCH	n/a	n/a
VALID	Solution validity bits	n/a	1012	n/a	n/a	n/a
VDOP	Vertical Dilution of Precision	n/a	1003	GSA	103	GSA
VELE	Velocity - east	m/sec	n/a	n/a	103	n/a
VELN	Velocity - north	m/sec	n/a	n/a	103	n/a
VELU	Velocity - up	m/sec	n/a	n/a	103	n/a
VELX	ECEF velocity X	m/sec	1001	n/a	n/a	n/a
VELY	ECEF velocity Y	m/sec	1001	n/a	n/a	n/a

Table 3-1. Output Data Shown On The Main Display Screen (4 of 4)

ITEM LABEL	DESCRIPTION	UNITS	SOURCE			
			ZODIAC		NAVCORE	
			BINARY	NMEA	BINARY	NMEA
VELZ	ECEF velocity Z	m/sec	1001	n/a	n/a	n/a
WEEK	GPS week number	weeks	1000, 1001, 1002	n/a	102, 103, 104, 111	n/a
XSV	Excluded candidate SV	n/a	1012	n/a	n/a	n/a
ZCOUNT	DGPS modified zcount	counts	n/a	n/a	106	DGP

Note 1: When operating LABMON using delta positions, the LAT, LON, and ALT fields display the difference between the current and reference positions in meters.

Note 2: Speed units depends on the configuration data contained in the LABMON.CFG file (refer to paragraph 3.3.1.4 for additional information).

Note 3: UTC seconds uses data from binary message 1108 if available. Otherwise, data from binary messages 1000 and 1001 is used.

Table 3-2. Input Data Provided By Keyboard Keys (1 of 2)

ITEM LABEL	DESCRIPTION	SOURCE			
		ZODIAC		NAVCORE	
		BINARY	NMEA	BINARY	NMEA
Menu: GPS INPUT OPTIONS					
F1	Time initialization	1200	INIT	201	INIT
F2	Position and velocity initialization	1200	INIT	201	INIT
F3	Altitude input	1219	INIT	201	INIT
F4	Datum definition	1210	n/a	n/a	n/a
F5	Reserved	n/a	n/a	n/a	n/a
F6	Reserved	n/a	n/a	n/a	n/a
F7	Reserved	n/a	n/a	n/a	n/a
F8	Built-In Test	1300	IBIT	101	n/a
F9	Reserved	n/a	n/a	n/a	n/a
F10	Reserved	n/a	n/a	n/a	n/a
F11	Reset receiver	1303	INIT	201	INIT
F12	Reset counters	n/a	n/a	n/a	n/a
Menu: GPS I/O OPTIONS					
<Shift>F1	GPS I/O port settings	1330	n/a	217	ICOM
<Shift>F2	GPS message protocol type	1331	IPRO	n/a	n/a
<Shift>F3	Message log control (Note 1)	log	ILOG	213	LOG
<Shift>F4	Message query (Note 1)	query	Q	213	Q
<Shift>F5	NMEA generic message (Note 2)	n/a	n/a	n/a	n/a
<Shift>F6	NMEA typical message request (Note 3)	n/a	n/a	n/a	LOG
<Shift>F7	Reserved	n/a	n/a	n/a	n/a
<Shift>F8	Store almanac data	n/a	n/a	206	n/a
<Shift>F9	Request pseudoranges (Note 1)	n/a	n/a	213	n/a
<Shift>F10	Request ephemeris data	n/a	n/a	213	n/a
<Shift>F11	Request iono and UTC data	n/a	n/a	213	n/a
<Shift>F12	Load almanac data	n/a	n/a	213	n/a

Table 3-2. Input Data Provided By Keyboard Keys (2 of 2)

ITEM LABEL	DESCRIPTION	SOURCE			
		ZODIAC		NAVCORE	
		BINARY	NMEA	BINARY	NMEA
Menu: SOLUTION CONTROL					
<Ctrl>F1	Navigation validity criteria	1217	n/a	201	n/a
<Ctrl>F2	Platform type	1220	n/a	n/a	n/a
<Ctrl>F3	Navigation configuration	1221	n/a	n/a	n/a
<Ctrl>F4	Reserved	n/a	n/a	n/a	n/a
<Ctrl>F5	Cold start	1216	INIT	n/a	INIT
<Ctrl>F6	Datum select	1211	n/a	n/a	n/a
<Ctrl>F7	Reserved	n/a	n/a	n/a	n/a
<Ctrl>F8	Antenna elevation mask	1212	n/a	208	n/a
<Ctrl>F9	SV selection	1213	n/a	208	n/a
<Ctrl>F10	DGPS control	1214	n/a	209	IDGP
<Ctrl>F11	Power management	n/a	n/a	211	n/a
Menu: LABMON CONFIGURATION OPTIONS					
<Alt>F1	LABMON I/O port settings	n/a	n/a	n/a	n/a
<Alt>F2	LABMON message protocol type	n/a	n/a	n/a	n/a
<Alt>F3	Reference position	n/a	n/a	n/a	n/a
<Alt>F4	Main display background color	n/a	n/a	n/a	n/a
<Alt>F5	Main display text color	n/a	n/a	n/a	n/a
<Alt>F6	Main display data color	n/a	n/a	n/a	n/a
<Alt>F7	Menu background color	n/a	n/a	n/a	n/a
<Alt>F8	Menu key color	n/a	n/a	n/a	n/a
<Alt>F9	Menu description color	n/a	n/a	n/a	n/a
<p>Note 1: The Zodiac binary "log" and "query" messages inherit the numeric identifier of the message being requested.</p> <p>Note 2: The <Shift>F5 keys are used to transmit a NMEA message entered by the user.</p> <p>Note 3: The <Shift>F6 keys are used to send a series of log messages requesting a pre-defined set of output messages that can be used for receiver evaluation.</p>					

Table 3-3. LABMON Keyboard Key Functions (1 of 4)

Keyboard Key	Function	Action
KEYBOARD KEYS		
M	Menu change	Press the "M" key to cycle through the Function, <Shift>+Function, <Ctrl>+Function, and <Alt>+Function key menus.
N	No menu	Press the "N" key to toggle the display of the menu option portion of the main display screen on or off. This allows data to be viewed that is normally hidden behind the menu options.
R	Replay	Press the "R" key to replay a log file.
P	Pause	Press the "P" key to pause the receiver output data displayed on the screen. Press the "P" key again to resume data updates. The screen may also be paused by pressing the spacebar.
F	Filter	Press the "F" key to set the parameters used to "filter," or screen, data (refer to Section 3.3).
D	Delta (Note 1)	Press the "D" key to toggle LABMON between the current location (in degrees) and the delta position (in meters).
X	Extract data	Press the "X" key after starting to replay a log file (using the "R" key) to extract data from the file to a selected tab delimited file for plotting purposes.
+,-	Speed of replay	Press the "+" or "-" keys to increase or decrease the rate at which messages are processed during the replay of log files.
< >	Single step in replay	Press the "<" or ">" keys to step a single message backward or forward during replay of log files.
Q	Quit	Press the Q key to exit LABMON.
C	Clear screen	Press the "C" key to clear the LABMON screen outputs until they are refreshed at their normal time.
<Esc>	Exit prompt without changes	Press the <Esc> key to exit a prompt without sending the command.
FUNCTION KEYS		
F1	Time initialization	Press the F1 key to send the estimated user time and date. The time must be entered in 24-hour format and referenced to UTC or Greenwich Mean Time (GMT) rather than local time. The time input should be accurate to within an hour to acquire the first satellite when Cold Start is disabled. If Cold Start is enabled, the time and position do not need to be initialized.
F2	Position and velocity initialization	Press the F2 key to send latitude, longitude, speed, heading, and height to be used as the estimated user state. The latitude and longitude data must be referenced to the datum selected and entered in decimal degrees rather than degrees:minutes:seconds. South latitude and west longitude must be entered as negative numbers. The height is the altitude in meters above the datum ellipsoid. The WGS-84 datum is assumed if no datum is selected.
F3	Altitude input	Press the F3 key to send a value to be used as the estimated user altitude. Unless the force option is used, this value is only used while in 2-D navigation or acquisition modes.
F4	Datum definition	Press the F4 key to send datum definition parameters to be used.
F5	Reserved	None
F6	Reserved	None

Table 3-3. LABMON Keyboard Key Functions (2 of 4)

Keyboard Key	Function	Action
FUNCTION KEYS (continued)		
F7	Reserved	None
F8	Built-In Test	Press the F8 key to send a Built-In Test (BIT) command. Navigation and tracking of satellites is interrupted during this test. When the BIT ends, the receiver is reset.
F9	Reserved	None
F10	Reserved	None
F11	Reset receiver	Press the F11 key to send a reset command. This will reset certain receiver parameters. The message counters are reset at this time also.
F12	Reset counters	Press the F12 key to reset the message and error counters.
SHIFT + FUNCTION KEYS		
Shift + F1	GPS I/O port settings	Press the <Shift>F1 keys to send the receiver serial port settings for the baud rate, parity, number of data bits, and number of stop bits to be used by the receiver.
Shift + F2	GPS message protocol type	Press the <Shift>F2 keys to select the message protocol type used by the receiver.
Shift + F3	Message log control	Press the <Shift>F3 keys to send a log control message to request messages on a periodic basis or upon update. When using Zodiac binary protocol, the message timing may need to be modified to obtain message output. <i>NOTE: The special values of "???" when using NMEA protocol, or "65535" when using Zodiac binary protocol, disables all messages. After this, no messages are output by the receiver unless a query message is sent, the receiver is reset, or messages are turned back on using the log control message. In binary mode, press the <Shift>F3 keys followed by "65535." Respond to the modify timing prompt with a "Y" (for yes).</i>
Shift + F4	Message query	Press the <Shift>F4 keys to send a query message to request a one-time output of a message from the Zodiac receiver.
Shift + F5	NMEA generic message	Press the <Shift>F5 keys to enter the ASCII text for a non-supported generic NMEA message to send to the receiver. The entire message should be entered following the \$ prompt; use null fields as required. The checksum will be computed and appended by LABMON before the message is transmitted.
Shift + F6	NMEA typical message request	Press the <Shift>F6 keys to send a series of NMEA log messages to enable the receiver to output a set of messages containing the typical data needed for performance evaluation.
Shift + F7	Reserved	None
Shift + F8	Store almanac data	Press the <Shift>F8 keys to request raw almanac data. LABMON receives the data and stores it in the file ALMANAC.GPS.
Shift + F9	Request pseudoranges	Press the <Shift>F9 keys to request the output of pseudoranges.
Shift + F10	Request ephemeris data	Press the <Shift>F10 keys to request output of all available ephemeris data or new ephemeris data when available.

Table 3-3. LABMON Keyboard Key Functions (3 of 4)

Keyboard Key	Function	Action
SHIFT + FUNCTION KEYS (continued)		
Shift + F11	Request iono and UTC data	Press the <Shift>F11 keys to request output of current ionospheric and UTC time data or new ionospheric and UTC time data when available.
Shift + F12	Load almanac data	Press the <Shift>F12 keys to upload raw almanac data from a selected binary almanac file to the receiver.
CONTROL + FUNCTION KEYS		
Ctrl + F1	Navigation validity criteria	Press the <Ctrl>F1 keys to send navigation solution validity parameters (2-D navigation allowed, DGPS required, number of satellites used, and expected position errors).
Ctrl + F2	Platform type	Press the <Ctrl>F2 keys to select the type of application platform to be used.
Ctrl + F3	Navigation confirmation	Press the <Ctrl>F3 keys to send navigation configuration parameters (held altitude, ground track smoothing, position pinning, measurement filtering)
Ctrl + F4	Reserved	None
Ctrl + F5	Cold start	Press the <Ctrl>F5 keys to send a Cold Start command. When Cold Start is enabled, the receiver will only enter Cold Start after failing to acquire satellites that should be visible based on the current receiver position and time. The receiver automatically searches the entire sky for satellites in Cold Start.
Ctrl + F6	Datum select	Press the <Ctrl>F6 keys to send a datum number to the Zodiac receiver or to set the datum used by LABMON to transform NavCore receiver outputs. Out of range numbers default to zero which corresponds to WGS-84. Refer to Appendix E for datum names and numbers.
Ctrl + F7	Reserved	n/a
Ctrl + F8	Antenna elevation mask	Press the <Ctrl>F8 keys to send the elevation mask angle to be used. Angles below the horizon must be entered as negative numbers. The default value for the Zodiac receiver is +10 degrees.
Ctrl + F9	SV selection	Press the <Ctrl>F9 keys to send satellite selection commands to enable or disable the use of selected satellites by the receiver. Enter a satellite's SV number to toggle between enabled and disabled. Enter zero to enable all satellites. Disabled satellites are displayed after XSV beneath the satellite visibility list on the main display.
Ctrl + F10	DGPS control	Press the <Ctrl>F10 keys to send a Differential GPS Control command.
Ctrl + F11	Power management	Press the <Ctrl>F11 keys to send power management parameters to be used for power conservation. Valid NavCore update rates must be from one to five seconds

Table 3-3. LABMON Keyboard Key Functions (4 of 4)

Keyboard Key	Function	Action
ALT + FUNCTION KEYS		
Alt + F1	LABMON I/O port settings	Press the <Alt>F1 keys to change the parameters associated with the PC serial ports. These include the PC COM port number, the PC IRQ interrupt number, baud rate, parity, number of data bits, and number of stop bits (refer to Section 3.3 for additional information about these settings). After these values have all been entered, LABMON displays the selected COM port, the PC interrupt number, and the port address at the bottom of the screen.
Alt + F2	LABMON message protocol type	Press the <Alt>F2 keys to set the LABMON message processing protocol to Zodiac binary, Zodiac NMEA, NavCore binary, or NavCore NMEA.
Alt + F3	Reference position	Press the <Alt>F3 keys to set the reference position as a default for the position initialization function (using the F2 key) and as a reference for computing delta position.
Alt + F4	Main display background color	Press the <Alt>F4 keys to change the background color of the data portion of the main display screen.
Alt + F5	Main display text color	Press the <Alt>F5 keys to change the color of the field titles in the data portion of the main display screen.
Alt + F6	Main display data color	Press the <Alt>F6 keys to change the color of the data shown in the data portion of the main display screen.
Alt + F7	Menu background color	Press the <Alt>F7 keys to change the background color of the menu options portion of the main display screen.
Alt + F8	Menu key color	Press the <Alt>F8 keys to change the color of the function key designations in the menu options portion of the main display screen.
Alt + F9	Menu description color	Press the <Alt>F9 keys to change the color of the function key descriptions in the menu options portion of the main display screen.
<p>Note 1: LABMON's delta position is useful to monitor changes in position relative to the reference position. The "D" key is used to toggle between the current location, in degrees, and the distance, in meters, from the reference position (set using the <Alt>F3 keys).</p>		

3.11 Receiver Evaluation Using LABMON

There are a number of powerful features in LABMON that are useful to evaluate receiver performance. The features are described below along with other useful information related to receiver configuration and operation.

3.11.1 Message Set. The Zodiac Family and NavCore Series receivers have a very extensive message set that can provide a great deal of information from the receiver. When operating the receiver for evaluation purposes, it is likely that the user will require a different message set than the default set. The default set is chosen to provide typically needed data for use in the OEM product, without extra data needed for detailed evaluation or analysis.

Requesting too much data from the receiver on a periodic basis may result in processing problems by an OEM processor or the receiver. If too many output messages are created, a data checksum error may occur on a receiver output message during receipt of a new input message. This is an indication that a large number of periodic messages are being output.

3.11.2 Baud Rates. The user must ensure that the baud rates chosen will support the number and size of the messages requested. It is possible to request enough messages to prevent the receiver from keeping up at rates lower than 9600, for example. In this case, some of the messages cannot be output until the number is decreased or the baud rate is increased.

3.11.3. Message Logging. The user should turn off unneeded messages that occur at a high periodic rate if others are to be turned on. The default Zodiac message output timing prompt in LABMON is Time, but the Update option for data output should be used where appropriate. The NavCore Series supports message output based on time only.

To obtain a one time output of a message, use a query message. This avoids loading down the receiver with periodic output of fixed data. To obtain message output only when the data has changed or new data is available, use a log message with the Update output option. This will

result in a message output upon change of the data only. To obtain periodic output use a log message with the Time output option. To turn off all messages in NMEA mode, use a log message with '???' as the message identifier. To turn off all messages in Zodiac binary mode, use a log message with '65535', which corresponds to FFFF Hex, as the message identifier; then, respond to the modify timing prompt by entering "Y" (for yes).

For Zodiac receiver evaluation, the following changes to the default message configuration are recommended:

- Turn on message 1012 for output on update.
- Turn on message 1102 for output at a rate of once per second.
- Message 1005 should also be turned on for output at a rate of once per second for DGPS evaluation. For NavCore receiver evaluation, the 106 message should be turned on for output at a rate of once per second for DGPS evaluation.

Use the message counters to monitor the number and rate at which messages are output from the receiver and to keep track of which input messages have been sent. It is often useful to reset these after changing the output messages to verify the desired configuration has been achieved. If the list of messages sent or received grows long enough to begin blocking other data, the message counters should also be reset.

3.11.4 Screen Clearing. Clearing the screen after the output message configuration has changed is recommended to clear data which will become stale if it is no longer being updated. This also makes it easy to see if data that is no longer requested has been turned off.

3.11.5 Data Logging. To review data carefully, the data should be logged and then replayed using LABMON. During replay, the user can single step through messages forward and backward to examine events or time periods of interest.

3.11.6 Data Reduction. The Extract function can be used to extract data from a log file, decode it if necessary, and write it into a tab-delimited file for plotting or data reduction using spreadsheet programs.

The Filter parameters are used to control which data points are written to the file. Using different settings for these and plotting the resultant ground tracks may help the user determine what criteria should be used in the OEM application to obtain the best performance in their operating environment. The Filter parameters are also used during normal receiver monitoring to indicate at a glance whether the navigation solution is meeting the current Filter criteria.

3.11.7. Post Processing Of Logged Data.

LABMON has the capability to post-process previously logged data and to extract certain information that has been written to a text file.

3.11.7.1 Specifics Of Data Extraction Types.

There are five types of data extraction based on the specific type of data. When the "X" key is pressed after starting to replay a log file (using the "R" key), a prompt is displayed requesting the operator to enter one of the following extraction types: LLA, PV, COV, RNG, and SVD.

- a. **LLA.** This type extracts the longitude, latitude, and altitude into a tab-delimited text file. This text file may be directly imported into a spreadsheet and plotted, producing a "bread crumb" ground track. Once selected, the LLA extraction offers the option of removing the sign of the extracted data, thereby recording only the absolute values of the data. The delta locations, in meters, from the reference position are also recorded.

Format: GPSTIMESECS LON LAT ALT
 Δ LON Δ LAT Δ ALT

Message 1000 must be enabled while logging this data.

- b. **PV.** This type extracts the ECEF positions X, Y, and Z and the ECEF velocities X, Y, and Z into a tab-delimited text file. This text file may be directly imported into a spreadsheet and plotted, producing a track of ECEF

positions or the spreadsheet can be analyzed for velocity verifications.

Format: GPSTIME SEC POSX POSY POSZ
 VELX VELY VELZ

Message 1001 must be enabled while logging this data.

- c. **COV.** This type extracts covariance data into a tab-delimited text file.

Format: GPSTIMESEC EHPE EVPE EHVE
 ETE CB ... CBSig CD CDSig

Message 1001 must be enabled while logging this data.

- d. **RNG.** This type extracts channel status, code phase, carrier phase, and carrier rate data into a tab-delimited text file.

Format: GPS Measurement Time
 Channel Status Code Phase
 ... Carrier Phase Carrier
 Rate ...

Message 1102 must be enabled while logging this data.

Note: The Channel Status, Code Phase, Carrier Phase, and the Carrier Rate are repeated for each channel.

- e. **SVD.** This type extracts satellite vehicle data (i.e., ephemeris, almanac, and UTC data) into a text file that lists each parameter, its value, and units of measure for each satellite found in the recorded data. The operator has the option to extract either ephemeris, almanac, or UTC data - or all three - into a tab-delimited text file.

A fast extract feature is included to prevent any message other than an 1102 to be processed while extracting SVD data.

Message 1102 must be enabled while logging this data.

3.11.7.2 Logging A Data File. To log a data file, type "LABMON <filename.ext>," where

<filename.ext> is any legal DOS filename and extension (see paragraph 3.5). This action causes all data on the Host port to be written to the specified file. The full path and drive designation must also be included if logging to a specific location is desired.

When logging data to a file, be sure that the message which contains the data to be post-processed has been enabled and is being output by the receiver. For example, to log ephemeris data, Message 1102 must be enabled.

3.11.7.3 Extracting Data From A Log File. To extract data from a previously recorded log file, do the following:

- a. Start LABMON as described in Section 3.5 for no data recording.
- b. Press the "R" key for replay.
- c. Enter Log <filename.ext>. This must be the exact filename and extension including any drive and path designations.
- d. Press the "X" key for extract.
- e. Select the desired type of data to extract (either LLA, PV, COV, RNG, or SVD -- see paragraph 3.11.7.1).

- f. Enter a <filename.ext> that will contain the extracted data.
- g. Press <spacebar> to start playback and extraction.
- h. When finished, quit LABMON and edit the extraction file using any text editor.

3.11.8 DGPS Operation. Whenever DGPS operation is being evaluated, it is recommended to use the LABMON logging function. RTCM SC-104 data should also be gathered so that its format and integrity may be verified with the RTCMCHK utility program provided on the LABMON software disk.

Some DGPS reference station equipment may be configured in such a way as to output data which is non-compliant with the RTCM standard. Rockwell GPS receivers are designed to be tolerant of these format errors where possible, but in some circumstances, intermittent loss of DGPS operation may result. There may also be excessive latency or problems in the data links which can be observed and corrected by examination of this raw input data to the receiver.

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4 HARDWARE INTERFACE

Details of the specific Zodiac GPS receiver's electrical interface are contained in the applicable Data Sheet for the receiver. A copy of this document is provided with this *Designer's Guide*. Besides the pinout descriptions for the interface, the Data Sheet also contains a product overview, a technical description and specification, and a brief description of the Rockwell binary and NMEA data messages applicable to the specific GPS receiver.

Information about the 2x10 pin field connector is contained in Appendix F. RF connector information is provided in Appendix G.

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5 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 Zodiac Global Positioning System (GPS) receiver engine. The structure and contents of each binary message is described in Section 5.2. The structure and contents of each National Marine Electronics Association (NMEA) message is described in Section 5.3.

5.1 Binary Message Format And Word Structure

5.1.1 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 nearly 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 made using headers as well. Table 5-1 shows the data types used to define the elements of the binary interface messages.

5.1.2 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

Table 5-1. Binary Message Data Types

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	-2147483648 to +2147483647
Triple Integer	TI	3	48	-140737488355328 to +140737488355327
Unsigned Integer	UI	1	16	0 to 65535
Unsigned Double Integer	UDI	2	32	0 to 4294967295
Unsigned Triple Integer	UTI	3	48	0 to 281474976710656
<p>Note 1: The term "word" is used throughout this document to specify a quantity which occupies 16 bits of storage.</p> <p>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).</p> <p>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 Zodiac receiver software will pack/unpack the character data internally as needed.</p>				

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

Figure 5-1. Binary Message Header Format

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.

5.2 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 5-1.

5.2.1 Message Header Word 1. Each input/output message starts with a synchronization word of the form 0xFF81_{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 synchronization word.

5.2.2 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}.

5.2.3 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.

5.2.4 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 zeroes represented in the word 4 field shown in Figure 5-1 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 behavior. 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

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

Figure 5-2. Standard Log Request Message Format (Data Portion)

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. 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.

5.2.5 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 2^{16}) all words (including the word containing DEL and SOH)

contained in the header and then performing a two's complement on the sum.

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

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

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 2^{16} 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.

5.2.6 Log Request Messages. Figure 5-2 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	0 to 60 seconds (an offset of zero specifies an initial output relative to the current time. An offset of 60 specifies an initial output relative to the next

even minute [zero 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).

5.3 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 5-2).

When the Word Count field is zero, the Data Checksum does not exist. It is computed by summing (modulo 2^{16}) all words in the data portion of the message and then complementing that sum. The mathematical expression for the Data Checksum is:

$$SUM = Mod\ 2^{16} \sum_{i=6}^{5+N} Word(i)$$

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 2^{16} 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.

Data elements identified as “Reserved” must be set to zero for input messages and are undefined for output messages. All data storage which is not explicitly defined should be handled as if it were 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.

5.4 NMEA Messages, Format, And Sentence Structure

NMEA messages are output in response to standard Q (Query) or proprietary ILOG (Log Control) messages as described in Section 5.6. The timing of output messages is synchronized with the Time Mark output event.

5.4.1 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 Zodiac receiver also supports the following Rockwell proprietary output messages:

- BIT: Rockwell Proprietary Built-In Test Results
- RID: Rockwell Proprietary Receiver ID
- ZCH: Rockwell Proprietary Zodiac Channel Status

These proprietary messages conform to the message format described below.

5.4.2 NMEA Input Messages. The Zodiac receiver supports the following proprietary input messages:

- IBIT: Rockwell Proprietary Built-In Test Command
- ILOG: Rockwell Proprietary Log Control
- INIT: Rockwell Proprietary Receiver Initialization
- IPRO: Rockwell Proprietary Protocol

The INIT message is used to command initialization 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 Rockwell International (RWI) according to Appendix III of the NMEA-0183 standard.

5.4.3 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 5-2.

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 5-3.

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.

5.4.4 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.
.	.
.	.
.	.
[";"<data field>]	
["*"<checksum field>]	Optional checksum field.
<CR><LF>	End of sentence delimiter (0D 0A _{HEX}).

NOTE: Since the Zodiac receiver is a GPS device, the "talker" identifier is always "GP."

Table 5-2. NMEA Reserved Characters

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 5-3. NMEA Field Type Summary

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	III.L	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. 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	yyyy.yy	Fixed/variable length field: Degrees/minutes.decimal -- three fixed digits of degrees, two fixed digits of minutes and a <u>variable</u> number of digits for decimal-fraction of minutes. 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 <u>variable</u> number of digits for decimal-fraction of seconds. 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," "III.L," "x," and "yyyy.yy."
Numeric Value Fields		
Variable numbers	x.x	Variable length integer or floating point numeric field: Optional leading and trailing zeros. The decimal point and associated decimal-fraction are optional if full resolution is not required (e.g., 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	c- - 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.
NOTES:		
1. Spaces may only be used in variable text fields.		
2. A negative sign ("- " or 2D _{HEX}) is the first character in a field if the value is negative. The sign is omitted if the value is positive.		
3. All data fields are delimited by a comma (" , ").		
4. Null fields are indicated by no data between two delimiters.		

5.4.5 Proprietary Sentences. Proprietary sentences allow OEMs to transfer data that does not fall within the scope of approved NMEA sentences.

[“*”<checksum field>] Optional checksum field.
 <CR><LF> End of sentence delimiter (0D 0A_{HEX}).

A proprietary sentence contains the following elements, in the order shown:

- “ \$ ” Start of the sentence (24_{HEX})
- “ P ” Proprietary sentence ID (50_{HEX}).
- <aaa> OEM’s mnemonic code. [*<valid characters, OEM’s data>*]

5.4.6 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.

5.5 Zodiac Binary Data Messages

This section describes the binary data messages of the Zodiac GPS receiver. All of the output and input binary messages are listed in Table 5-4 together with their corresponding message IDs. Power-up default messages are also identified.

Binary mode is selected according to the logic described in the “Jupiter” Data Sheet that accompanies this Designer’s Guide. Binary messages are transmitted and received across the host port serial I/O interface (RS-232) with the

Table 5-4. Zodiac Binary Data Messages

Output Message Name	Message ID	Input Message Name	Message ID
Geodetic Position Status Output (*)	1000	Geodetic Position and Velocity Initialization	1200
ECEF Position Status Output	1001	User-Defined Datum Definition	1210
Channel Summary (*)	1002	Map Datum Select	1211
Visible Satellites (*)	1003	Satellite Elevation Mask Control	1212
Differential GPS Status	1005	Satellite Candidate Select	1213
Channel Measurement	1007	Differential GPS Control	1214
Receiver ID (**)	1011	Cold Start Control	1216
User-Settings Output	1012	Solution Validity Criteria	1217
Built-In Test Results	1100	User-Entered Altitude Input	1219
Measurement Time Mark	1102	Application Platform Control	1220
UTC Time Mark Pulse Output (*)	1108	Nav Configuration	1221
Serial Port Communication Parameters In Use	1130	Perform Built-In Test Command	1300
EEPROM Update	1135	Restart Command	1303
EEPROM Status	1136	Serial Port Communications Parameters	1330
		Message Protocol Control	1331
		Raw DGPS RTCM SC-104 Data	1351
(*) Enable by default at power-up			
(**) Once at power-up/reset			

following default communications parameters:

- 9600 bps • no parity
- 8 data bits • 1 stop bit

5.5.1 Binary Output Message Descriptions.

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

5.5.1.1 Geodetic Position Status Output

(Message 1000). This message outputs the receiver's estimate of position, ground speed, course over ground, climb rate, and map datum. A solution status indicates whether or not the solution is valid (based on the solution validity

criteria) and also the type of solution. The number of measurements used to compute the solution is also included.

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.

The contents of the Geodetic Position Status Output Message are described in Table 5-5.

Table 5-5. Message 1000: Geodetic Position Status Output Message (1 of 3)

Message ID: 1000					
Rate: Variable; defaults to 1 Hz					
Message Length: 55 words					
Word No.:	Name:	Type:	Units:	Range:	Resolution:
1-4	Message Header				
5	Header Checksum				
6-7	Set Time (Note 1)	UDI	10 msec ticks	0 to 4294967295	
8	Sequence Number (Note 2)	I		0 to 32767	
9	Satellite Measurement Sequence Number (Note 3)	I		0 to 32767	
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 Maximum EHPE (Note 4)	Bit		1 = true	
10.4	Solution Invalid - Exceeded Maximum EVPE (Note 4)	Bit		1 = true	
10.5-10.15	Reserved				
Navigation Solution Type (11.0-11.15)					
11.0	Solution Type - Propagated Solution (Note 5)	Bit		1 = propagated	
11.1	Solution Type - Altitude Used	Bit		1 = altitude used	
11.2	Solution Type -Differential	Bit		1 = differential	
11.3-11.15	Reserved				

Table 5-5. Message 1000: Geodetic Position Status Output Message (2 of 3)

Word No.:	Name:	Type:	Units:	Range:	Resolution:
12	Number of Measurements Used in Solution	UI		0 to 12	
13	Polar Navigation	Bit		1 = true	
14	GPS Week Number	UI	weeks	0 to 32767	
15-16	GPS SecondsFrom Epoch	UDI	seconds	0 to 604799	
17-18	GPS Nanoseconds From Epoch	UDI	nanosec	0 to 999999999	
19	UTC Day	UI	days	1 to 31	
20	UTC Month	UI	months	1 to 12	
21	UTC Year	UI	year	1980 to 2079	
22	UTC Hours	UI	hours	0 to 23	
23	UTC Minutes	UI	minutes	0 to 59	
24	UTC Seconds	UI	seconds	0 to 59	
25-26	UTC Nanoseconds From Epoch	UDI	nanosec	0 to 999999999	
27-28	Latitude	DI	radians	± 0 to $\pi/2$	10^{-8}
29-30	Longitude	DI	radians	± 0 to π	10^{-8}
31-32	Height	DI	meters	± 0 to 40000	10^{-2}
33	Geoidal Separation	I	meters	± 0 to 200	10^{-2}
34-35	Ground Speed	UDI	meters/sec	0 to 1000	10^{-2}
36	True Course	UI	radians	0 to 2π	10^{-3}
37	Magnetic Variation	I	radians	± 0 to $\pi/4$	10^{-4}
38	Climb Rate	I	meters/sec	± 300	10^{-2}
39	Map Datum (Note 6)	UI		0 to 188 and 300 to 304	

Table 5-5. Message 1000: Geodetic Position Status Output Message (3 of 3)

Word No.:	Name:	Type:	Units:	Range:	Resolution:
40-41	Expected Horizontal Position Error (Note 7)	UDI	meters	0 to 320000000	10 ⁻²
42-43	Expected Vertical Position Error (Note 7)	UDI	meters	0 to 250000	10 ⁻²
44-45	Expected Time Error (Note 7)	UDI	meters	0 to 300000000	10 ⁻²
46	Expected Horizontal Velocity Error (Note 7)	UI	meters/sec	0 to 10000	10 ⁻²
47-48	Clock Bias (Note 7)	DI	meters	±0 to 9000000	10 ⁻²
49-50	Clock Bias Standard Deviation (Note 7)	DI	meters	±0 to 9000000	10 ⁻²
51-52	Clock Drift (Note 7)	DI	m/sec	±0 to 1000	10 ⁻²
53-54	Clock Drift Standard Deviation (Note 7)	DI	m/sec	±0 to 1000	10 ⁻²
55	Data Checksum				

Note 1:
Set time is an internal 10 millisecond (T10) count since power-on initialization 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:
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 6:
The table in Appendix E contains map datum codes from 0 to 188. Codes 300 to 304 are user-defined.

Note 7:
The data displayed by this field is not valid until the receiver is in navigation mode.

5.5.1.2 ECEF Position Status Output (Message 1001). This message outputs the receiver's estimate of ECEF position and velocity, and map datum. A solution status indicates whether or not the solution is valid (based on the solution validity criteria) and also the type of solution.

The number of measurements used to compute the solution is also included.

The contents of the ECEF Position Status Output Message are described in Table 5-6.

Table 5-6. Message 1001: ECEF Position Status Output Message (1 of 2)

Message ID:		1001			
Rate:		Variable			
Message Length:		54 words			
Word No.:	Name:	Type:	Units:	Range:	Resolution:
1-4	Message Header				
5	Header Checksum				
6-7	Set Time (Note 1)	UDI	10 msec ticks	0 to 4294967295	
8	Sequence Number (Note 2)	I		0 to 32767	
9	Satellite Measurement Sequence Number (Note 3)	I		0 to 32767	
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 Maximum EHPE (Note 4)	Bit		1 = true	
10.4	Solution Invalid - Exceeded Maximum EVPE (Note 4)	Bit		1 = true	
10.5-10.15	Reserved				
Navigation Solution Type (11.0-11.15)					
11.0	Solution Type - Propagated Solution (Note 5)	Bit		1 = propagated	
11.1	Solution Type - Altitude Used	Bit		1 = alt used	
11.2	Solution Type - Differential	Bit		1 = differential	
11.3-11.15	Reserved				
12	Number of Measurements Used in Solution	UI		0 to 12	
13	GPS Week Number	UI	weeks	0 to 32767	
14-15	GPS Seconds Into Week	UDI	seconds	0 to 604799	
16-17	GPS Nanoseconds From Epoch	UDI	nanosec	0 to 999999999	
18	UTC Day	UI	days	1 to 31	
19	UTC Month	UI	months	1 to 12	
20	UTC Year	UI	year	1980 to 2079	
21	UTC Hours	UI	hours	0 to 23	
22	UTC Minutes	UI	minutes	0 to 59	

Table 5-6. Message 1001: ECEF Position Status Output Message (2 of 2)

Word No.:	Name:	Type:	Units:	Range:	Resolution:
23	UTC Seconds	UI	seconds	0 to 59	
24-25	UTC Nanoseconds From Epoch	UDI	nanosec	0 to 999999999	
26-27	ECEF Position - X (Note 7)	DI	meters	±0 to 9000000	10 ⁻²
28-29	ECEF Position - Y (Note 7)	DI	meters	±0 to 9000000	10 ⁻²
30-31	ECEF Position - Z (Note 7)	DI	meters	±0 to 9000000	10 ⁻²
32-33	ECEF Velocity - X (Note 7)	DI	meters/sec	±0 to 1000	10 ⁻²
34-35	ECEF Velocity - Y (Note 7)	DI	meters/sec	±0 to 1000	10 ⁻²
36-37	ECEF Velocity - Z (Note 7)	DI	meters/sec	±0 to 1000	10 ⁻²
38	Map Datum (Note 6)	UI		0 to 188 and 300 to 304	
39-40	Expected Horizontal Position Error (Note 7)	UDI	meters	0 to 1000	10 ⁻²
41-42	Expected Vertical Position Error (Note 7)	UDI	meters	0 to 1000	10 ⁻²
43-44	Expected Time Error (Note 7)	UDI	meters	0 to 1000	10 ⁻²
45	Expected Horizontal Velocity Error (Note 7)	UI	meters/sec	0 to 300	10 ⁻²
46-47	Clock Bias (Note 7)	DI	meters	±0 to 9000000	10 ⁻²
48-49	Clock Bias Standard Deviation (Note 7)	DI	meters	±0 to 9000000	10 ⁻²
50-51	Clock Drift (Note 7)	DI	m/sec	±0 to 1000	10 ⁻²
52-53	Clock Drift Standard Deviation (Note 7)	DI	m/sec	±0 to 1000	10 ⁻²
54	Data Checksum				

Note 1:

Set time is an internal 10 millisecond (T10) count since power-on initialization 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:

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 6:

The table in Appendix E contains map datum codes from 0 to 188. Codes 300 to 304 are user-defined.

Note 7:

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

5.5.1.3 Channel Summary (Message 1002).

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 5-7.

Table 5-7. Message 1002: Channel Summary Message

Message ID: 1002					
Rate: Variable; defaults to 1 Hz					
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 msec ticks	0 to 4294967295	
8	Sequence Number (Note 2)	I		0 to 32767	
9	Satellite Measurement Sequence Number (Note 3)	I		0 to 32767	
10	GPS Week Number	UI	weeks	0 to 32767	
11-12	GPS Seconds Into Week	UDI	sec	0 to 604799	
13-14	GPS Nanoseconds From Epoch	UDI	nanosec	0 to 999999999	
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	
15.4-15.5	Reserved				
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 initialization 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>					

5.5.1.4 Visible Satellites (Message 1003). This message outputs the list of satellites visible to the receiver and the corresponding elevations and azimuths for each satellite. The best possible

DOPs, calculated from this visible list, are also provided. The contents of the Visible Satellites Message are described in Table 5-8.

Table 5-8. Message 1003: Visible Satellites Message

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 msec ticks	0 to 4294967295	
8	Sequence Number (Note 2)	I		0 to 32767	
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	radians	$\pm\pi$	10^{-4}
17 + (3*j)	Satellite Elevation	I	radians	$\pm\pi/2$	10^{-4}
51	Data Checksum				
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialization 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 (0 to 11).</p>					

5.5.1.5 Differential GPS Status (Message 1005). This message contains DGPS status information derived from the last set of differential corrections processed by the receiver.

The contents of the Differential GPS Status Message are described in Table 5-9.

Table 5-9. Message 1005: Differential GPS Status Message (1 of 2)

Message ID: 1005					
Rate: Variable					
Message Length: 25 words					
Word No.:	Name:	Type:	Units:	Range:	Resolution:
1-4	Message Header				
5	Header Checksum				
6-7	Set Time (Note 1)	UDI	10 msec ticks	0 to 4294967295	
8	Sequence Number (Note 2)	I		0 to 32767	
Status (9.0-9.15)					
9.0	Station Health	Bit		1 = station bad	
9.1	Use of DGPS Corrections	Bit		1 = user disabled	
9.2-9.15	Reserved				
10	Station ID	UI		0 to 1023	
11	Age of Last Correction	UI	seconds	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	

Table 5-9. Message 1005: Differential GPS Status Message (2 of 2)

Word No.:	Name:	Type:	Units:	Range:	Resolution:
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 initialization 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>					

5.5.1.6 Channel Measurement (Message 1007). 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 5-10.

Table 5-10. Message 1007: Channel Measurement Message

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 msec ticks	0 to 4294967295	
8	Sequence Number (Note 2)	I		0 to 32767	
9	Satellite Measurement Sequence Number (Note 3)	I		0 to 32767	
CHANNEL MEASUREMENT DATA					
10 + 12*j	Pseudorange (Note 4)	TI	meters	$\pm 1.4^{14}$	10^{-3}
13 + 12*j	Pseudorange Rate	DI	meters/sec	± 21474836	10^{-3}
15 + 12*j	Carrier Phase	TI	meters	$\pm 1.4^{14}$	10^{-3}
18 + 12*j	Carrier Phase Bias	TI	meters	$\pm 1.4^{14}$	10^{-3}
21 + 12*j	Phase Bias Count	UI		0 to 65535	
154	Data Checksum				
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialization 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>					

5.5.1.7 Receiver ID (Message 1011). This message is output automatically at startup after the receiver has completed its initialization. It can be used to determine when the receiver is ready to accept serial input. Manual requests for this

message are also honored. 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 5-11.

Table 5-11. Message 1011: Receiver ID Message

Message ID: 1011					
Rate: Variable (see above)					
Message Length: 59 words					
Word No.:	Name:	Type:	Units:	Range:	Resolution:
1-4	Message Header				
5	Header Checksum				
6-7	Set Time (Note 1)	UDI	10 msec ticks	0 to 4294967295	
8	Sequence Number (Note 2)	I		0 to 32767	
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	C			
59	Data Checksum				
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialization 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 options list is a bit-encoded configuration word represented as an ASCII four-digit hexadecimal number:</p> <ul style="list-style-type: none"> bit 0 minimize ROM usage bit 1 minimize RAM usage bits 2-15 reserved 					

5.5.1.8 User-Settings Output (Message 1012).

This message provides a summary of the settings for many of the user-definable parameters, which were set either to default values or to values

supplied by the user in input messages. The contents of the User-Settings Output Message are described in Table 5-12.

Table 5-12. Message 1012: User-Settings Output Message (1 of 2)

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 msec ticks	0 to 4294967295	
8	Sequence Number (Note 2)	I		0 to 32767	
Operational Status (9.0-9.15)					
9.0	Reserved				
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	
9.6-9.7	Reserved				
9.8	Reserved				
9.9-9.15	Reserved				
10	Cold Start Time-Out	UI	seconds	0 to 32767	
11	DGPS Correction Time-Out	UI	seconds	0 to 32767	
12	Elevation Mask	I	radians	0 to $\pm\pi/2$	10^{-3}
SELECTED CANDIDATES:					
13.0-14.15	Selected Candidate (Note 3)	Bit		1 = included candidate	
SOLUTION VALIDITY CRITERIA (15-20)					
15.0	Attitude Not Used	Bit		1 = required	
15.1	Differential GPS	Bit		1 = required	
15.2-15.15	Reserved				
16	Number of Satellites in Track	UI		0 to 12	

Table 5-12. Message 1012: User Settings Output Message (2 of 2)

Word No.:	Name:	Type:	Units:	Range:	Resolution:
17-18	Minimum Expected Horizontal Error	UDI	meters	0 to 1000	10^{-2}
19-20	Minimum Expected Vertical Error	UDI	meters	0 to 1000	10^{-2}
21	Application Platform	UI		0 = default 1 = reserved 2 = pedestrian (low) 3 = reserved 4 = reserved 5 = land (medium) 6 = air (high)	
22	Data Checksum				
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialization 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 selected candidate list is a 32-bit flag, each bit representing candidate selection status for one satellite (i.e., bit 0 = SV1 status, bit 1 = SV2 status...bit 31 = SV32 status).</p>					

5.5.1.9 Built-In Test (BIT) Results (Message 1100). This message provides detailed test results of the last BIT is 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 Built-In Test (BIT) Results Message are described in Table 5-13.

Table 5-13. Message 1100: Built-In Test Results Message

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 msec ticks	0 to 4294967295	
8	Sequence Number (Note 2)	I		0 to 32767	
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 65535	
16	Serial Port 2 Receive Error Count	UI		0 to 65535	
17	Serial Port 1 Receive Byte Count	UI		0 to 65535	
18	Serial Port 2 Receive Byte Count	UI		0 to 65535	
19	Software Version	UI		0.00 to 655.35	0.01
20	Data Checksum				
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialization 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: 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.</p> <p>Note that the Dual Port RAM Failure test is currently not implemented. Therefore, word 12 will report a value of zero.</p>					

5.5.1.10 Measurement Time Mark (Message 1102). This message provides raw measurement and associated data. The contents of the

Measurement Time Mark Message are described in Table 5-14.

Table 5-14. Message 1102: Measurement Time Mark Message (1 of 3)

Message ID: 1102					
Rate: Variable					
Message Length: 253 words					
Word No.:	Name:	Type:	Units:	Range:	Resolution:
1-4	Message Header				
5	Header Checksum				
6-7	Set Time (Note 1)	UDI	10 msec ticks	0 to 4294967295	
8	Sequence Number (Note 2)	I		0 to 32767	
9-12	GPS Measurement Time: Integer portion (Note 3) Fractional portion (Note 4)	DI DI	seconds seconds	0 to 604799.98 0 to ± 0.02	20 _{ms} $2^{-29}/50$
GPS Time Status (13.0-13.15)					
13.0	Reserved				
13.1	Reserved				
13.2	Hand-Over Word Decoded Flag (Note 5)	Bit		1 = Hand-Over Word decoded	
13.3-13.15	Reserved				
14-24	Reserved				
PER CHANNEL OUTPUT					
n	Data Word Subframe Index (Note 6)	UI		0 to 9	1
Channel Status Word One:					
(n+1).0	Weak Signal (Note 7)	Bit		0 to 1	
(n+1).1	High $\Delta\theta$ (Note 8)	Bit		0 to 1	
(n+1).2	Parity Error(s) (Note 9)	Bit		0 to 1	
(n+1).3	Reserved				
(n+1).4	Reserved				
(n+1).5	Bit Sync Flag	Bit		1 = bit sync unknown	
(n+1).6	Frame Sync Flag	Bit		1 = frame sync unknown	
(n+1).7	Z Count Flag	Bit		1 = z count unknown	

Table 5-14. Message 1102: Measurement Time Mark Message (2 of 3)

Word No.:	Name:	Type:	Units:	Range:	Resolution:
(n+1).8 to (n+1).15	Reserved				
Channel Status Word Two:					
(n+2).0 to (n+2).4	Pre-Detection Interval (PDI)	UI		1 to 20	
(n+2).5 to (n+2).15	Reserved				
SATELLITE MEASUREMENTS					
n+3	Satellite Pseudorandom Noise Number (PRN) (Note 10)	I		0 to 32	1
n+4	C/No (Note 11)	I	dBHz	0 to ± 128	2^{-8}
n+5	Code Phase Measurement (Note 12)	UTI	seconds	0 to 0.16	$2^{-45}/50$
n+8	Carrier Phase Measurement (Note 13)	UTI	seconds	0 to 0.16	$2^{-45}/50$
n+11	Carrier Velocity Measurement	DI	sec/sec	0 to $\pm 2^{-14}$	2^{-45}
n+13	Code Phase Standard Deviation	UI	seconds	0 to 0.0025	$2^{-19}/50$
n+14	Carrier Phase Standard Deviation	UI	seconds	0 to 0.0025	$2^{-19}/50$
Channel Data Word One (Note 14):					
(n+15).0 to (n+15).29	SV Data Word One (Note 15)				
(n+15).30	Validity			0 = Invalid (unused) 1 = Valid (used)	
(n+15).31	Parity Error (Note 16)			0 = Correct 1 = Error	
Channel Data Word Two (Note 14):					
(n+17).0 to (n+17).29	SV Data Word Two (Note 15)				
(n+17).30	Validity			0 = Invalid (unused) 1 = Valid (used)	
(n+17).31	Parity Error (Note 16)			0 = Correct 1 = Error	
253	Data Checksum				
<p>Note 1: Set time is an internal 10 millisecond (T10) count since power-on initialization 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 GPS time associated with the valid satellite measurement data. The integer portion is the GPS second count from the start of week.</p>					

Table 5-14. Message 1102: Measurement Time Mark Message (3 of 3)**Note 4:**

The fractional portion of the solution measurement time is the offset from the GPS second count.

Note 5:

The Measurement Engine has decoded and applied at least one Hand-Over Word.

Note 6:

Indication of the position of subframe data word one within the GPS satellite's 50 bps telemetry data stream. For example, a value of 0 indicates that subframe data word one represents the first word of a particular telemetry data subframe. The data word subframe index is repeated once for each channel.

$$n = 25 + (j \cdot 19), \text{ where } j = 0 \text{ to } 11$$

Note 7:

1 = the signal strength fell below a threshold.

Note 8:

1 = a carrier phase change exceeded a threshold.

Note 9:

1 = carrier cycle slips may have affected this measurement or the previous measurement.

Note 10:

PRN equal to 0 is used to indicate an unused channel.

Note 11:

C/No observed for this measurement interval.

Note 12:

Code phase (pseudorange) at the measurement epoch. The physical range value in meters is obtained by scaling by $c(2-45/50)$, where c is the WGS-84 value of the speed of light. The factor of 50 results from the 50 Hz accumulation of code phase.

Note 13:

Continuously integrated carrier phase at the measurement epoch.

Note 14:

If channel data word one is unused, so is channel data word two. Channel data word one is indexed into the telemetry subframe by the Data Word Frame Index.

Note 15:

30-bit subframe data word from the 50 bps satellite telemetry data stream.

Note 16:

Parity is computed based on the six parity bits found at the end of each 30-bit subframe data word. Parity is computed based on the parity algorithm given in the *Global Positioning System Standard Positioning Service Signal Specification* (November 5, 1993).

5.5.1.11 UTC Time Mark Pulse Output (Message 1108). This message provides the UTC seconds into week associated with the UTC synchronized 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 5-15.

Table 5-15. Message 1108: UTC Time Mark Pulse Output Message

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 msec ticks	0 to 4294967295	
8	Sequence Number (Note 2)	I		0 to 32767	
UTC TIME					
9-13	Reserved				
14-15	UTC Seconds Of Week	UDI	seconds	0 to 604799	1 second
16	GPS to UTC Time Offset (integer part)	I	seconds	-32768 to +32767	1 second
17-18	GPS to UTC Time Offset (fractional part)	DI	nanoseconds	-2147483648 to +2147483647	1 nanosecond
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				
Note 1:					
Set time is an internal 10 millisecond (T10) count since power-on initialization 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.					

5.5.1.12 Serial Port Communication Parameters In Use (Message 1130). 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 5-16.

Table 5-16. Message 1130: Serial Port Communication Parameters In Use Message (1 of 2)

Message ID: 1130					
Rate: Variable					
Message Length: 21 words					
Word No.:	Name:	Type:	Units:	Range:	Resolution:
1-4	Message Header				
5	Header Checksum				
6-7	Set Time (Note 1)	UDI	10 msec ticks	0 to 4294967295	
8	(Sequence Number (Note 2))	I		0 to 32767	
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 Bits Per Second (bps) Rate (Note 3)	UI		0 = custom 1 = 300 2 = 600 3 = 1200 4 = 2400 5 = 4800 6 = 9600 7 = 19200	
13	Port 1 Pre-Scale (Note 3)	UI		0 to 255	
14	Port 1 Post-Scale (Note 3)	UI		0 to 7	

Table 5-16. Message 1130: Serial Port Communication Parameters In Use Message (2 of 2)

Word No.:	Name:	Type:	Units:	Range:	Resolution:
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)	UI		0 = custom 1 = 300 2 = 600 3 = 1200 4 = 2400 5 = 4800 6 = 9600 7 = 19200	
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 initialization 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>					

5.5.1.13 EEPROM Update (Message 1135). 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 5-17.

Table 5-17. Message 1135: EEPROM Update Message

Message ID:		1135																													
Rate:		Variable; default on update																													
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 msec ticks	0 to 4294967295																											
8	Sequence Number (Note 2)	I		0 to 32767																											
9.0-9.7	Data ID (Note 3)	Bit		0 to 25																											
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 initialization 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> <table> <tr> <td>0 = Status</td> <td>13 = Satellite candidate list</td> </tr> <tr> <td>1 = Position</td> <td>14 = Reserved</td> </tr> <tr> <td>2 = UTC/lon0</td> <td>15 = User entered altitude</td> </tr> <tr> <td>3 = Frequency standard cubic parameters</td> <td>16 = DGPS control</td> </tr> <tr> <td>4 = Host port communication configuration</td> <td>17 = Host port protocol selection</td> </tr> <tr> <td>5 = Auxiliary port communication configuration</td> <td>18 = Auxiliary port protocol selection</td> </tr> <tr> <td>6 = Memory options</td> <td>19 = Host port enabled messages</td> </tr> <tr> <td>7 = Solution validity criteria</td> <td>20 = Reserved (auxiliary port enabled messages)</td> </tr> <tr> <td>8 = Power management selections</td> <td>21 = User datums</td> </tr> <tr> <td>9 = Selected datum</td> <td>22 = Frequency/temperature table</td> </tr> <tr> <td>10 = Platform class</td> <td>23 = Almanac</td> </tr> <tr> <td>11 = Cold start control</td> <td>24 = Frequency standard calibration data</td> </tr> <tr> <td>12 = Elevation mask angle</td> <td>25 = Nav configuration data</td> </tr> </table> <p>Note 4: This field is only valid when the Data ID = 23 (Almanac).</p>						0 = Status	13 = Satellite candidate list	1 = Position	14 = Reserved	2 = UTC/lon0	15 = User entered altitude	3 = Frequency standard cubic parameters	16 = DGPS control	4 = Host port communication configuration	17 = Host port protocol selection	5 = Auxiliary port communication configuration	18 = Auxiliary port protocol selection	6 = Memory options	19 = Host port enabled messages	7 = Solution validity criteria	20 = Reserved (auxiliary port enabled messages)	8 = Power management selections	21 = User datums	9 = Selected datum	22 = Frequency/temperature table	10 = Platform class	23 = Almanac	11 = Cold start control	24 = Frequency standard calibration data	12 = Elevation mask angle	25 = Nav configuration data
0 = Status	13 = Satellite candidate list																														
1 = Position	14 = Reserved																														
2 = UTC/lon0	15 = User entered altitude																														
3 = Frequency standard cubic parameters	16 = DGPS control																														
4 = Host port communication configuration	17 = Host port protocol selection																														
5 = Auxiliary port communication configuration	18 = Auxiliary port protocol selection																														
6 = Memory options	19 = Host port enabled messages																														
7 = Solution validity criteria	20 = Reserved (auxiliary port enabled messages)																														
8 = Power management selections	21 = User datums																														
9 = Selected datum	22 = Frequency/temperature table																														
10 = Platform class	23 = Almanac																														
11 = Cold start control	24 = Frequency standard calibration data																														
12 = Elevation mask angle	25 = Nav configuration data																														

5.5.1.14 EEPROM Status (Message 1136). 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 5-18.

Table 5-18. Message 1136: EEPROM Status Message

Message ID:		1136																															
Rate:		Variable																															
Message Length:		18 words																															
Word No.:	Name:	Type:	Units:	Range:	Resolution:																												
1-4	Message Header																																
5	Header Checksum																																
6-7	Set Time (Note 1)	UDI	10 msec ticks	0 to 4294967295																													
8	Sequence Number (Note 2)	l		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 initialization 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:</p> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%;">0 = Status</td> <td style="width: 50%;">14 = Reserved</td> </tr> <tr> <td>1 = Position</td> <td>15 = User entered altitude</td> </tr> <tr> <td>2 = UTC/lon0</td> <td>16 = DGPS control</td> </tr> <tr> <td>3 = Frequency standard cubic parameters</td> <td>17 = Host port protocol selection</td> </tr> <tr> <td>4 = Host port communication configuration</td> <td>18 = Auxiliary port protocol selection</td> </tr> <tr> <td>5 = Auxiliary port communication configuration</td> <td>19 = Host port enabled messages</td> </tr> <tr> <td>6 = Memory options</td> <td>20 = Reserved (auxiliary port enabled messages)</td> </tr> <tr> <td>7 = Solution validity criteria</td> <td>21 = User datums</td> </tr> <tr> <td>8 = Power management selections</td> <td>22 = Frequency/temperature table</td> </tr> <tr> <td>9 = Selected datum</td> <td>23 = Reserved</td> </tr> <tr> <td>10 = Platform class</td> <td>24 = Frequency standard calibration data</td> </tr> <tr> <td>11 = Cold start control</td> <td>25 = Nav configuration data</td> </tr> <tr> <td>12 = Elevation mask angle</td> <td>26-30 = Reserved</td> </tr> <tr> <td>13 = Satellite candidate list</td> <td>31 = Data is being updated</td> </tr> </table>						0 = Status	14 = Reserved	1 = Position	15 = User entered altitude	2 = UTC/lon0	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 enabled 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 = Reserved	10 = Platform class	24 = Frequency standard calibration data	11 = Cold start control	25 = Nav configuration data	12 = Elevation mask angle	26-30 = Reserved	13 = Satellite candidate list	31 = Data is being updated
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4 = Host port communication configuration	18 = Auxiliary port protocol selection																																
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8 = Power management selections	22 = Frequency/temperature table																																
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10 = Platform class	24 = Frequency standard calibration data																																
11 = Cold start control	25 = Nav configuration data																																
12 = Elevation mask angle	26-30 = Reserved																																
13 = Satellite candidate list	31 = Data is being updated																																

5.5.2 Binary Input Message Descriptions. This section provides details for each of the input binary messages.

5.5.2.1 Geodetic Position and Velocity

Initialization (Message 1200). This message allows the user to initialize 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 Initialization Message are described in Table 5-19.

Table 5-19. Message 1200: Geodetic Position and Velocity Initialization Message (1 of 2)

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	
Initialization 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 32767	
9-10	GPS Seconds Into Week	UDI	seconds	0 to 604799	
11	UTC Day	UI	days	1 to 31	

Table 5-19. Message 1200: Geodetic Position and Velocity Initialization Message (2 of 2)

Word No.:	Name:	Type:	Units:	Range:	Resolution:
12	UTC Month	UI	months	1 to 12	
13	UTC Year	UI	year	1980 to 2079	
14	UTC Hours	UI	hours	0 to 23	
15	UTC Minutes	UI	minutes	0 to 59	
16	UTC Seconds	UI	seconds	0 to 59	
17-18	Latitude	DI	radians	± 0 to $\pi/2$	10^{-8}
19-20	Longitude	DI	radians	± 0 to π	10^{-8}
21-22	Altitude	DI	meters	± 0 to 40000	10^{-2}
23-24	Ground Speed	DI	meters/sec	0 to 1000	10^{-2}
25	Course	UI	radians	0 to 2π	10^{-3}
26	Climb Rate	I	meters/sec	± 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 output.					

5.5.2.2 User-Defined Datum Definition

(Message 1210). 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 Definition Message are

described in Table 5-20.

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.

Table 5-20. Message 1210: User-Defined Datum Definition Message

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	meters	6300000 to 6400000	
10	Semi-Major Axis - Fractional Part	UI	meters	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	meters	0 to ± 9000000	10^{-2}
16-17	WGS-84 Datum Offset - dY	DI	meters	0 to ± 9000000	10^{-2}
18-19	WGS-84 Datum Offset - dZ	DI	meters	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 output.					

6 ZODIAC GPS RECEIVER OPERATION

This section presents a detailed operational description of the Zodiac family 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 initialized and used to control operational configurations. This section also provides a description of start-up modes and satellite management.

6.1 Internal (Onboard) Data Sources

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

6.1.1 Static RAM (SRAM). SRAM is used to store all firmware variables manipulated by the GPS receiver. If external power has been supplied to SRAM during the “idle” state, this data will be available to the initialization functions at start-up. Satellite ephemeris, last position, and frequency standard parameters are important data that helps to minimize TTFF if the data is available in SRAM.

6.1.2 Real-Time Clock (RTC). Along with SRAM, an onboard RTC is a valuable source of data at system start-up. If external power has been applied to the RTC during the “idle” state, time/date information will be available to the initialization functions at start-up.

Valid time/date is a key component used to compute satellite visibility and to minimize TTFF.

Note that a value of “last known time” is available in SRAM. On the “Jupiter” board, the RTC is powered whenever SRAM is powered (refer to section 6.7 for more information about the RTC).

6.1.3 Electrically Erasable Programmable Read-Only Memory (EEPROM). Onboard 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 minimize TTFF includes satellite almanac, last known position, and frequency standard parameters. Note that EEPROM is used only if the required data is not available from SRAM (refer to section 6.7 for more information about the EEPROM).

6.1.4 Read-Only Memory (ROM). Onboard 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.

6.2 Initialization

6.2.1 Definition. Initialization is defined as the set of data and/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) initialization. For a GPS receiver installed in an automobile, this information is constantly changing as time progresses and the vehicle moves from location to location.

Initialization data is required when the onboard 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.

6.2.2 Position, Velocity, Time (PVT) Data. The most common form of user supplied initialization data is position and time (velocity is normally included in this group, but 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.

6.2.3 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.

6.2.4 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 onboard EEPROM and SRAM. Like ephemeris data, “over-the-air” availability means that the user does not normally have to supply almanac data.

6.2.5 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 onboard 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.

6.3 Configuration

6.3.1 Definition. Configuration is defined as the set of data and/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 customizes and/or optimizes the GPS receiver for use in a particular situation. In general, this data is held constant until the user decides to change it. Table 6-1 provides a brief description of all default configuration parameters.

Configuration data controls the “personality” of the receiver. Stated another way, configuration data controls how the receiver works on a daily basis. Typically, this information is stored in EEPROM, accessed at the time of initialization, 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 customized way.

Each of the various types of configuration data is briefly described in the following paragraphs.

6.3.2 Geodetic Datums. Zodiac 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

predefined 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 predefined set. A maximum of five user-defined datums is supported. Refer to section 6.6 (Navigation) for more details.

6.3.3 Satellite Selection. Zodiac 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. Refer to sections 6.6 and 6.7 (Navigation and Support Functions, respectively) for more details.

6.3.4 Differential GPS (DGPS) Control. Zodiac GPS receivers provide two configuration features related to DGPS operation: disable and correction

Table 6-1. Default Configuration Data

Parameter	Value/Description
Datum	WGS-84
Mask angle	10 degrees
Cold start control	Enabled
Timeout	300 seconds
Platform class	Automotive
Altitude measurement validity	Mark altitude solutions valid
Maximum Expected Horizontal Position Error (EHPE) validity	10 meters (*)
Maximum Expected Vertical Position Error (EVPE) validity	25 meters (*)
Criterion for the minimum number of satellites used for a solution	Zero (*) (**)
DGPS validity	Not required for a valid solution (*)
Held altitude	Enabled
Position pinning	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 (Rockwell binary)	9600-N-8-1
Host port communication parameters (NMEA)	4800-N-8-1
Auxiliary port communication parameters (RTCM input only)	9600-N-8-1

(*) Solution validity criteria.

(**) After a "fully determined" or successful transition to navigation.

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. Refer to sections 6.6 and 6.7 (Navigation and Support Functions, respectively) for more details.

6.3.5 Cold Start Control. A simple control that enables or disables this feature and sets the timeout for automatic transition to cold start is available. Refer to section 6.4 for a description of this feature.

6.3.6 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).

Refer to section 6.6 (Navigation) for a description of this feature.

6.3.7 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. Refer to section 6.6 (Navigation) for more details.

6.3.8 Vehicle Platform Select. This configuration feature allows the user to specify the type of vehicle in which the Zodiac receiver has been installed. Refer to section 6.6 (Navigation) for more details.

6.3.9 Navigation Control. Several navigation control features are provided by the Zodiac GPS receivers. These features are:

- Groundtrack smoothing.
- Position pinning.
- Validity criteria.

Refer to section 6.6 for more details on these features.

6.3.10 Configuration Straps. Configuration straps control the use of available configuration data at the time of initialization. These straps act as metacommands that can override or complement an existing set of configuration data. Note that these straps are only read once at initialization time, so a power cycle or software reset must be executed after any strap changes are made.

6.3.10.1 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 message set are contained in Section 5 of this Designer's Guide.

6.3.10.2 ROM Defaults. When asserted, all configuration and initialization data is 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 Rockwell binary operation (9600-8-N-1). When de-asserted (the normal operational state), configuration and initialization data are obtained from all valid sources (SRAM, EEPROM, RTC, etc.).

6.4 Start-Up Modes

Zodiac GPS receivers have four types of start-up modes (Warm, Initialized, Cold, and Frozen) based on the availability and source of initialization data. Each of these modes are briefly described in the following paragraphs.

6.4.1 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.

6.4.2 Initialized 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 initialization or continuous RTC operation with

an accurate last known position available from EEPROM.

6.4.3 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 minimizes satellite acquisition uncertainties.

6.4.4 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.

6.5 Satellite Management

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

6.5.1 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).

6.5.1.1 DOPs. 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), which reflects the effects of geometry on three-dimensional position estimates, and Time Dilution of Precision (TDOP), which reflects geometric effects on time estimates. The relationship can be expressed as:

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

In turn, PDOP can be separated into horizontal and vertical components: Horizontal Dilution of Precision (HDOP) and 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:

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

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.

6.5.2 Acquisition Modes. Two methods of satellite acquisition are used by the Zodiac GPS receiver: sequential acquisition and parallel acquisition.

6.5.2.1 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 Initialized Start.

6.5.2.2 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.

6.5.2.3 Overall Search Process. Figure 6-1 depicts the overall search process as it interacts with the visible satellite list generation described in section 6.5.1. Sequential or parallel acquisition is selected based on channel availability and the required frequency search range (the number of doppler bins) for each satellite.

6.5.3 Data Collection. Subframe 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).

6.5.3.1 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 reacquisition processes. Note that this data is not maintained in EEPROM due to its limited time validity.

6.5.3.2 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).

6.5.3.3 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 (weeks).

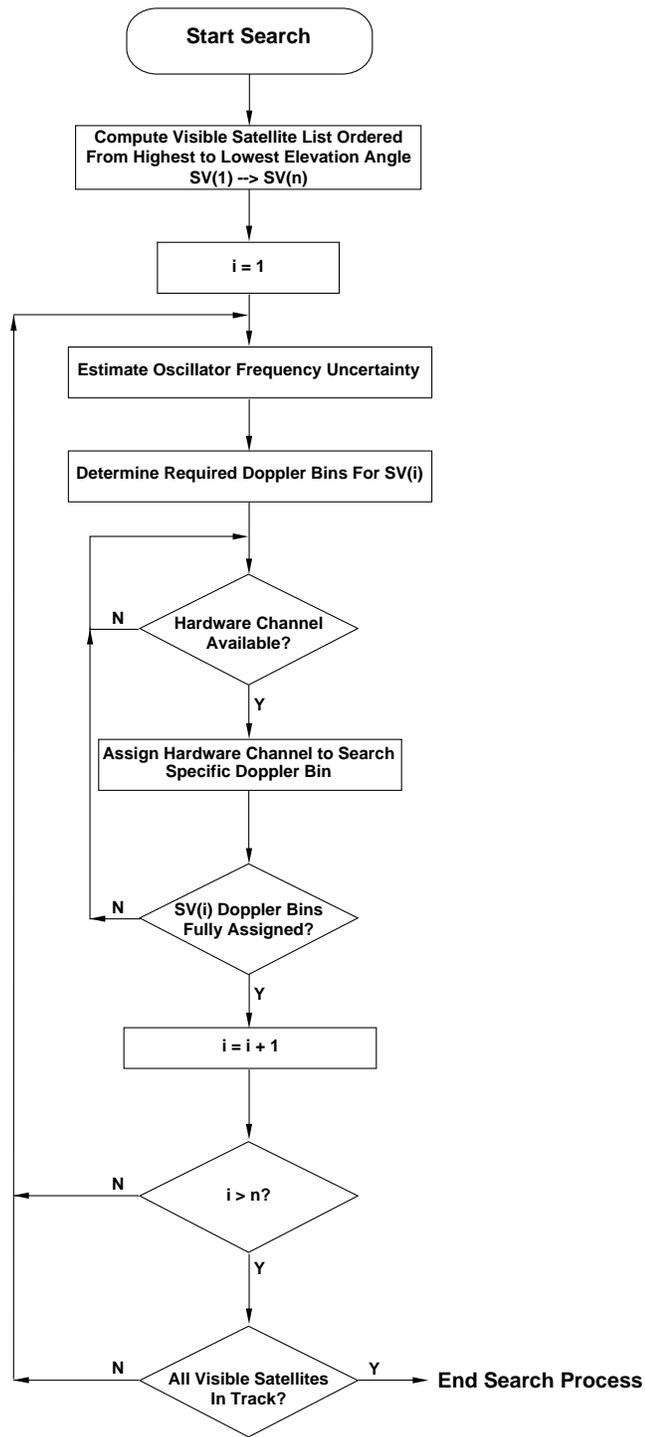


Figure 6-1. Zodiac Search Process

6.6 Navigation

This section describes the operation of the navigation software in the GPS receiver. This software initializes and maintains a state vector which is used to report time, position, and velocity to the user.

The navigation software uses pseudorange, 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 customize it for a specific application. This section defines many of the features of the navigation system with emphasis on those that the OEM can control.

6.6.1 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 and longitude. The receiver expects geodetic parameters as part of the Geodetic Position and Velocity Initialization 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 Designer's Guide. All of the pre-defined datums are taken from the U.S. Government document, *Department of Defense World Geodetic System 1984*.

6.6.1.1 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 Rockwell binary mode and the OEM wanted to use a previously recorded position to initialize 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 Initialization 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 Rockwell 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.

6.6.1.2 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 6.6.1 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 Rockwell 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.

6.6.2 Platform Class. The Zodiac GPS receiver supports three platform classes:

- Pedestrian (low dynamics)
- Automotive (medium dynamics)
- Aircraft (high dynamics)

The platform class is set by the OEM to optimize 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.

6.6.2.1 Pedestrian. This platform class is used when the receiver is mobile in a low dynamic environment. An example would be a handheld GPS receiver used for hiking.

6.6.2.2 Automotive. This platform class is for moderate dynamic environments where altitude is not constant. A common example would be a car or truck, although motorcycles and touring bicycles also fall into this category.

6.6.2.3 Aircraft. This platform class is for high dynamic environments where altitude may

change rapidly. Examples are airplanes and helicopters.

6.6.3 Navigation Cycle. The navigation software nominally executes once per second. During each execution, the navigation state is propagated forward in time 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 Rockwell binary or NMEA).

6.6.3.1 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, the velocity estimate is considered less reliable and is decayed exponentially with platform class dependent time constants.

6.6.3.2 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.

6.6.3.3 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.
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/sec. The OEM can disable the use of held altitude using the Nav Configuration message (binary Message 1221).

6.6.3.4 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 meters per second. The position estimate of the receiver will wander around inside a circle of approximately 100 meters (the 2-Drms position error specified in the *GPS SPS Signal Specification*).

This wandering 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 wandering behavior of the solution in static situations, but introduces some risk that actual platform motion will be mistaken for SA induced wandering.

By default, the position pinning feature of the Zodiac GPS receiver is enabled. The OEM can turn it off using the Nav Configuration message (binary Message 1221). Users who expect to see the effects of SA in their solutions should turn it off to prevent the possibility of mistaking platform motion as SA wander. The configuration word which controls this feature is stored in EEPROM and the user setting will be retained through power-off and reset cycles.

6.6.3.5 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 meters. The receiver processes all satellites above the mask angle to minimize 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 to 20 meters, but up to 100 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 groundtrack 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 groundtrack smoothing will be retained through power-off and reset cycles.

6.6.4 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.

6.6.4.1 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.

6.6.4.2 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.

6.6.4.3 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.

6.6.4.4. Maximum EHPE Validity Criterion.

The EHPE is the one sigma horizontal position error estimate for the solution. The validity criterion default is 10 meters. 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).

6.6.4.5 Maximum EVPE Validity Criterion.

The EVPE is the one sigma vertical position error estimate for the solution. The default is 25 meters. The operation and meaning of this criterion is analogous to the EHPE criterion in section 6.6.4.4. The threshold can be set in the binary Solution Validity Criteria message (Message 1217).

6.6.5 Mean Sea Level (MSL). MSL is a geoid, or a 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. A 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 (WGS-84 by default) 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.

6.7 Support Functions

This section describes the support functions of the GPS receiver.

6.7.1 Serial Communication Interfaces. Zodiac GPS receivers provide two bi-directional serial communication interfaces: the Host and Auxiliary ports. More information on these interfaces is provided in Section 5 of this Designer's Guide.

6.7.1.1 The Host Port. The Host port is the primary interface to the controlling application and provides all the services for initializing 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 Rockwell 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

6.6.6 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 Center (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.

previously stored selections for the Host port configuration and communication settings.

While using the Rockwell binary communications protocol on the Host port, a number of application specific parameters can be configured to customize the receiver for a specific application. The ability to freely switch between Rockwell 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 Rockwell binary and NMEA message protocols. Changes to the port configuration settings, communications protocol, and message controls are stored in non-volatile EEPROM.

6.7.1.2 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.

6.7.2 EEPROM Services. The EEPROM services provide for the non-volatile storage and retrieval of system configuration parameters and data that

vary somewhat by time but are, in general, fairly constant for short periods of time (weeks).

The configuration and operational data stored in EEPROM is only read during system initialization 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 initialization is invalid, default values from ROM will be used to initialize 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 Zodiac receiver's EEPROM are listed in Table 6-2.

6.7.3 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 initialization as needed.

The time/date data is only read from the RTC during system initialization. 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 initialization, 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.

Table 6-2. Parameters And Data Maintained In EEPROM

<p>Configuration Data</p>	<ul style="list-style-type: none"> • Serial Port Configuration (both ports) • Solution Validity Criteria • Selected Datum • Platform Class • Cold Start Control • Satellite Elevation Mask Angle • Satellite Candidate List • Differential GPS Control • Default Serial Output Messages • User Defined Datums • Navigation Control
<p>Satellite Management Parameters</p>	<ul style="list-style-type: none"> • UTC and Ionosphere Model Parameters • Frequency Standard Data • Almanac Data
<p>Navigation Data</p>	<ul style="list-style-type: none"> • Last Known Position • User-Entered Altitude

6.7.4 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 pseudorange 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 measurements before computing a position solution. This technique effectively eliminates much of the error due to SA as well as errors due to unmodeled 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 Zodiac 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. More detailed information on the format of this message is provided in Section 5 of this Designer's Guide.

6.7.4.1 The RTCM Protocol. The Zodiac 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.

6.7.4.2 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 Rockwell “Jupiter” *Global Positioning System (GPS) Receiver* Data Sheet 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. (The user should be aware that RTCM SC-104 is still an evolving standard, and that future releases of Zodiac software may be modified to accommodate its revision.)

Type 1 Message. Type 1 messages contain pseudorange and pseudorange 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 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.

6.7.4.3 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. The Zodiac family of receivers complies with the current version of this standard (version 2.1) with the exception of the serial data hardware implementation.

The specification for the serial data interface will be as described in Section 5 of this Designer's Guide. The Zodiac is not configured as "terminal equipment" as specified in paragraph 5.3.4 of the RTCM SC-104 standard.

6.7.4.4 DGPS Initialization And

Configuration. At power-on, the receiver initializes 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 eight meters for all four satellites.
- The RTCM SC-104 source declares itself to be in good health.
- The user has not turned DGPS operation off.

6.7.4.5 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.

6.7.4.6 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 initialization 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 Differential GPS 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.

6.7.4.7 DGPS Status Request. The user may request that the status of DGPS operation be provided. When requested, the Differential GPS 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.

6.7.5 Built-In Test (BIT). The receiver can be commanded to execute a BIT at any time while in Rockwell 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.

6.7.5.1 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.

2-D	Two dimensional
2-Drms	Two-dimensional root mean square
3-D	Three dimensional
3-Drms	Three-dimensional root mean square
AAMP	Advanced Architecture Microprocessor
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 which 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 center (WGS-84 reference ellipsoid center).
AP	Application Processor. The processor connected to the Zodiac 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 3-D navigation as the current value of Held Altitude when entering Altitude Hold 2-D navigation. It will continue to use this value throughout this Altitude Hold event unless an Amended Altitude is received from the application processor. The 3-D 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 have been built and launched as of August 1995. Twenty-Four of these have been successfully orbited.
Block IIR Satellite	Satellites being designed to eventually replace Block II satellites. The first Block IIR satellite is scheduled to be ready for launch in 1995.
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, centered at the user's true location, that contains 50 percent 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 synchronize their clocks.
dB	Decibel
DB-9	9-pin D-Subminiature Connector
DB-25	25-pin D-Subminiature Connector
dBic	Decibel-Isometric-Circular (measure of power relative to an isometric antenna with circular polarization)

dBm	Decibels per 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 pseudorange 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-Centered Earth-Fixed. A Cartesian coordinate system with its origin located at the center 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
FFC	Flex cable
FOM	Figure Of Merit
FP	Floating Point
FRP	Federal Radionavigation 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.
Horizontal Dilution of Precision	(see HDOP)

Hz	Hertz
I/O	Input/output
I	Integer
IF	Intermediate Frequency
IGRF	International Geomagnetic Reference Field
I/O	Input/Output
IODE	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	kilometer
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 atmosphere. 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/sec	Meters per second (units of velocity)
m/sec/sec	Meters per second per second (units of acceleration)
m/sec/sec/sec	Meters 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	Millivolt
mW	Milliwatt
NF	Noise Factor
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
Overdetermined Solution	The solution of a system of equations containing more equations than unknowns. The GPS receiver computes, when possible, an overdetermined 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.
	Also: Precise Positioning Service. The GPS positioning, velocity, and time service which will be available on a continuous, worldwide basis to users authorized by the DoD.
PRN	Pseudorandom 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 pseudorandom noise codes.
PRR	Pseudo-Range Rate
Pseudorange	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 pseudorange instead of a true range.
PSF	Post Select Filter
PVT	Position, velocity, and time
PWB	Printed Wiring Board
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, centered 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.
Standby 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.
SRAM	Static Random Access Memory
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 (3-D) Navigation	Navigation Mode in which altitude and horizontal position are determined from satellite range measurements.
Time Mark Pulse	A one pulse per second (1PPS) output synchronized to UTC when the receiver is in its Navigation Mode.
TOW	Time Of Week

TTF	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 (2-D) Navigation	Navigation Mode in which a fixed value of altitude is used for one or more position calculations while horizontal (2-D) 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.
UERE	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 center of the WGS-84 ellipsoid as the center of the GPS ECEF reference frame.

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APPENDIX B: References

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

1. *Global Positioning System Standard Positioning Service Signal Specification*, United States Department of Defense, 5 November 1993.
2. *Standard For Interfacing Marine Electronic Devices, NMEA 0183, Version 2.00*, National Marine Electronics Association, January 1992
3. *RTCM Recommended Standards for Differential NAVSTAR GPS Service, Version 2.1*, Radio Technical Commission for Maritime Services, January 1994.
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 2nd Edition, 1 September 1991.
6. Internet Web Site: "<http://julius.ngdc.noaa.gov/seg/potfld/geomag.html>"

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APPENDIX C: NAVSTAR GPS Operation

The 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 three-dimensional 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.

The GPS system consists of three major segments: Space, Control, and User as illustrated in Figure C-1.

GPS System Design

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 (as shown in Figure C-2) about 10,900 miles (20,200 km) 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 minimum of 5 satellites in view from any point on Earth at any one time.

Each satellite continuously broadcasts an RF signal at a center 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 bits per second (bps) navigation data. This navigation data, which is computed and controlled by the GPS Control Segment, includes the satellite's time, its

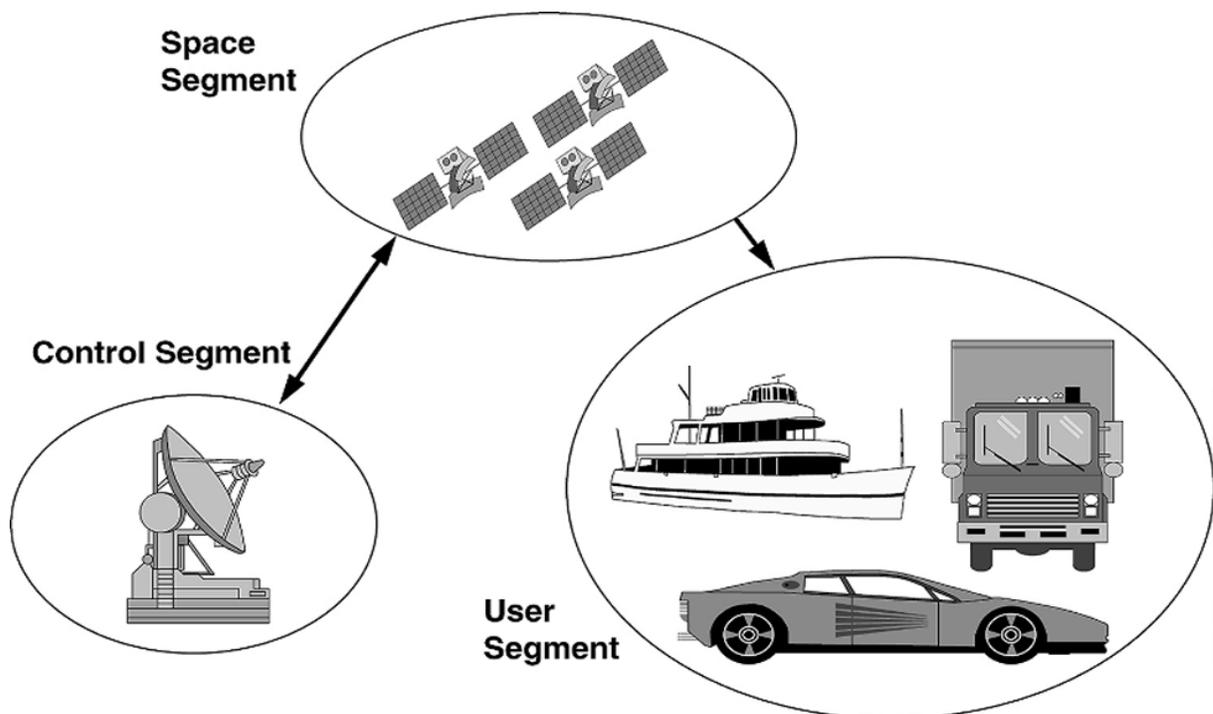


Figure C-1. Major Segments of the NAVSTAR GPS System

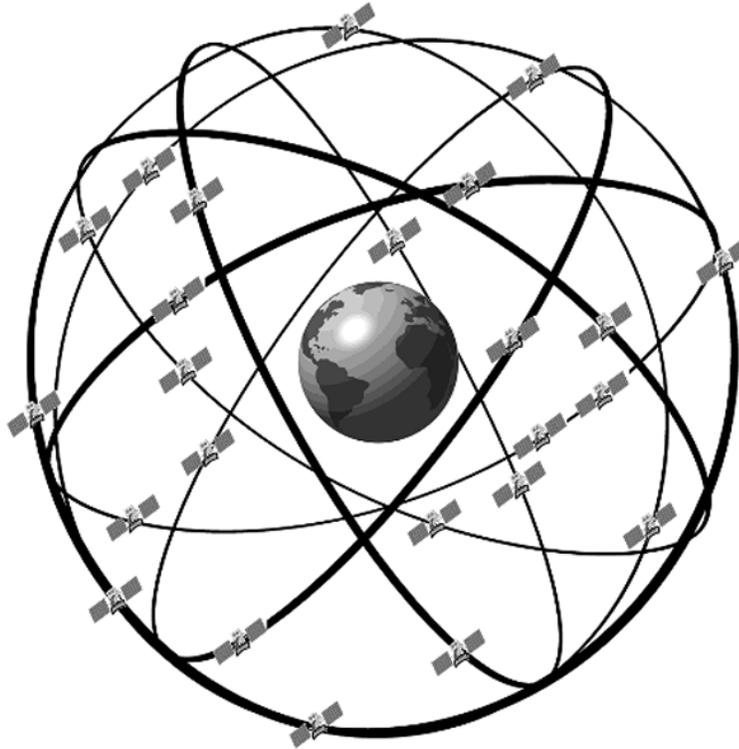


Figure C-2. NAVSTAR GPS Operational Satellite Constellation

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 unauthorized 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. There, 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 rebroadcast 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 standalone mode or integrated with other systems to enhance the overall system performance.

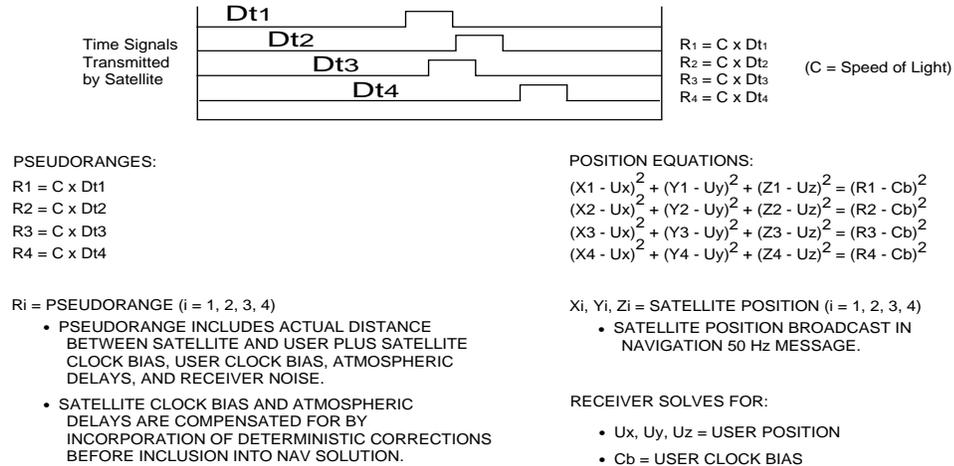


Figure C-3. Range Processing Equations

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 pseudoranges 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 pseudorange 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-3. The solution of these equations may be visualized as the geometric intersection of four ranges from four known satellite locations.

Figure C-4 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. Similar equations are then used to calculate velocity using relative velocities instead of pseudoranges. 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 pseudorange 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.

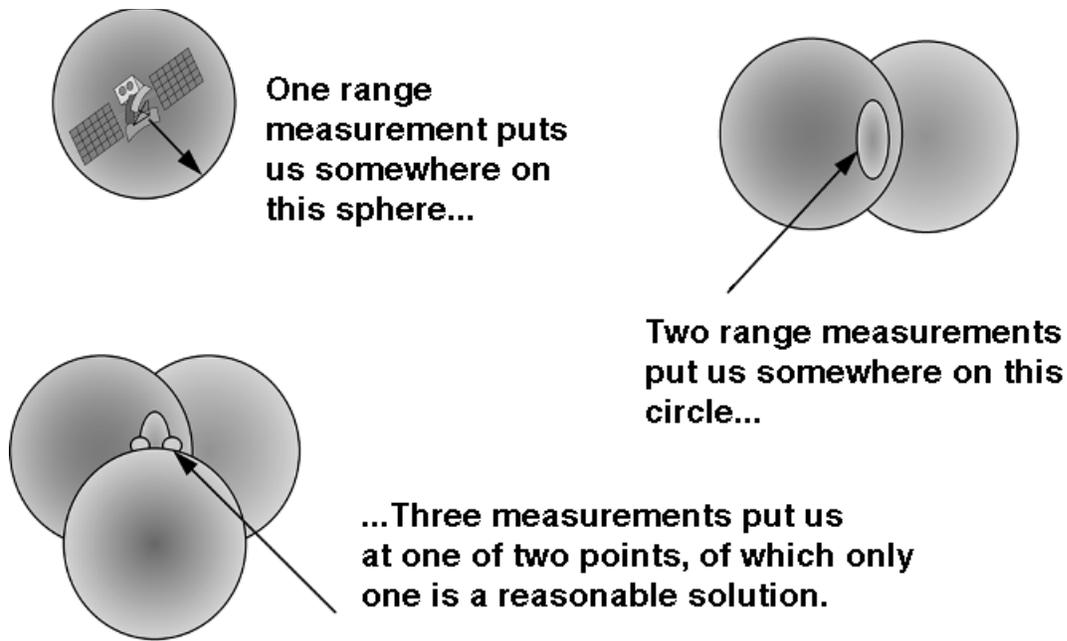


Figure C-4. Satellite Ranging Intersections

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.

There are four other DOP components which 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-5).

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.

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 authorized users. SPS is less accurate and intended for general public use. This is the level of accuracy used by the Zodiac family of GPS receivers.

The SPS signal is 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 U.S. national security.

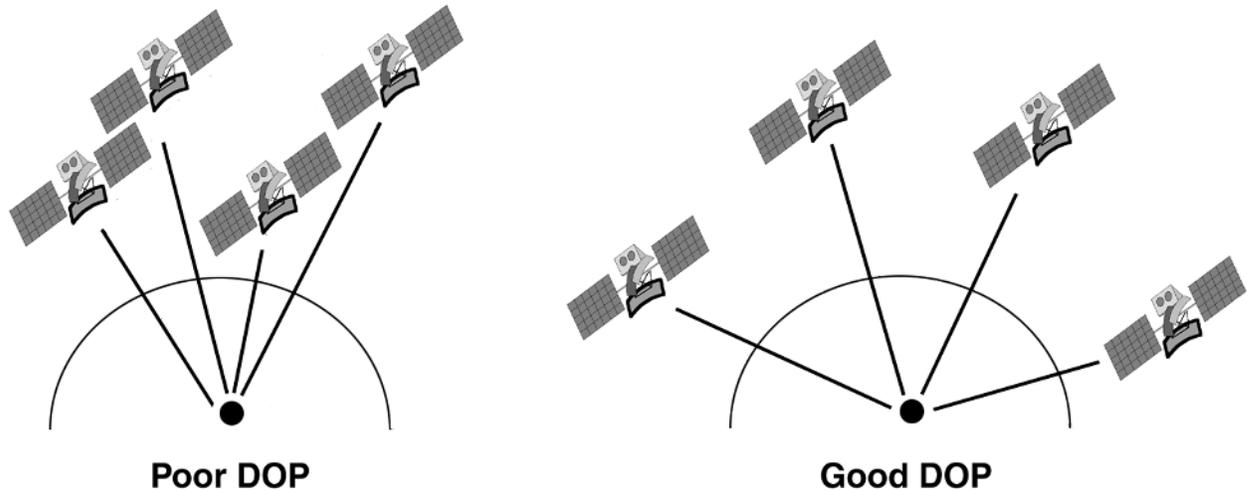


Figure C-5. Geometrical Dilution of Precision

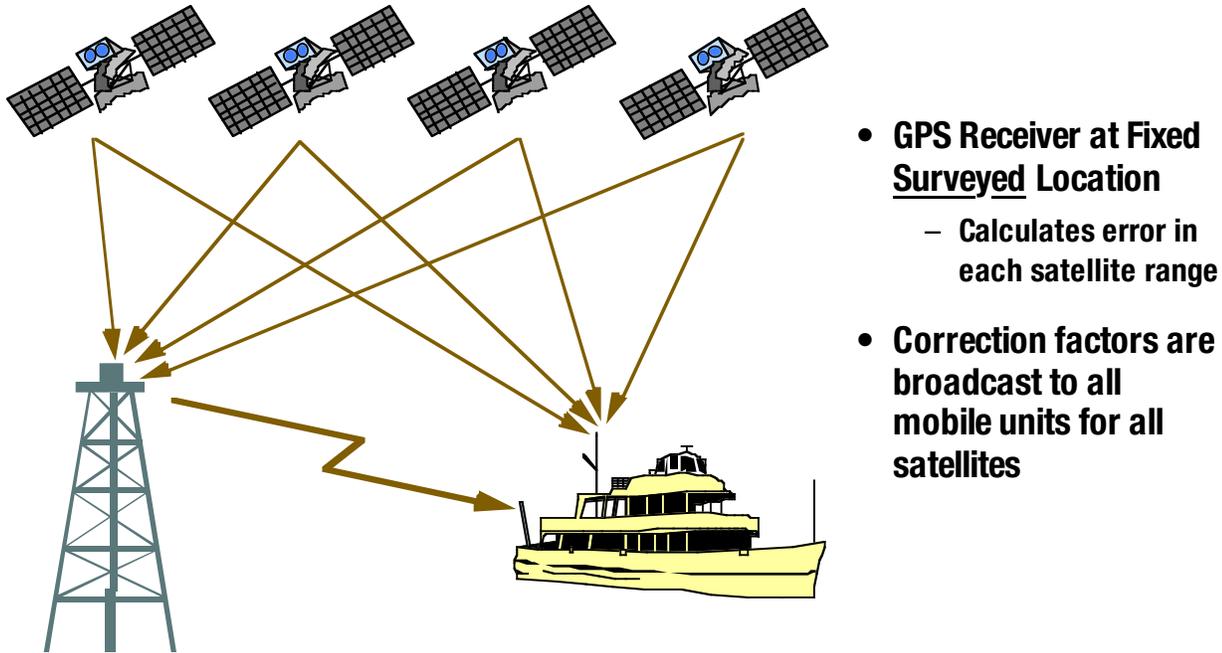
Differential GPS (DGPS)

DGPS Description. The following general description of DGPS is excerpted 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 to 10 meters for dynamic, navigation applications. As illustrated by Figure C-6, 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 preponderant errors are bias errors due to causes outside the receiver. This is the case for GPS. The major sources of error are the following:

1. SA errors: artificial errors introduced at the satellites for security reasons. Pseudorange errors of this type are about 30 meters, 1-sigma. PPS users have the capability to eliminate them entirely.
2. Ionospheric delays: signal propagation group delay which is typically 20 to 30 meters during the day and 3 to 6 meters at night.
3. Tropospheric delays: signal propagation delays caused by the lower atmosphere. While the delays are as much as 30 meters 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 meters for low-lying satellites.
4. 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 meters, but they could be more than 30 meters under SA.
5. 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.



- **GPS Receiver at Fixed Surveyed Location**
 - **Calculates error in each satellite range**
- **Correction factors are broadcast to all mobile units for all satellites**

Figure C-6. DGPS Operation

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 meters 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 so that compensation is almost complete. As the user-reference station separation is increased, the different ionospheric and tropospheric paths to the satellites may be sufficiently far apart that the atmospheric inhomogeneities cause the delays to differ somewhat. To the extent they differ, they constitute an error in the DGPS measurement, called spatial decorrelation. This type of error will be greater at larger user-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-7. The data processor applies the corrections

received from the reference station to the pseudorange 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 pseudorange measurement, as follows:

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

where $\text{PRC}(t)$ is the correction to be applied, $\text{PRC}(t_0)$ is the range correction from the message, RRC is the range-rate correction from the message, t_0 is the time reference of the correction, and t is the time associated with the pseudorange 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

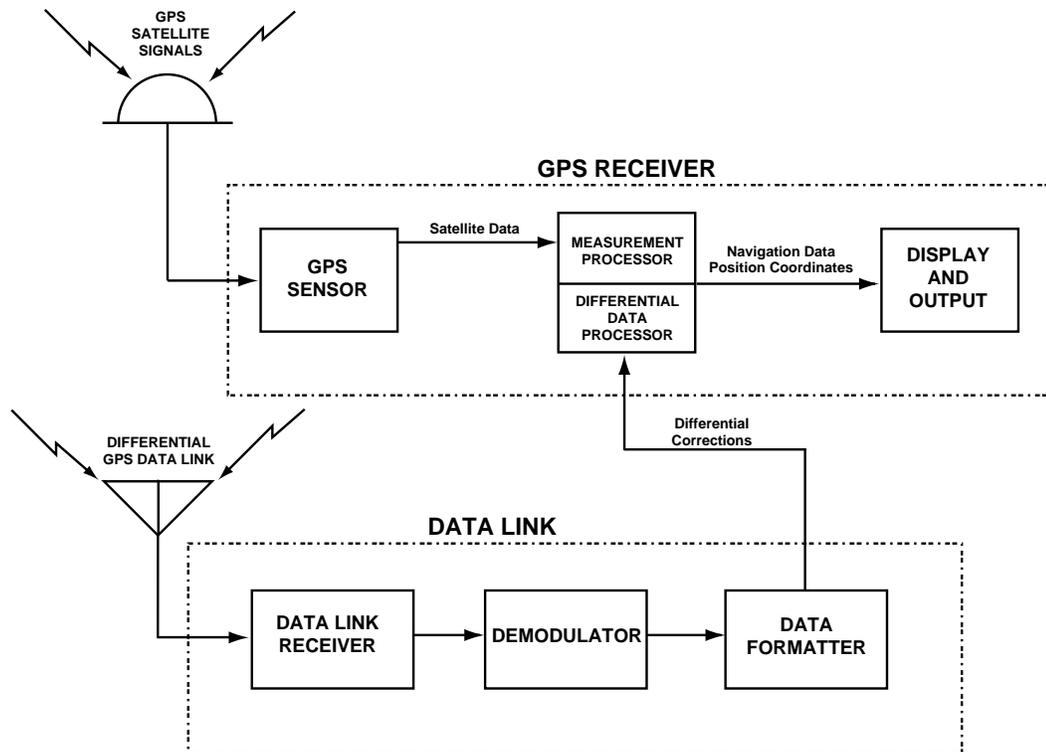


Figure C-7. User Equipment Block Diagram

the 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-7 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 five-meter accuracy.

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APPENDIX D: Frequently Asked Questions

This Appendix provides answers to frequently asked questions about GPS in general and about the Zodiac family of GPS receivers in particular. These questions are intended to supplement the operational description provided in Section 6 of this Designer's Guide.

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. Rockwell generally recommends limiting cable loss to 3 dB between the antenna and the receiver board. If attenuation exceeds this value there likely will be degraded signal acquisition and navigation accuracy performance. It is true that GPS satellites transmit more power than their specification requires, but that margin has been 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 Zodiac receiver operate efficiently in an urban location with tall office structures and buildings?

The receiver operates efficiently in an urban environment because it contains 12 parallel channels and CityTracker™ software which allows optimal performance in this setting. The parallel channels maintain continuous tracking of all satellites that are visible at any point in time and are used to produce an overdetermined solution that minimizes the effects of signal blockage. When these signals are momentarily lost due to blockage or attenuation, the navigation process typically has more than enough signals remaining to support continuous navigation. The CityTracker™ software provides additional smoothing by minimizing the effects of selective availability on different combinations of GPS satellite signals.

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

Yes. If preamp 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 preamp 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 Zodiac receiver continuously tracks all visible satellites. The measurements from these satellites are all used in an overdetermined 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 meters 95 percent of the time and less than 300 meters 99.99 percent 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-Centered-Earth-Fixed (ECEF)?

ECEF refers to a Cartesian (rectangular) coordinate system (x,y,z,) whose center 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 a good, well-accepted model worldwide. The model does have some limitations that must be understood. For example, 0 meters altitude may differ from sea level in this model by as much as ~100 meters. 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 Zodiac receiver provide an overdetermined solution?

The Zodiac provides all-in-view parallel tracking of all visible satellites. In SPS mode all valid measurements are used to produce an overdetermined navigation solution to minimize position excursions arising from selective availability and loss of signals. In DGPS all valid measurements with valid DGPS corrections are also used in an overdetermined solution. For example, if 8 satellites are in track, all are producing valid measurements, and DGPS corrections are available for 7 of the 8, then 7 DGPS corrected measurements will be used in the overdetermined DGPS solution.

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

The Zodiac and other Rockwell receivers compute velocity from the carrier loop Doppler information. Heading angle is then computed from east and north velocity as the arctangent (V_e/V_n). Selective availability induces an error on the GPS clock and thus the carrier Doppler information is corrupted just as the pseudorange is corrupted. However, the carrier data is a much better source of velocity information than position differences.

The worst case heading error at 5 meters per second is 1.1 degrees when selective availability 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 Zodiac 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	WGS 72	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 &	6377298.556000	300.801700
26	SGS 85	6378136.000000	298.257000

Zodiac Datum Table: The following list of datums, maintained and selectable through the LABMON evaluation software, applies to Rockwell's Zodiac Family of GPS receivers.

ROM Datums					
Code:	Name:	Ell:	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

Code:	Name:	Ell:	dx:	dy:	dz:
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:	Ell:	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

Code:	Name:	Ell:	dx:	dy:	dz:
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:	Ell:	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

Code:	Name:	Ell:	dx:	dy:	dz:
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:	Ell:	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 Metereo 1939 Azores (Corvo & Flores 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

Code:	Name:	Ell:	dx:	dy:	dz:
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, 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:	Ell:	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

Code:	Name:	Ell:	dx:	dy:	dz:
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 - Venezuela	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

Code:	Name:	Ell:	dx:	dy:	dz:
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

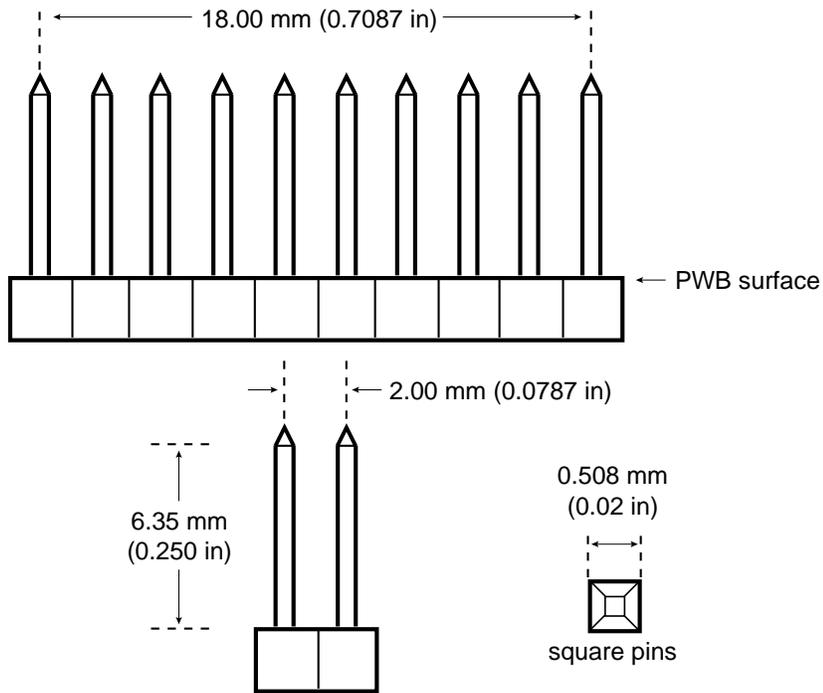
NavCore Datum Table: The following list of datums, maintained and selectable through the LABMON evaluation software, applies to Rockwell's NavCore GPS receivers:

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	Pico 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

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APPENDIX F: 2x10 Pin Field Connector Information

This appendix contains specifications and ordering information for the 2x10 pin field connector (available from Elco, Inc.).



2x10 Pin Field Header Mechanical Detail

APPENDIX G: RF Connector Information

This appendix contains specifications and ordering information for the RF connector.

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APPENDIX H: RG-142 and RG-316 Specifications

This appendix provides technical specifications for the RG-142 and RG-316 antenna cables used with the Zodiac GPS receiver.

Typical Specification for RG-142:

I. Electrical Characteristics:

Nominal impedance	50 ohms
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 32.0 dB/100 ft
Nominal shield dc resistance @ 20 degrees C	2.3 ohms/1000 ft
Nominal conductor dc resistance @ 20 degrees C	16.3 ohms/1000 ft
Continuous working voltage	1400 V RMS maximum

II. Physical Characteristics:

Nominal weight	43 lbs/1000 ft
Minimum bending radius	2.0 inches
Temperature rating	-70 to +200 degrees C
Type shield and percent coverage	2 silver coated copper Inner braid, 96% Outer braid, 95%
Maximum pulling tension	146 lbs
Insulation material	TFE Teflon*
Jacket material	Brown tint FEP Teflon*
Conductor diameter	0.037 inches nominal
Core diameter	0.1155 inches nominal
Outside dimensions	0.195 inches nominal

*Teflon is a trademark of DuPont

Typical Specification for RG-316:

I. Electrical Characteristics:

Nominal impedance	50 ohms
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 @ 20 degrees C	6.5 ohms/1000 ft
Nominal conductor dc resistance @ 20 degrees C	33.0 ohms/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 degrees C
Type shield and percent coverage	Silver coated copper Inner braid, 96% Outer braid, 96%
Maximum pulling tension	21 lbs
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

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