

Test Bed Receiver Subsystem

Addendum

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FOREWORD

SCOPE

The *Test Bed Receiver Subsystem Addendum* is written for users of the Test Bed Receiver Subsystem and contains information specific to the TESTBEDW and TESTBEDGLO software models.

This manual describes the NovAtel Test Bed Receiver Subsystem in sufficient detail to allow effective integration and operation. The manual is organized into sections, which allow easy access to appropriate information.

It is beyond the scope of this manual to provide service or repair details. Please contact your NovAtel Service Center for any customer service inquiries.

PREREQUISITES

The Test Bed Receiver is a stand-alone fully functional GPS and Test Bed Receiver. Refer to *Chapter 2, Installation of Test Bed Receiver* for more information on installation requirements and considerations.

The NovAtel Test Bed Receiver module utilizes a comprehensive user interface command structure, which requires communications through its serial (COM) ports. To utilize the built-in command structure to its fullest potential, it is recommended that some time be taken to review and become familiar with commands and logs in the *MiLLennium Command Descriptions Manual* before operating the Test Bed Receiver.

1 INTRODUCTION

The Test Bed Receiver is based on a Wide Area Augmentation System receiver (NovAtel WAAS). See *Appendix A, Page 22* for an overview of the WAAS system.

THE NOVATEL TEST BED RECEIVER

Figure 1 The NovAtel Test Bed Receiver



The Test Bed Receiver consists of two NovAtel Millennium receivers packaged along with associated support circuitry in a NovAtel WAAS Receiver style enclosure (a 4U high 19" sub rack). The first Millennium receiver (GPS GEO) tracks 12 GPS L1/L2 satellites with narrow correlator spacing, **or** 10 GPS L1/L2 satellites with narrow correlator spacing and 1 WAAS satellite with wide correlator spacing **or** 8 GPS L1/L2 satellites with narrow correlator spacing and 2 WAAS satellites with wide correlator spacing. The second Millennium receiver (GPS GLONASS) tracks 12 GPS L1 satellites with narrow correlator spacing and 6 GLONASS L1 satellites with narrow correlator spacing. Refer to *Default Channel Assignments* in *Appendix E, Page 50* for more details on the channel configurations. Data output rates will be nominally at one hertz.

It is possible to upgrade this configuration in the future to become a full EGNOS RIMS-C, WAAS or MSAS receiver, by the addition of several MEDLL receiver cards and replacement of the GPS GLONASS card with a second GPS GEO card.

The GPS GLONASS card uses Narrow Correlator tracking technology to track the L1 GPS satellite signals. This enhances the accuracy of the pseudorange measurements as well as mitigating the effects of multipath.

The GPS GEO card will track GEO satellites that transmit using the RTCA/DO-229A WAAS signal structure. The GEO satellites are tracked using standard correlator spacing. This configuration is chosen based on the signal bandwidth of the IMMARSAT GEO satellites, which is constrained to 2.2 MHz. The GPS GEO card can track two C/A code GEOs on L1.

The Test Bed Receiver incorporates a L1/L2 GPSCards, which uses NovAtel's P-Code Delayed Correlation Technology, providing superior performance even in the presence of P-code encryption. Each GPSCard is an independent GPS receiver.

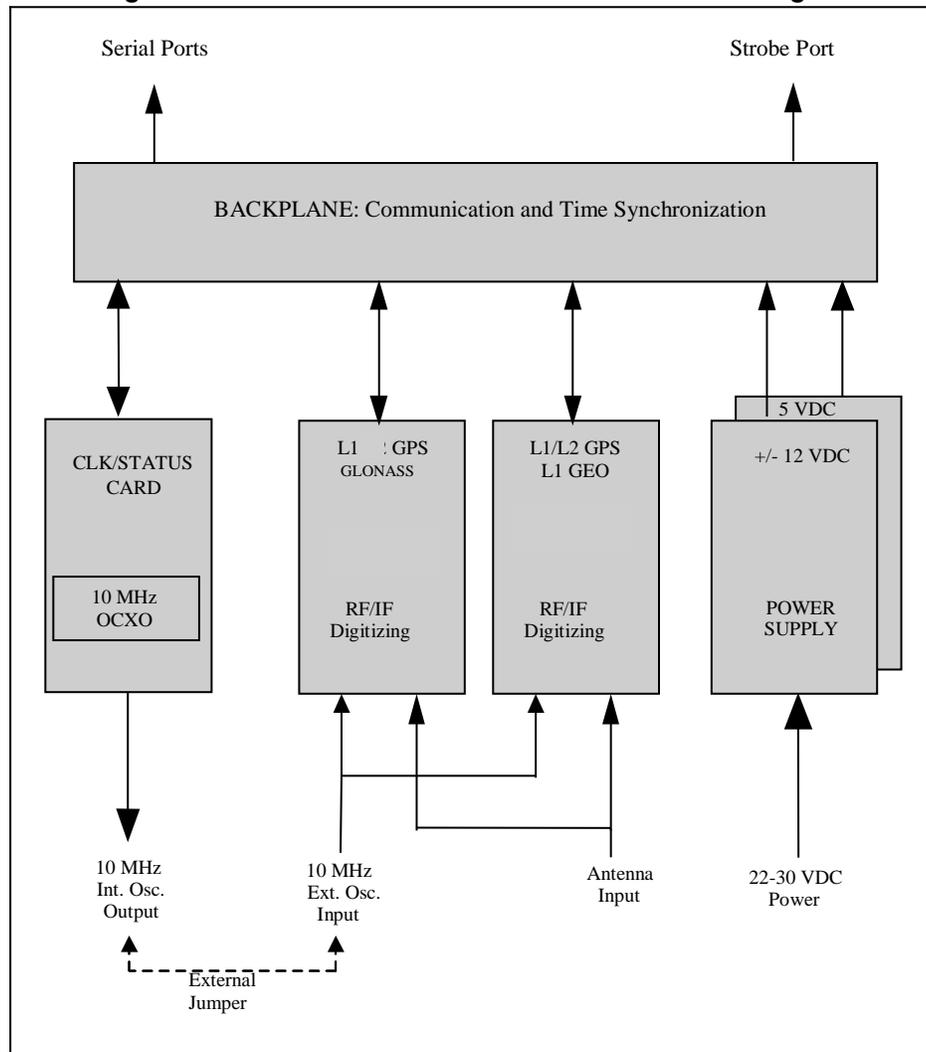
The Test Bed Receiver is packaged in a standard 4U x 19" sub-rack. The rear panel's 9-pin D connectors as well as the antenna and external oscillator connectors provide easy I/O access.

OPERATIONAL OVERVIEW

The NovAtel Test Bed Receiver has two functional blocks (see *Figure 2*):

- Single Frequency GPS GLONASS
- Dual Frequency GPS GEO

Figure 2 Test Bed Receiver Functional Block Diagram



GEO Processing

Specific channels on the GPS GEO card have the capability to receive and process the GEO WAAS signal. The signal is in-band at L1 and is identified with WAAS-specific PRN numbers. The WAAS message is decoded and separated into its various components. The WAAS message and associated pseudorange is provided as an output.

Single Frequency GPS GLONASS

The GPS GLONASS is configured to track 12 L1 C/A-code signals (Narrow Correlator tracking technology), and 6 L1 GLONASS C/A-code signals. The output is used to compute ionospheric corrections.

Dual Frequency GPS GEO

Within the GPS GEO group, up to 2 channels can be configured to track L1 C/A code GEOs
The L1 C/A code and L2 C/A code measurements are used to derive ionospheric corrections.

Other Outputs & Inputs

- A 10 MHz output is available for use with an internal clock.
- Two serial ports provide:
 - raw satellite measurements (pseudorange, carrier & time)
 - receiver status data (communications & tracking)
 - raw satellite data (ephemeris & almanac)
 - fast code corrections for signal stability monitoring
- The receiver accepts an external input from a 10MHz atomic clock or its internal OCXO for synchronization.

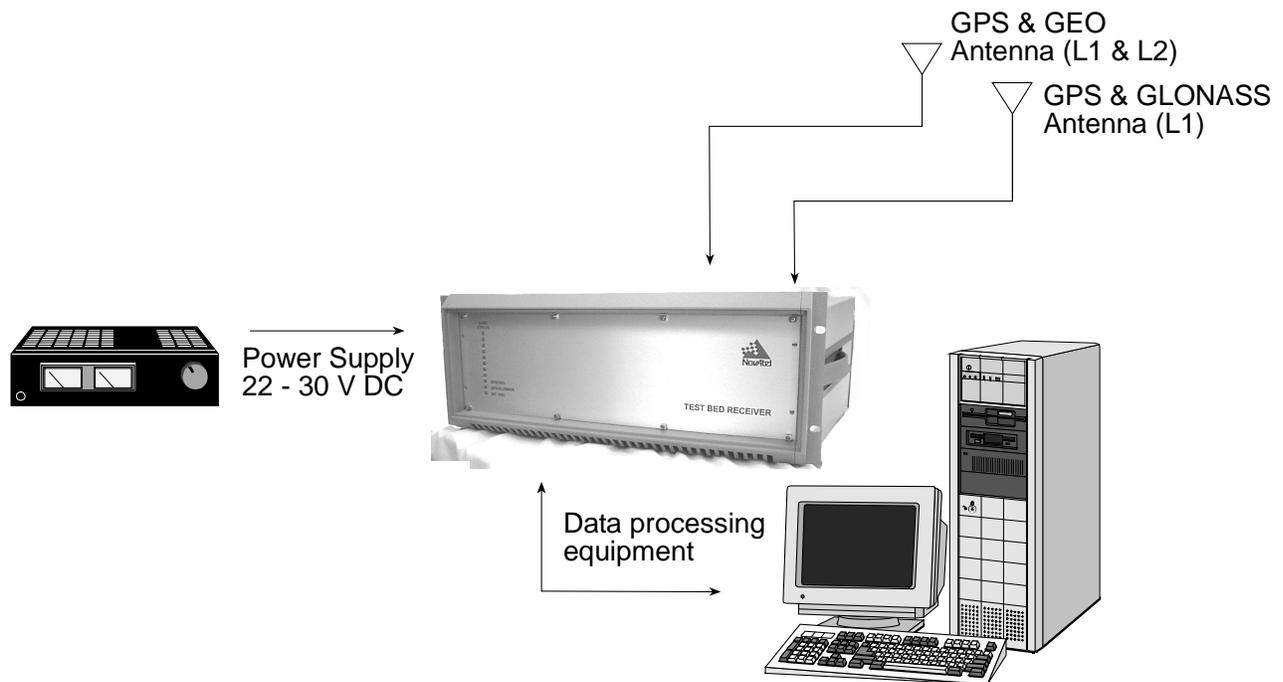
2 INSTALLATION OF TEST BED RECEIVER

This chapter provides sufficient information to allow you to set up and prepare the Test Bed Receiver for initial operation.

MINIMUM CONFIGURATION

In order for the Test Bed Receiver to function as a complete system, a minimum equipment configuration is required. This is illustrated in *Figure 3*.

Figure 3 Test Bed Minimum System Configuration



The recommended minimum configuration and required accessories are listed below:

- NovAtel Test Bed Receiver
- User-supplied L1/L2 GPS and L1 GLONASS antennas and LNA
- User-supplied power supply (+22 to +30 V DC, 5 A maximum)
- Optional (could use internal 10 MHz OCXO) user-supplied external frequency reference (10 MHz).
- User-supplied interface, such as a PC or other data communications equipment, capable of standard serial communications (RS-232C).
- User-supplied data and RF cables

Of course, your intended set-up may differ significantly from this minimum configuration. The Test Bed Receiver has many features that would not be used in the minimum configuration shown above. This section merely describes the basic system configuration, which you can modify to meet your specific situation.

For the minimum configuration, setting up the Test Bed Receiver involves the following steps:

1. Connect the user interface to the Test Bed Receiver (“GPS GLONASS” and/or “GPS GEO” connectors)
2. Install the GPS and GLONASS antennas and low-noise amplifier, and make the appropriate connections to the Test Bed Receiver (“GPS GLONASS ANT” or “GPS GEO ANT” connector)
3. Supply power to the Test Bed Receiver (“22-30 VDC” connector)

The connections on the rear panel are shown in *Figure 4* below:

Figure 4 Rear Panel of Test Bed Receiver



The information from each receiver subsection is accessed through individual RS–232 serial communication ports. The two ports using DE9P connectors are located on the back panel of the receiver. Serial baud rates up to 115,200 bps are usable selectable with 9600 bps set as the default configuration. The second serial port of each receiver subsection is used internally and is therefore not available for user access.

The receivers communicate with each other across the backplane within the enclosure. The GPS GEO receiver is considered the master as far as the time goes. The 1PPS output of the GPS GEO receiver is connected to the Mark In input of the GPS GLONASS receiver. The time information associated with the 1PPS pulse is sent from the GPS GEO to the GPS GLONASS across a high-speed (TLink) serial communication line on the backplane. The GPS GLONASS then synchronizes its time to that of the GPS GEO.

INTERNAL AND EXTERNAL OSCILLATORS

A 10 MHz OCXO is provided within the enclosure. The internal OCXO is connected to a BNC connector on the back panel of the receiver. Another BNC connector on the back panel routes the 10 MHz external oscillator signal through a splitter to the two receiver subsections. If the receiver is to be operated from the internal 10 MHz OCXO then a jumper cable is connected from the 10 MHz output BNC connector to the 10 MHz input BNC connector. If the receiver is to be operated from an external 10 MHz frequency source such as a Cesium or Rubidium oscillator then that frequency reference will be connected to the 10 MHz IN port on the rear panel of the receiver. In that case the 10 MHz OUT port should be terminated with a 50 Ω terminator.

Without an external oscillator the GPS GLONASS and GPS GEO will operate independently using their own on-board TCXO after they are given the appropriate software command. If an external oscillator input is not supplied, the GPS GLONASS card must be sent the command “SETTIMESYNC DISABLE”. The CLOCKADJUST command should also be enabled so that both receivers will independently try to align their time to GPS time. If the CLOCKADJUST

command is disabled, or if the EXTERNAL clock command is disabled, then the two receivers will drift away from each other in time. The normal mode of operation is to use either the internal OCXO or a highly stable external oscillator.

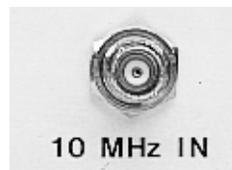
The 10 MHz OCXO is mounted within the enclosure on the Clock/Status card. This card has bi-colored LEDs that visually indicate when the receiver is powered and also reflect whether the receiver has passed its power on self-test. The lower LED will monitor the signal power of the internal 10 MHz OCXO. If it turns from green to off a failure of the OCXO or its power supply would be indicated. Only the first, second and third LED from the bottom are used. The others are only active when the enclosure is populated as a WAAS, MSAS, or EGNOS RIMS-C receiver.

CONNECTING THE EXTERNAL FREQUENCY REFERENCE

The Test Bed Receiver can be used with an external, user-supplied frequency reference; this would typically take the form of a high-accuracy oscillator. Please refer to *Appendix B* for the recommended specifications of this device.

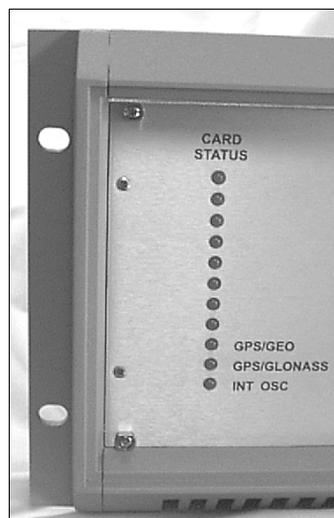
The frequency reference is connected to the 10 MHz BNC female connector on the rear panel of the Test Bed Receiver. Refer to *Figure 5* below.

Figure 5 **10 MHz In (External Frequency Reference) - Test Bed**



The 11th (bottom) LED on the front panel indicates the status of the internal clock reference. A *clear* LED indicates that no internal reference is present. *Green* indicates that the clock is present. Refer to *Figure 6* below.

Figure 6 **Lights on Front Panel of Test Bed Receiver**

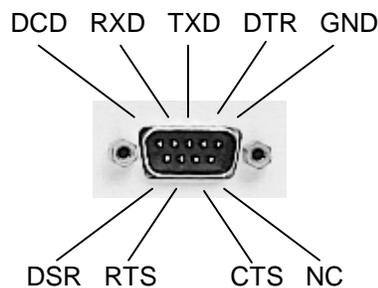


CONNECTING DATA COMMUNICATIONS EQUIPMENT

There are two serial ports on the back panel of the Test Bed Receiver; both are configured for RS-232 protocol. These ports make it possible for external data communications equipment - such as a personal computer - to communicate with the Test Bed Receiver. Each of these ports has a DE9P connector.

The GPS GLONASS and GPS GEO ports (see *Figure 7*) allow two-way communications. Each is configured as COM1 if you attempt to communicate directly with it. They are each connected to a GPSCard within the Test Bed Receiver unit. Each of these ports can be addressed independently of the other.

Figure 7 Pinout for GPS GLONASS and GPS GEO Ports - Test Bed



CONNECTING THE GPS ANTENNA

Selecting and installing an appropriate antenna system is crucial to the proper operation of the Test Bed Receiver.

The antenna connectors for both GPS and GLONASS are located on the back panel of the enclosure and are type TNC. Antenna power is provided to the center pin of these connectors. The power is 5 V DC with a current up to 100 mA. The power supply for the antenna originates from each receiver card in this enclosure and its status is reflected in the Antenna Status bit of either receiver subsystem.

Keep these points in mind when installing the antenna system:

- Ideally, select an antenna location with a clear view of the sky to the horizon so that each satellite above the horizon can be tracked without obstruction.
- Ensure that the antenna is mounted on a secure, stable structure capable of withstanding relevant environmental loading forces (e.g. due to wind or ice).

Use high-quality coaxial cables to minimize signal attenuation. The gain of the LNA must be sufficient to compensate for the cabling loss.

The antenna ports on the Test Bed Receiver have TNC female connectors, as shown in *Figure 8*.

Figure 8 Antenna Inputs - Test Bed



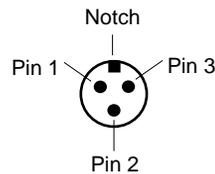
CONNECTING THE EXTERNAL POWER INPUT

The Test Bed Receiver requires one source of external regulated power. The input can be in the +22 to +30 V DC range. The receiver draws up to 3 A at start-up, but the steady-state requirement is approximately 1.5 A.

Five and twelve volt power supplies are installed internally within the enclosure. The 5-volt supply is used to power the two receivers and the antenna. The 12-volt supply is used for OCXO power. Both of these supplies receive their power from a connector on the enclosure back panel and accept DC power within a voltage range of +22 to +30 volts.

The power-input connector on the Test Bed Receiver is a 3-position chassis jack. It mates to a 3-position inline plug supplied with the Test Bed Receiver. Pin 1 (+22 to +30 V DC), and Pin 2 (GND) connect to the Test Bed Receiver's internal power supply, which performs filtering and voltage regulation functions. Pin 3 serves as ground connection protection. Refer to *Figure 9*.

Figure 9 External Power Connections - Test Bed



USING THE 10 MHz OUTPUT SIGNAL

The 10 MHz output provides a high-stability reference clock to the Test Bed Receiver. It permits the synchronization of the two receiver subsystems in the Test Bed Receiver. See *Internal and External Oscillators* on *Page 12* for more information.

If the receiver is to be operated from the internal 10 MHz OCXO then a jumper cable is connected from the 10 MHz output BNC connector to the 10 MHz input BNC connector (see *Figure 10*). If the receiver is to be operated from an external 10 MHz frequency source such as a Cesium or Rubidium oscillator then that frequency reference will be connected to the 10 MHz IN port on the rear panel of the receiver. In that case the 10 MHz OUT port should be terminated with a 50 Ω terminator.

Figure 10 10 MHz Output – Test Bed

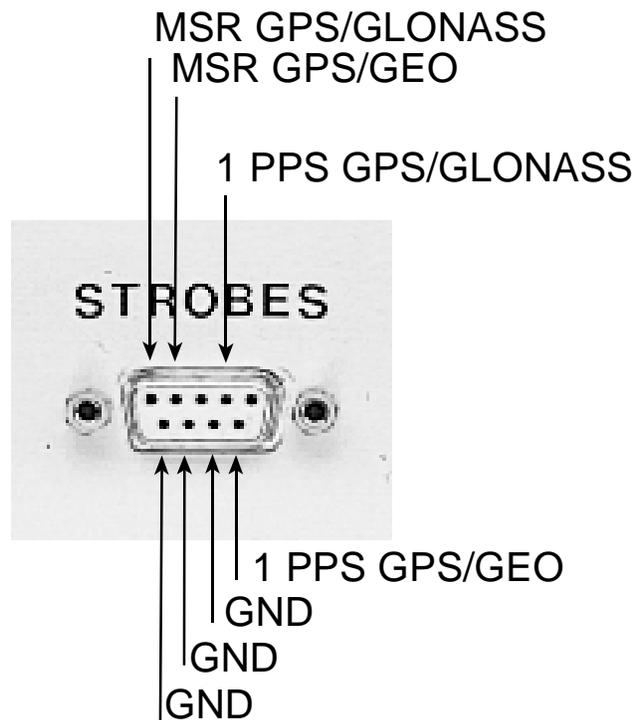


ACCESSING THE STROBE SIGNALS

A strobe port is located on the enclosure back panel. This is a diagnostic connector and is in the form of a DE9S connector (see *Figure 11*). The 1PPS and Measurement pulse from both receiver subsystems are available on this connector for verifying synchronization using an oscilloscope. These are the only strobe signals made available from the two receiver subsystems. The specifications and electrical characteristics of these signals are described in *Appendix B*.

The GPS GLONASS and GPS GEO ports are each connected to a GPS receiver within the Test Bed Receiver unit.

Figure 11 **Strobe 9-pin D-Connector Pinout - Test Bed**



3 OPERATION

Before operating the Test Bed Receiver for the first time, ensure that you have followed the installation instructions in *Chapter 2*.

From here on, it will be assumed that testing and operation of the Test Bed Receiver will be performed while using a personal computer (PC); this will allow the greatest ease and versatility.

PRE-START CHECK LIST

Before turning on power to the Test Bed Receiver, ensure that all of the following conditions have been met:

- The antenna(s) is (are) properly installed and connected.
- The PC is properly connected using a null-modem cable, and its communications protocol has been set up to match that of the Test Bed Receiver.
- The optional external frequency reference is properly installed, connected, powered-up, and stabilized.

Supply power to the Test Bed Receiver only after all of the above checks have been made. Note that the warm-up process may take several minutes, depending on ambient temperature.

SERIAL PORTS - DEFAULT SETTINGS

Because the Test Bed Receiver communicates with the user's PC via serial ports, both units require the same port settings. The communications settings of the PC should match these on the receiver:

- RS-232 protocol
- 9600 bits per second (bps)
- No parity
- 8 data bits
- 1 stop bit
- No handshaking
- Echo off

Once initial communications are established, the port settings for the Test Bed Receiver can be changed using the *COMn* command, which is described in the *MiLLennium Command Descriptions Manual*.

START-UP

The Test Bed Receiver's firmware resides in non-volatile memory. Supply power to the unit, wait a few moments for self-boot, and the Test Bed Receiver will be ready for command input.

There are two initial start-up indicators to let you know that the Test Bed Receiver's serial ports are ready to communicate:

1. Status lights on the Test Bed Receiver's front panel (lower three LEDs) should turn from *red* to *green* to indicate that all cards are healthy. If any one of the LEDs does not turn *green*, then the system should be considered unreliable. If this situation occurs, contact NovAtel Customer Service for assistance.
2. Your external terminal screen will display one of the following prompts:

Com1> if you are connected to the GPS GLONASS or GPS GEO serial port.

The Test Bed Receiver is now ready for command input from either of the two COM1 ports.

INITIAL COMMUNICATIONS WITH THE TEST BED RECEIVER

Communicating with the Test Bed Receiver is a straightforward process and is accomplished by issuing desired commands to the COM1 ports from an external serial communications device. For your initial testing and communications, you will probably be using either a remote terminal or a personal computer that is directly connected to a Test Bed Receiver's serial port by means of a null modem cable.

To change the default communication settings, such as bit rate, use the *COMn* command, see the *MiLLennium Command Descriptions Manual*.

When the Test Bed Receiver is first powered up, no activity information is transmitted from the COMn ports except for the **COM1>** prompt described in the *Start-Up* section above.

Commands are directly input to Test Bed Receiver using the external terminal. It should be noted that most commands do not echo a response to a command input. Return of the **COM1>** prompt indicates that the command has actually been accepted from the Test Bed Receiver. Note that *VERSION* is the only command that does provide an echo response other than the port prompt.

Examples:

1. If you type *VERSION* <Enter> from a terminal, this will cause the Test Bed Receiver to echo the firmware version information.
2. An example of a no-echo response to an input command is the *FIX POSITION* command. It can be input as follows:

```
COM1>fix position 51.113 -114.043 1060 <Enter>
```

This example illustrates command input to the COM1 port that sets the Test Bed Receiver's position. However, your only confirmation that the command was actually accepted is the return of the **COM1>** prompt.

If a command is erroneously input, the Test Bed Receiver will respond with the "Invalid Command Option" response followed by the **COM1>** prompt.

4 UPDATE OR UPGRADE YOUR GPSCARD

The MiLLennium stores its program firmware in non-volatile memory, which allows you to perform firmware upgrades and updates without having to return the MiLLennium to the distributor. New firmware can be transferred to the MiLLennium through a serial port, and the unit will immediately be ready for operation at a higher level of performance.

The first step in upgrading your receiver is to contact your local NovAtel dealer. Your dealer will assist you in selecting the best upgrade option that suits your specific GPS needs. If your needs are still unresolved after seeing your dealer then you can contact NovAtel directly through any of the methods described in the *Software Support* section, at the beginning of the *MiLLennium Command Descriptions Manual*.

When you call, be sure to have available your MiLLennium model number, serial number, and program revision level. This information is printed on the original shipping box as well as on the back side of the MiLLennium itself. You can also verify the information by issuing the VERSION command at the port prompt.

After establishing which new model/revision level would best suit your needs, and having described the terms and conditions, you will be issued with an authorization code (*auth-code*). The auth-code is required to unlock the new features according to your authorized upgrade/update model type.

There are two procedures to choose from, depending on the type of upgrade/update you require:

1. If you are **upgrading** to a higher performance model at the same firmware revision level (e.g. upgrading from a MiLLennium Standard rev. 4.50, to a MiLLennium RT-2 rev. 4.50), you can use the \$AUTH special command.
2. If you are **updating** to a higher firmware revision level of the same model (e.g. updating a MiLLennium Standard rev. 4.45 to a higher revision level of the same model, such as MiLLennium Standard rev. 4.50), you will need to transfer new program firmware to the MiLLennium using the *Loader* utility program. As the *Loader* and update programs are generally provided in a compressed file format, you will also be given a file decompression password. The *Loader* and update files can be found on NovAtel's FTP site at <http://www.novatel.ca>, or can be sent to you on floppy disk or by e-mail.

Your local NovAtel dealer will provide you with all the information that you require to update or upgrade your receiver.

UPGRADING USING THE \$AUTH COMMAND

The \$AUTH command is a special input command which authorizes the enabling or unlocking of the various model features. Use this command when upgrading to a higher performance MiLLennium model available within the same revision level as your current model (e.g., upgrading from a MiLLennium Standard rev. 4.50, to a MiLLennium RT-2 rev. 4.50). This command will only function in conjunction with a valid auth-code assigned by GPS Customer Service.

The upgrade can be performed directly from Loader's built-in terminal emulator, *GPSolution's* Command Line Screen, or from any other communications program. The procedure is as follows:

- 1) Power-up the MiLLennium and establish communications over a serial port (see *Chapter 3, Operation on Page 17*).
- 2) Issue the VERSION command to verify the current firmware model number, revision level, and serial number.
- 3) Issue the \$AUTH command, followed by the auth-code and model type. The syntax is as follows:

Syntax:

\$auth *auth-code*

where

`$auth` is a special command which allows program model upgrades
`auth-code` is the upgrade authorization code, expressed as *hhhh, hhhh, hhhh, hhhh, hhhh, model#* where the *h* characters are an ASCII hexadecimal code, and the *model#* would be ASCII text

Example:

```
$auth 17cb,29af,3d74,01ec,fd34,millennrt2
```

Once the \$AUTH command has been executed, the MiLLennium will reboot itself. Issuing the VERSION command will confirm the new upgrade model type and version number.

UPDATING USING THE LOADER UTILITY

Loader is required (instead of the \$AUTH command) when updating previously released firmware with a newer version of program and model firmware (e.g., updating a MiLLennium Standard rev. 4.45 to a higher revision level of the same model, such as MiLLennium Standard rev. 4.50). *Loader* is a DOS utility program designed to facilitate program and model updates. Once *Loader* is installed and running, it will allow you to select a host PC serial port, bit rate, directory path, and file name of the new program firmware to be transferred to the MiLLennium.

TRANSFERRING FIRMWARE FILES

To proceed with your program update, you must first acquire the latest firmware revision. You will need a file with a name such as OEMXYZ.EXE (where XYZ is the firmware revision level). This file is available from NovAtel's FTP site (<http://www.novatel.ca>), or via e-mail (support@novatel.ca). If transferring is not possible, the file can be mailed to you on floppy disk. For more information on how to contact NovAtel Customer Service please see the *Software Support* section at the beginning of the *MiLLennium Command Descriptions Manual*.

You will need at least 1 MB of available space on your hard drive. For convenience, you may wish to copy this file to a GPS sub-directory (e.g., C:\GPS\LOADER).

The file is available in a compressed format with password protection; Customer Service will provide you with the required password. After copying the file to your computer, it must be decompressed. The syntax for decompression is as follows:

Syntax:

```
[filename] -s[password]
```

where

filename is the name of the compressed file (but not including the .EXE extension)
 -s is the password command switch
password is the password required to allow decompression

Example:

```
oem442 -s12345678
```

The self-extracting archive will then generate the following files:

- LOADER.EXE *Loader* utility program
- LOADER.TXT Instructions on how to use the *Loader* utility
- XYZ.BIN Firmware version update file, where XYZ = program version level (e.g. 442.BIN)

USING THE LOADER UTILITY

The *Loader* utility can operate from any DOS directory or drive on your PC. The program is comprised of three parts: *Program Card* (authorization procedure), *Setup* (communications configuration) and *Terminal* (terminal emulator). The main screen is shown in *Figure 12*.

Figure 12 Main Screen of LOADER Program



If you are running *Loader* for the first time, be sure to access the *Setup* menu (step 3 below) before proceeding to *Program Card* (step 4 below); otherwise, you can skip step 3. The procedure is as follows:

1. Turn off power to the MiLLennium.
2. Start the *Loader* program.
3. From the main menu screen, select **Setup** to configure the serial port over which communication will occur (default: COM1), and the data transfer rates for both programming (default: 115 200 bits per second) and terminal emulation (default: 9600 bps). To minimize the time required, select the highest serial bit rate your PC can reliably support. *Loader* will verify and save your selections in a file named LOADER.SET, and return to the main menu screen.
4. From the main screen, select **Program Card**.
5. Select the disk drive (e.g., A, B, C, D) in which the update file (e.g. 442.BIN) is located. Select the path where the update program file is located (e.g., C:\GPS\LOADER); the directory from which you started *Loader* is the default path. Select the required update file (e.g. 442.BIN).
6. At the prompt, enter your update auth-code (e.g. 17b2,32df,6ba0,92b5,e5b9,millenrt2).
7. When prompted by the program, turn on power to the MiLLennium. *Loader* will automatically establish communications with the MiLLennium. The time required to transfer the new program data will depend on the bit rate, which was selected earlier.
8. When the transfer is complete, use a terminal emulator such as that in *Loader* (select **Terminal**) to issue the VERSION command; this will verify your new program version number. When using the terminal emulator in *Loader*, a prompt does not initially appear; you need to enter the command first, which then produces a response, after which a prompt will appear.
9. Exit *Loader* (select **Quit**).

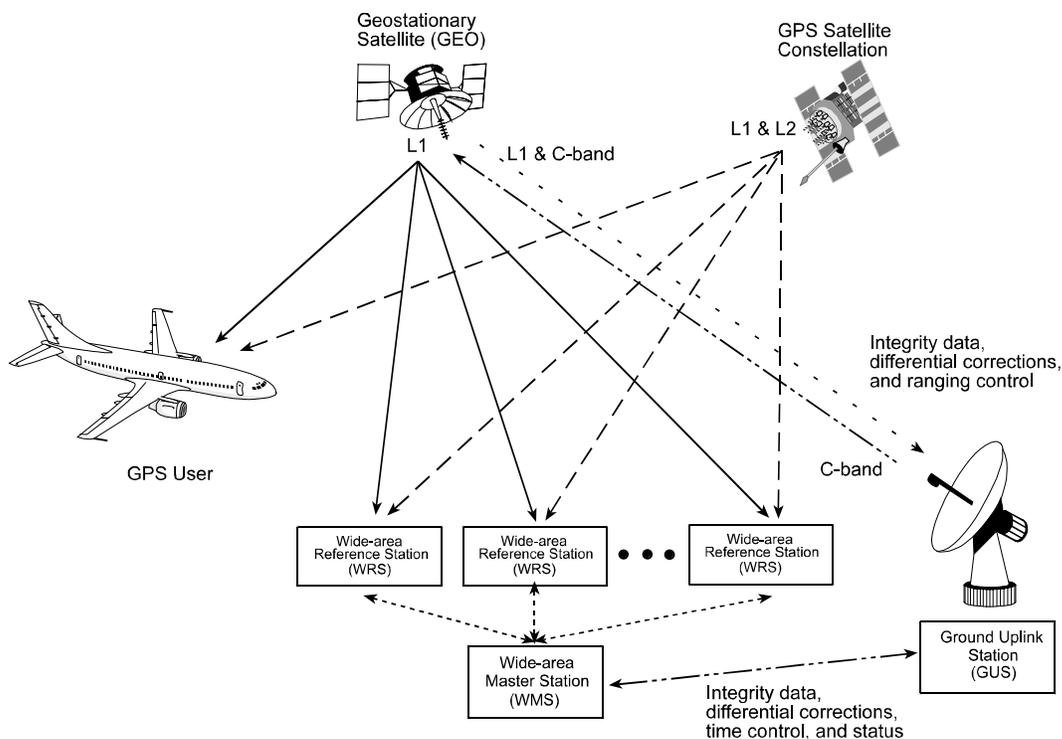
This completes the procedure required for field-updating a MiLLennium.

A WAAS OVERVIEW

The Wide Area Augmentation System (WAAS) is a safety-critical system which is designed to enable the GPS to meet the US Federal Aviation Administration (FAA) navigation performance requirements for domestic en route, terminal, non-precision approach and precision approach phases of flight. The primary functions of WAAS include:

- data collection
- determining ionospheric corrections, satellite orbits, satellite clock corrections and satellite integrity
- independent data verification
- WAAS message broadcast and ranging
- system operations & maintenance

Figure 13 The WAAS Concept



As shown in *Figure* , the WAAS is made up of a series of Wide Area Reference Stations, Wide Area Master Stations, Ground Uplink Stations and Geostationary Satellites (GEOs). The Wide Area Reference Stations, which are geographically distributed, pick up GPS satellite data and route it to the Wide Area Master Stations where wide area corrections are generated. These corrections are sent to the Ground Uplink Stations, which up-link them to the GEOs for re-transmission on the GPS L1 frequency. These GEOs transmit signals which carry accuracy and integrity messages, and which also provide additional ranging signals for added availability, continuity and accuracy. These GEO signals are available over a wide area and can be received and processed by ordinary GPS receivers. GPS user receivers are thus able to receive WAAS data in-band and use not only differential corrections, but also integrity, residual errors and ionospheric information for each monitored satellite.

The signal broadcast via the WAAS GEOs to the WAAS users is designed to minimize modifications to standard GPS receivers. As such, the GPS L1 frequency (1575.42 MHz) is used, together with GPS-type modulation - e.g. a Coarse/Acquisition (C/A) pseudorandom (PRN) code. In addition, the code phase timing is maintained close to GPS time to provide a ranging capability.

B GLONASS OVERVIEW

MILLENNIUM-GLONASS GPSCARD

The MiLlennium-GLONASS GPSCard can receive L1 signals from combined GPS/GLONASS satellites. This hybrid receiver offers combined GPS/GLONASS position solutions.

An RTK version of the MiLlennium-GLONASS GPSCard performs significantly better when tracking GPS and GLONASS satellites, than when tracking GPS satellites only. Faster floating-ambiguity solutions mean shorter observations times.

The use of GLONASS in addition to GPS provides very significant advantages:

- increased satellite signal observations
- markedly increased spatial distribution of visible satellites
- reduction in the Horizontal and Vertical Dilution of Precision factor
- no special precision degrading mode in GLONASS (unlike GPS Selective Availability mode)
- single frequency (L1) positioning accuracy is about 4 times better for GLONASS as compared to GPS single frequency signals
- improved RTK performance
- decreased occupation times result in faster surveying

The MiLlennium-GLONASS GPSCard is capable of combined GPS/GLONASS operation. In order to track GLONASS satellites the MiLlennium must track at least one GPS satellite to determine the GPS/GLONASS time offset. In order to determine a position in GPS-Only mode the receiver must track a minimum of four satellites, representing the four unknowns of 3-D position and time. In combined GPS/GLONASS mode the receiver must track five satellites, representing the same four previous unknowns as well as the GPS/GLONASS time offset.

With the availability of combined GPS/GLONASS receivers, users have access to a potential 48-satellite combined system. With 48 satellites, performance in urban canyons and other locations with restricted visibility, such as forested areas, is improved, as more satellites are visible in the non-blocked portions of the sky. A larger satellite constellation also improves real-time carrier-phase differential positioning performance. In addition, stand-alone position accuracies improve with the combined system, and in the absence of deliberate accuracy degradation, differential GLONASS requires a much lower correction update rate.

Table 1 lists the two types of NovAtel MiLlennium-GLONASS GPSCards available, each capable of multiple positioning modes of operation:

Table 1 Positioning Modes of Operation

Positioning Modes of Operation	MiLlennium-GLONASS GPSCard		
	MiLlEn-G	MiLlEn-G-RT10	TESTBEDGLO
Single Point	√	√	√
Waypoint Navigation	√	√	√
Pseudorange differential corrections (TX & RX)	√	√	√
RTK pseudorange & carrier-phase double differencing; < 10 cm RMS accuracies (floating)	X	√	X

The NovAtel MiLLennium-GLONASS GPSCards can be applied in mining and machine control, robotics, flight inspection, marine navigation, agriculture, military, direction finding and other custom OEM applications.

Some of the information used to create the Introduction was obtained from two sources.

1. Langley, Richard B. "GLONASS: Review and Update". *GPS World*, July 1997. 46-51
2. Kleusberg, Alfred. "Comparing GPS and GLONASS". *GPS World*, December 1990. 52-54

GLONASS SYSTEM DESIGN

As with GPS, the GLONASS system uses a satellite constellation to ideally provide a GLONASS receiver with six to twelve satellites at most times. A minimum of four satellites in view allows a GLONASS receiver to compute its position in three dimensions, as well as become synchronized to the system time.

The GLONASS system design consists of three parts:

- The Space segment
- The Control segment
- The User segment

All these parts operate together to provide accurate three-dimensional positioning, timing and velocity data to users worldwide.

The Space Segment

The Space Segment is the portion of the GLONASS system that is located in space, that is, the GLONASS satellites and any ancillary spacecraft that provide GLONASS augmentation information (i.e., differential corrections, integrity messages, etc.). This segment is composed of the GLONASS satellites which, when complete, will consist of 24 satellites in three orbital planes, with eight satellites per plane, see *Figure 14, Page 25*. Following are points about the GLONASS space segment.

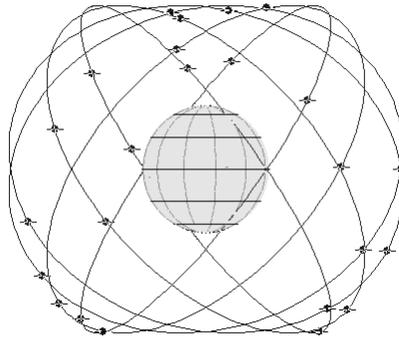
- The orbit period of each satellite is approximately 8/17 of a sidereal day such that, after eight sidereal days, the GLONASS satellites have completed exactly 17 orbital revolutions. A sidereal day is the rotation period of the earth and is equal to one calendar day minus four minutes.
- Because each orbital plane contains eight equally spaced satellites, one of the satellites will be at the same spot in the sky at the same sidereal time each day.
- The satellites are placed into nominally circular orbits with target inclinations of 64.8 degrees and an orbital height of about 19,123 km, which is about 1,060 km lower than GPS satellites.
- The GLONASS satellite signal identifies the satellite and provides:
 - the positioning, velocity and acceleration vectors at a reference epoch for computing satellite locations
 - synchronization bits
 - data age
 - satellite health
 - offset of GLONASS time
 - almanacs of all other GLONASS satellites.
- The GLONASS satellites each transmit on different L1 and L2 frequencies, with the P code on both L1 and L2, and with the C/A code, at present, only on L1. L1 is currently centered at 1602 - 1615.5 MHz.
- Some of the GLONASS transmissions initially caused interference to radio astronomers and mobile communication service providers. The Russians consequently agreed to reduce the number of

frequencies used by the satellites and to gradually change the L1 frequencies to 1598.0625 - 1609.3125 MHz. Eventually the system will only use 12 primary frequency channels (plus two additional channels for testing purposes).

- System operation (24 satellites and only 12 channels) can be accomplished by having antipodal satellites, satellites in the same orbit plane separated by 180 degrees in argument of latitude, transmit on the same frequency. This is possible because the paired satellites will never appear at the same time in your view. Already, eight pairs of satellites share frequencies.

Unlike GPS satellites, all GLONASS satellites transmit the same codes. They derive signal timing and frequencies from one of three onboard cesium atomic clocks operating at 5 MHz. The signals are right-hand circularly polarized, like GPS signals, and have comparable signal strength.

Figure 14 View of GLONASS Satellite Orbit Arrangement



The Control Segment

The Control Segment consists of the system control center and a network of command tracking stations across Russia. The GLONASS control segment, similar to GPS, must monitor the status of satellites, determine the ephemerides and satellite clock offsets with respect to GLONASS time and UTC (SU) time, and twice a day upload the navigation data to the satellites.

The User Segment

The User Segment consists of equipment (such as a NovAtel MiLLennium-GLONASS GPSCard receiver) which tracks and receives the satellite signals. This equipment must be capable of simultaneously processing the signals from a minimum of four satellites to obtain accurate position, velocity and timing measurements. Like GPS, GLONASS is a dual military/civilian-use system. Selective availability, however, will not be implemented on GLONASS C/A code. The system's potential civil applications are many and mirror that of GPS.

TIME

The GLONASS satellites broadcast their time within their satellite messages. NovAtel's MiLLennium GLONASS GPSCard is able to receive and record both time references as well as report the offset information between GPS and GLONASS time (see the *GCLA/B* log on *Page 41*). Although similar, GPS and GLONASS have several differences in the way they report time. Please see the following sections for information of GLONASS time.

GLONASS TIME VS. LOCAL RECEIVER TIME

GLONASS time is based on an atomic time scale similar to GPS. This time scale is Universal Time Coordinated as maintained by the former Soviet Union (UTC (SU)).

Unlike GPS, the GLONASS time scale is not continuous and must be adjusted for periodic leap seconds. Leap seconds are applied to all UTC time references about every other year as specified by the International Earth Rotation Service (IERS). Leap seconds are necessary because the orbit of the earth is not uniform and not as accurate as the atomic time references.

GLONASS time is maintained within 1 ms of UTC (SU) by the control segment with the remaining portion of the offset broadcast in the navigation message. As well, the GLONASS time is offset from UTC (SU) by plus three hours due to control segment specific issues. The *GCLA/B* log (see *Page 41*) contains the offset information between GPS and GLONASS time.

DATUM

Because a consistent transformation between WGS84 and the Parametry Zemli 1990 (PZ90) or, in English translation, Parameters of the Earth 1990 geodetic datum has not been defined, we have allowed for a new command, PZ90TOWGS84, and a new parameter, PZ90, for the DATUM command.

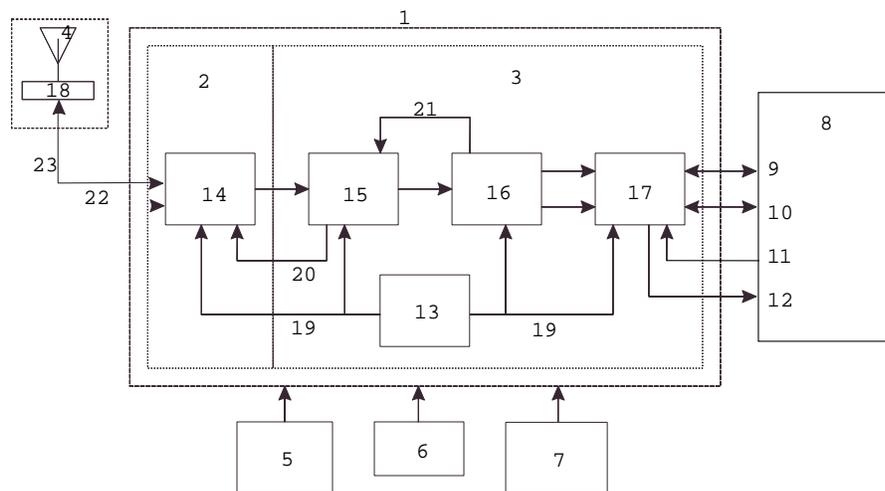
The PZ90TOWGS84 command (see *Page 35*) is intended to define the PZ90 transform for transferring GLONASS satellite coordinates to WGS84. However, it can also be used, in conjunction with the DATUM PZ90 command (see the *DATUM* command in the *MiLLennium Command Descriptions Manual*), to allow for position output in a user-defined PZ90 frame. The PZ90TOWGS84 command will override the default values for the DATUM PZ90 command and set them to the user-defined values. If the PZ90TOWGS84 command is not issued, the DATUM PZ90 command will use the default PZ90 values (see the *PZ90TOWGS84* command on *Page 35*) for the output position parameters. The PZ90 transform parameters can be saved in user-configurable memory for immediate use on power up.

FUNCTIONAL OVERVIEW

MILLENNIUM-GLONASS GPSCARD SYSTEM

The MiLLennium-GLONASS GPSCard consists of a radio frequency (RF) and a digital electronics section. Prior to operation, a GPS/GLONASS antenna, power supply, and data and signal interfaces must be connected. The overall system is represented in *Figure 15*. A brief description of each section follows.

Figure 15 MiLLennium-GLONASS GPSCard System Functional Diagram



Reference	Description	Reference	Description
1	MiLLennium-GLONASS GPSCard	11	Input timing strobe
2	RF section	12	Output timing strobe
3	Digital section	13	VCTCXO
4	Antenna capable of receiving L1 signal GPS/GLONASS antenna or user-supplied	14	RF - IF sections, NovAtel
5	Optional user-supplied LNA power (0 - 30 VDC)	15	Signal Processor
6	User-supplied power (5 VDC)	16	32-bit CPU
7	Optional external oscillator (5 or 10 MHz)	17	System I/O
8	User-supplied data and signal processing equipment	18	LNA
9	COM1	19	Clock signals
10	COM2	20	AGC signals
		21	Control signals
		22	RF and power connectors
		23	Primary antenna feed

GPS/GLONASS ANTENNA

The purpose of the GPS/GLONASS antenna is to convert the electromagnetic waves transmitted by the combined GPS/GLONASS satellites at the L1 frequency (1575.42 MHz for GPS and 1602 - 1615.5 MHz for GLONASS) into RF signals. The MiLLennium-GLONASS GPSCard will function best with an active GPS/GLONASS antenna; there is a hardware provision to select an internal or external DC power supply for an active GPS/GLONASS antenna. Note that the antenna self-test will return a “fail” condition if a passive antenna is used (for further information on self-test status codes, please see the *RVSA/B log* in the *MiLLennium Command Descriptions Manual*. NovAtel active antennas are recommended.

NovAtel offers the 504 and 514 model antennas to work with your MiLLennium-GLONASS GPSCard system. Both antennas use low-profile microstrip technology and include band-pass filtering and an LNA. The GPS/GLONASS antenna you choose will depend on your particular application. The NovAtel antennas available to work with your MiLLennium-GLONASS GPSCard system are single-frequency models, and each of these models offers exceptional phase-center stability as well as a significant measure of immunity against multipath interference. Both models have an environmentally-sealed radome.

NovAtel also offers high-quality coaxial cable in standard 5 (Model C005), 15 (Model C015) and 30 m (Model C030) lengths. These come with a TNC male connector at each end. Should your application require the use of cable longer than 30 m you will find the application note *Extended Length Antenna Cable Runs* at our website, <http://www.novatel.ca>, or you may obtain it from NovAtel Customer Service directly, see the *Software Support* section at the beginning of the *MiLLennium Command Descriptions Manual* for contact information.

While there may be other coaxial cables and antennas on the market that may also serve the purpose, please note that the performance specifications of the MiLLennium-GLONASS GPSCard are warranted only when it is used with NovAtel-supplied accessories.

RADIO FREQUENCY (RF) SECTION

The MiLLennium-GLONASS GPSCard receives partially filtered and amplified GPS and GLONASS signals from the antenna via the coaxial cable. The RF section does the following:

- filters the RF signals to reduce noise and interference
- down-converts (with further band-limiting) the RF signals to intermediate frequencies (IFs) that are suitable for the analog-to-digital (A/D) converter in the digital electronics section
- amplifies the signals to a level suitable for the A/D converter in the digital electronics section
- receives an automatic gain control (AGC) input from the digital signal processor (DSP) to maintain the IF signals at a constant level
- supplies power to the active antenna through the coaxial cable while maintaining isolation between the DC and RF paths. A hardware jumper configuration is provided to select an internal or external DC power supply for the active GPS/GLONASS antenna.

The RF section can reject a high level of potential interference (e.g., MSAT, Inmarsat, cellular phone, and TV sub-harmonic signals).

DIGITAL ELECTRONICS SECTION

The digital section of the MiLLennium-GLONASS GPSCard receives down-converted, amplified combined GPS/GLONASS signals which it digitizes and processes to obtain a GPS solution (position, speed, direction and time). The digital section consists of an analog-to-digital converter, a 32-bit 25 MHz system processor, memory, control and configuration logic, signal processing circuitry, serial peripheral devices, and supporting circuitry. I/O data and timing strobe signals are routed to and from the board via a 64-pin DIN 41612 Type B male connector. Two EIA RS-232C serial

communications ports support user-selectable bit rates of 300 - 115,200 bps, with a default of 9600 bps. The digital section does the following:

- converts the IF analog signals to a digital format
- tracks the C/A codes and carrier phases of the satellites in use
- performs channel and loop control
- performs position computation
- executes navigation software
- performs database management
- monitors self-test system status
- controls diagnostic LEDs: a red one which only lights up to indicate an error condition, and a green one (the “heartbeat”) which blinks on and off at approximately 1 Hz to indicate normal operation.
- controls I/O functions

You configure the MiLLennium-GLONASS GPSCard using special commands (see *Appendix D GLONASS Commands and Logs* on Page 34). In turn, the MiLLennium-GLONASS GPSCard presents information to you in the form of pre-defined logs in a number of formats. In addition, when a MiLLennium-GLONASS GPSCard is linked to a NovAtel GPSCard receiver or second MiLLennium-GLONASS GPSCard for differential positioning, they can communicate directly through their serial ports.



C WAAS COMMANDS AND LOGS

These commands and logs differ from the versions described in the MiLLennium Command Descriptions Manual for the Test Bed Receiver at the time of this publication.

COMMANDS

CONFIG

This command switches the channel configuration of the GPSCard between pre-defined configurations. When invoked, this command loads a new satellite channel-configuration and forces the GPSCard to reset. The types of configurations possible are listed by entering this command:

```
HELP CONFIG
```

In some applications, only the standard (default) configuration will be listed in response. The standard configuration of a MiLLennium GPSCard consists of 12 L1/L2 channel pairs.

Syntax:

```
CONFIG cfgtype
```

Command	Option	Description	Default
CONFIG		Command	
cfgtype	(none)	Displays present channel configuration	WF2L1L2 for TESTBEDW
	configuration name	Loads new configuration, resets GPSCard: TESTBEDW WF2L1L2 8 L1/L2 + 2 WAAS FEC WF1L1L2 10 L1/L2 + 1 WAAS FEC L1L2 12 L1/L2 MiLLen-STD STANDARD 12 GPS WAASCORR 10 GPS + 1 WAAS WAASCORR2 8 GPS + 2 WAAS	STANDARD for MiLLen-STD

IONOMODEL

This command allows the user to influence what ionospheric corrections the card uses. This command currently does not effect the ionospheric model that is used when the card is operating in RTK mode. Additional range values are reserved for future use.

The MiLLennium by default computes ionospheric corrections by attempting to use L1 & L2 signals first. To use the ionospheric corrections issued by the WAAS GEO satellite as a first choice, you need to issue the IONOMODEL WAAS command.

Syntax:

IONOMODEL [keyword]

Syntax	Range Value	Description
IONOMODEL	-	Command
keyword	WAAS	Card will use ionospheric corrections from WAAS broadcast messages as a first choice You must verify that the CONFIG command is set to either WF1L1L2 or WF2L1L2 for this command to work, see <i>Page 30</i> .
	L1L2	Card will use ionospheric corrections derived from L1 and L2 GPS measurements as a first choice. Card must have L2 observations in order for this setting to be effective.
	KLOBUCHAR ¹	Card will use ionospheric corrections as calculated by the broadcast klobuchar model parameters as a first choice.
	AUTO	Card will decide which ionospheric corrections to use based on availability. (default)

Note: You cannot change GPSCard modes on the fly because once a CONFIG command is issued, the card resets itself and starts the new mode requested.

¹ Please refer to ICD-GPS-200 for a description of the Klobuchar model and its parameters. To obtain copies of ICD-GPS-200 from the ARINC Research Corporation, contact them at the address given in *Appendix F* of the *MiLLennium Command Descriptions Manual*.



WAASCORRECTION

This command allows you to have an affect on how the card handles WAAS corrections. The card will switch automatically to Pseudorange Differential (RTCM or RTCA) or RTK if the appropriate corrections are being received, regardless of the current setting.

The ability to incorporate the WAAS corrections into the position solution is not the default mode. First enter the following command to put the card in WAAS mode:

```
config waascorr
```

Note: You cannot change GPSCard modes on the fly because once a CONFIG command is issued the card resets itself and starts the newly requested mode.

To enable the position solution corrections, you must issue the WAASCORRECTION ENABLE command.

Syntax:

```
WAASCORRECTION keyword [PRN] [mode]
```

Syntax	Range Value	Description
WAASCORRECTION	-	Command
keyword	ENABLE DISABLE	- Card will use the WAAS corrections it receives. - Card will not use the WAAS corrections that it receives.
[PRN]	120-138	- Card will use WAAS corrections from this PRN. - If no PRN is specified, the receiver will automatically select the best PRN (with the highest elevation and with a lock time greater than 134 seconds) to use when multiple GEOs are being tracked. If no GEO has a lock time of more than 134 seconds, the GEO with the highest amount of lock time is selected.
[mode]	NONE WAATESTMODE EGNOSTESTMODE	- Default. Card will interpret Type 0 messages as they are intended (as do not use). - Card will interperet Type 0 messages as Type 2. - Card will ignore the usual interpretation of Type 0 messages (as do not use) and continue.

Example:

```
waascorrection enable 122 waastestmode
```

LOGS

RCCA RECEIVER CONFIGURATION

This log outputs a list of all current GPSCard command settings. Observing this log is a good way to monitor the GPSCard configuration settings. See *RCCA* in the *MiLLennium Command Descriptions Manual* for the *RCCA* default list.

The following are the default parameters, for the TESTBEDW receiver, that are different than the standard Millenium WAAS receiver configuration:

CLOCKADJUST DISABLE

EXTERNALCLOCK OCXO

LOG CONSOLE TM1A ONTIME 10 HOLD*

* The logging of the TM1A log is done in order to time synchronize the TESTBEDGLO receiver to the TESTBEDW receiver.

The following are the default parameters, for the TESTBEDGLO receiver, that are different than the standard Millenium Glonass receiver configuration:

CLOCKADJUST DISABLE

EXTERNALCLOCK OCXO

SETTIMESYNC ENABLE*

* The SETTIMESYNC ENABLE allows the TESTBEDGLO receiver to accept the TM1A logs from the TESTBEDW receiver for time synchronization.

D GLONASS COMMANDS AND LOGS

GLONASS-SPECIFIC COMMANDS

This chapter describes MiLLennium-GLONASS GPSCard commands important to GLONASS.

GLONASS-specific commands are generated by using information obtained from the GLONASS satellite system. Please see the following sections for definitions of these commands.

DGLOTIMEOUT

The differential GLONASS time out (DGLOTIMEOUT) command's function is to set the maximum age of differential data that will be accepted when operating as a remote station. Differential data received that is older than the specified time will be ignored.

The ephemeris delay of the reference station is the same as for GPS and can be set using the DGPSTIMEOUT command (refer to the *MiLLennium Command Descriptions Manual* for information on this command).

Since there is no Selective Availability (SA) on the GLONASS correction the degradation over time is considerably less. It could be useful to allow a longer timeout for GLONASS than GPS.

Syntax:

DGLOTIMEOUT delay

Options:

delay: 2 - 1000 (seconds) (default 60)

PZ90TOWGS84

This command allows the user to input the Helmert transformation relating the GLONASS PZ90 reference frame to the GPS WGS-84 reference frame. In this case, (x,y,z) is the desired WGS-84 coordinate set and (u,v,w) is the given coordinate set in PZ90. The transformation is defined by an origin offset $(\Delta x, \Delta y, \Delta z)$, a linear scale factor (δs) and a series of small angle rotations (ϵ, ϕ, ω) , given in radians, around the u, v and w axes respectively. By default, the values are set to those published by Misra et al. (ION GPS 96, pg 307).

There are a number of different transformations that have been published but the majority of them are optimized for the particular region of the planet that the data was collected in. One of the objectives of the current International Glonass Experiment (IGE) is to accurately determine a PZ90 to WGS-84 transformation that is consistent on a global scale.

The PZ90TOWGS84 command can be used in conjunction with the DATUM PZ90 command (see *Datum on Page 26*) to allow for position output in a user-defined PZ90 frame.

The relevant parameters for the PZ90 ellipsoid are from the GLONASS Interface Control Document (ICD) version 4.0, 1998 Coordination Scientific Information Center (CSIC). Please see the following table for the reference ellipsoid constants.

ELLIPSOID	a (metres)	1/f	f
Parameters of Earth 1990	6378136.0	298.257839303	0.00335280374302

Syntax:

PZ90TOWGS84 option $[\Delta x]$ $[\Delta y]$ $[\Delta z]$ $[\delta s]$ $[\epsilon]$ $[\phi]$ $[\omega]$

Options:

ARGUMENT	DESCRIPTION
DEFAULT	Set to default Helmert transformation parameters
SET	Set to user specified values (all must be specified, see the following section of this table)
PARAMETER	DESCRIPTION
Δx	Origin offset in x direction [m]
Δy	Origin offset in y direction [m]
Δz	Origin offset in z direction [m]
δs	Scale factor given in parts per million (ppm), final linear scale factor given as $(1 + \delta s * 10^{-6})$
ϵ	Small angle rotation around u axis [arcsec]. A positive sign for counter clockwise direction and a negative sign for clockwise direction taking into consideration that the transformation is going from PZ90 to WGS84.
ϕ	Small angle rotation around v axis [arcsec]. A positive sign for counter clockwise direction and a negative sign for clockwise direction taking into consideration that the transformation is going from PZ90 to WGS84.
ω	Small angle rotation around w axis [arcsec]. A positive sign for counter clockwise direction and a negative sign for clockwise direction taking into consideration that the transformation is going from PZ90 to WGS84.

Example:

```
PZ90TOWGS84 DEFAULT
PZ90TOWGS84 SET 0.1,0.4,-0.3,6,0,0,4
```

NOTE: The format and sign conventions in this command are set up to conform to the given reference and differ from the NovAtel USERDATUM command.

UNIMPLEMENTED COMMANDS

Currently, the ability to set satellite health, and the ability to de-weight the range of a satellite in the solution computations, is not enabled for GLONASS. Because of this, the following commands will not work with the MiLLennium-GLONASS GPSCard for GLONASS satellites.

- SETHEALTH
- RESETHEALTH
- RESETHEALTHALL
- LOCKOUT

NOTE: The unimplemented commands are disabled for GLONASS satellites only. These commands can still be used with GPS satellites.

If, by mistake, you issue an unimplemented command to the MiLLennium-GLONASS GPSCard for a GLONASS satellite, the MiLLennium-GLONASS GPSCard will simply inform you that the PRN is invalid. The MiLLennium-GLONASS GPSCard is unable to accept a GLONASS PRN as an argument.

For further information on these commands, please consult the *MiLLennium Command Descriptions Manual*.

GLONASS-SPECIFIC LOGS

GLONASS-specific logs provide data by using information obtained from the GLONASS satellite system. Following are the descriptions of MiLLennium-GLONASS GPSCard's CALA/B, GALA/B, GCLA/B and GEPA/B logs. The syntax and fields are as described below.

CALA/B CALIBRATION INFORMATION

GPS satellites all broadcast on the same frequency but broadcast different codes. GLONASS satellites broadcast on different frequencies but use the same code. The former technique is known as Code Division Multiple Access (CDMA) while the latter is known as Frequency Division Multiple Access (FDMA).

Frequency dependent characteristics of the hardware result in small biases in the GLONASS pseudoranges. You can enter calibration numbers for the various frequencies which will be subtracted from each pseudorange with the CALA/ B input. The numbers can also be output as a log, CALA/B.

CALA

Structure:

\$CALA	week	sec	reserved	reserved
--------	------	-----	----------	----------

bias 1	std. dev. bias 1
--------	------------------

...	
bias 32	std. dev. bias 32

[CR][LF]	*xx
----------	-----

Field #	Field	Description	Example
1	\$CALA	Log Header	\$CALA
2	Week	GPS week number	992
3	Sec	GPS time into week, in seconds	453075
4	Reserved for future use		
5	Reserved for future use		
6,7	Bias 1, Std. Dev. Bias 1	Pseudorange bias for frequency, Std Dev of bias in meters	-0.491, 0.050
8, 9,	Bias 2, Std Dev Bias 2		1.070,0.041
10, 11,	Bias 3, Std Dev Bias 3		1.029,0.041
....
50, 51,	Bias 23, Std Dev Bias 23		-1.999,0.500,
52, 53,	Bias 24, Std Dev Bias 24		-2.813,0.500,
....	Bias 25, Std Dev Bias 25		0.000,5.000
68, 69,
	Bias 32, Std Dev Bias 32		0.000,5.000
70	* xx		Checksum
71	[CR][LF]	Sentence terminator	[CR][LF]

Example:

```

$CALA,4,480377,2,FFFFFF00,1.070,0.041,1.029,0.041,1.054,0.043,0.646,0.041,0.
735,0.041,0.526,0.040,0.456,0.039,
0.520,0.040,0.148,0.040,0.469,0.039,0.156,0.040,0.000,0.000,0.115,0.039,
-0.281,0.040,-0.269,0.039,-0.246,0.039,
-0.685,0.039,-0.391,0.039,-0.661,0.039,-0.967,0.040,-1.121,0.500,
-1.471,0.500,-1.999,0.500,
-
2.813,0.500,0.000,5.000,0.000,5.000,0.000,5.000,0.000,5.000,0.000,5.000,0.00
0,5.000,0.000,5.000,
0.000,5.000*2A[CR][LF]

```



CALB

Format:

Message ID = 87

Message byte count = 32 + (16 * 32)

Field #	Data	Bytes	Format	Units	Offset
1	Sync	3	char		0
	Checksum	1	char		3
	Message Id	4	integer		4
	Message byte count	4	integer	bytes	8
2	Week number	4	integer	weeks	12
3	Seconds of week	8	double	seconds	16
4	Reserved for future use				
5	Reserved for future use				
6	GloBias (*32)				32
	dBias	8	double	meters	
	dStdev	8	double	meters	

GALA/B ALMANAC INFORMATION

The GLONASS almanac reference time and week are in GPS time coordinates. GLONASS ephemeris information is available through the GEPA/B log.

GALA

Structure:

\$GALA	week	seconds	week	time	SVID	freq	health	TlambdaN
--------	------	---------	------	------	------	------	--------	----------

LambdaN	deltal	ecc	argperig	deltaT	deltaTD	tau	*xx	[[CR]][LF]
---------	--------	-----	----------	--------	---------	-----	-----	------------

Field #	Field	Description	Example
1	\$GALA	Log Header	\$GALA
2	Week	GPS Week, in weeks	991
3	Seconds	GPS Time, in seconds	496470.59
4	Week	GPS Week for almanac reference time (GLONASS time in GPS format), in weeks	991
5	Time	GPS Time for almanac reference time (GLONASS time in GPS format), in seconds	374232.88
6	SVID	Slot number for satellite, ordinal	16
7	Freq	Frequency for satellite, ordinal	22
8	Health	Ephemeris Health (1 = GOOD, 0 = BAD)	1
9	TlambdaN	GLONASS Time of ascending node equator crossing, in seconds	3.94199E+004
10	LambdaN	Longitude of ascending node equator crossing (PZ90), in radians	-9.2257260E-001
11	Deltal	Correction to nominal inclination, in radians	3.02841363E-002
12	Ecc	Eccentricity	1.49440765E-003
13	ArgPerig	Argument of perigee (PZ90), in radians	1.04694189E-001
14	DeltaT	Offset to nominal orbital period, in seconds	-2.6561113E+003
15	DeltaTD	Rate of orbital period, in seconds per orbital period	3.66210937E-004
16	Tau	Clock offset, in seconds	-2.0217896E-004*38

Example:

```
$GALA,991,496470.59,991,374232.88,16,22,1,3.94199E+004,-9.2257260E-001
3.02841363E-002,1.49440765E-003,1.04694189E-001,-2.6561113E+003,
3.66210937E-004,-2.0217896E-004*38
```

GALB

Format:

Message ID = 78

Message byte count = 112

Field #	Data	Bytes	Format	Units	Offset
1	Sync	3	char		0
	Checksum	1	char		3
	Message Id	4	integer		4
	Message byte count	4	integer	bytes	8
2	Week number	4	integer	weeks	12
3	Seconds of week	8	double	seconds	16
4	Reference week (GLONASS time in GPS format)	4	integer	weeks	24
5	Reference time (GLONASS time in GPS format)	8	double	seconds	28
6	Slot number	4	integer	ordinal	36
7	Frequency	4	integer	ordinal	40
8	Health	4	integer	-	44
9	Ascending node time	8	double	seconds	48
10	Ascending node longitude	8	double	rad	56
11	Inclination correction	8	double	rad	64
12	Eccentricity	8	double	-	72
13	Argument of perigee	8	double	rad	80
14	Orbital period correction	8	double	seconds	88
15	Orbital period rate	8	double	s/orbit	96
16	Clock offset to UTC	8	double	seconds	104

GCLA/B CLOCK INFORMATION

This log contains the time difference information between GPS and GLONASS time as well as status flags. The status flags are used to indicate the type of time processing used in the least squares adjustment. GPS and GLONASS time are both based on the Universal Time Coordinated (UTC) time scale with some adjustments. GPS time is continuous and does not include any of the leap second adjustments to UTC applied since 1980. The result is that GPS time currently leads UTC time by 13 seconds.

GLONASS time applies leap seconds but is also three hours ahead to represent Moscow time. The nominal offset between GPS and GLONASS time is therefore due to the three hour offset minus the leap second offset. Currently this value is at 10787 seconds with GLONASS leading. As well as the nominal offset, there is a residual offset on the order of nanoseconds which must be estimated in the least squares adjustment. The GLONASS-M satellites will broadcast this difference in the navigation message.

This log will also contain information from the GLONASS navigation data relating GLONASS time to UTC.

GCLA

Structure:

\$GCLA	week	sec	nominal offset	residual offset	residual offset variance
--------	------	-----	----------------	-----------------	--------------------------

NA	τ c	# GPS sv	# GLONASS sv	time status	*xx	[CR][LF]
----	----------	----------	--------------	-------------	-----	----------

Field #	Field	Description	Example
1	\$GCLA	Log Header	\$GCLA
2	Week	GPS week number	994
3	Sec	GPS time into week	149871.00
4	Nominal Offset	Nominal offset between GPS and GLONASS time references, in seconds	10787
5	Residual Offset	Residual offset estimated in filter, in meters	10.62179349
6	Residual Offset Variance	Variance of residual offset, in meters	167.82950123
7	NA	Calendar day number within four year period beginning since the leap year, in days	1121
8	τ c	From GLONASS almanac - GLONASS time scale correction to UTC(SU) given at beginning of day NA, in seconds	-3.0544738044739E-007
9	# GPS sv	Number of good GPS sv tracked	9
10	# GLONASS sv	Number of good GLONASS sv tracked	4
11	Time Status	Time status (see below)	00000000
12	* xx	Checksum	*7B
13	[CR][LF]	Sentence terminator	[CR][LF]

Table 2 Time Status

Value	Description
0	GLONASS time floating
1	GLONASS time fixed

Example:

\$GCLA,994,149871.00,10787,10.62179349,167.82950123,1121,
-3.0544738044739E-007,9,4,00000000*7B,[CR][LF]GCLB

GCLB

Format:

Message ID = 88

Message byte count = 68

Field #	Data	Bytes	Format	Units	Offset
1	Sync	3	char		0
	Checksum	1	char		3
	Message Id	4	integer		4
	Message byte count	4	integer	bytes	8
2	Week number	4	integer	weeks	12
3	Seconds of week	8	double	seconds	16
4	Leap seconds plus three hour Moscow time offset	4	integer	seconds	24
5	Fractional offset calculated by filter	8	double	meters	28
6	Variance of fractional offset	8	double	metres ²	36
7	Calendar day number within four year period beginning since the leap year	4	integer	day	44
8	From GLONASS almanac - GLONASS time scale correction to UTC (SU) given at beginning of day NA	8	double	seconds	48
9	Number of GPS satellites	4	integer		56
10	Number of GLONASS satellites	4	integer		60
11	Status flags	4	integer	-	64

GEPA/B EPHEMERIS INFORMATION

GLONASS ephemerides are referenced to the Parametry Zemli 1990 (PZ-90) geodetic datum, and GLONASS ephemeris information is available through the GEPA/B log. GLONASS coordinates are reconciled internally through a position filter and output to WGS84. Refer to the *SVDA/B* log in the *MiLLennium Command Descriptions Manual* for information on WGS84.

GEPA

Structure:

\$GEPA	week	seconds	ephweek	ephtime	time offset
--------	------	---------	---------	---------	-------------

svid	freq	issue	health	posX	posY	posZ
------	------	-------	--------	------	------	------

velX	velY	velZ	LSAccX	LSAccY	LSAccZ	tau
------	------	------	--------	--------	--------	-----

gamma	tk	age	flags	*xx	[CR][LF]
-------	----	-----	-------	-----	----------

Field #	Field	Description	Example
1	\$GEPA	Log Header	\$GEPA
2	Week	GPS Week of log output	991
3	Seconds	GPS Time of log output	496487
4	EphWeek	Reference week of ephemeris (in GPS time)	991
5	EphTime	Reference time of ephemeris (in GPS time)	495913
6	Time offset	Integer seconds between GPS and GLONASS Time + implies GLONASS ahead of GPS	107871
7	SVID	Slot number for satellite	4
8	Freq	Frequency number for satellite	12
9	Issue	15-minute interval number corresponding to ephemeris reference time	83
10	Health	Ephemeris Health (0 = GOOD, 1 = BAD)	0
11	PosX	X coordinate for satellite at reference time (PZ90), in meters	-2.102581933593754E+007
12	PosY	Y coordinate for satellite at reference time (PZ90), in meters	-1.216645166015627E+007
13	PosZ	Z coordinate for satellite at reference time (PZ90), in meters	7.7982763671875110E+006
14	VelX	X coordinate for satellite velocity at reference time (PZ90), in meters/s	-9.655075073242192E+002
15	VelY	Y coordinate for satellite velocity at reference time (PZ90), in meters/s	-5.014476776123048E+002



16	VelZ	Z coordinate for satellite velocity at reference time (PZ90), in meters/s	-3.387468338012698E+003
17	LSAccX	X coordinate for lunisolar acceleration at reference time (PZ90), in meters/s/s	-1.862645149230957E-006
18	LSAccY	Y coordinate for lunisolar acceleration at reference time (PZ90), in meters/s/s	9.3132257461547851E-007
19	LSAccZ	Z coordinate for lunisolar acceleration at reference time (PZ90), in meters/s/s	-9.313225746154785E-007
20	Tau	Clock offset from GLONASS time, in seconds	-3.913920372724533E-004
21	Gamma	Frequency Correction, in seconds/second	7.2759576141834267E-012
22	Tk	Time of frame start (since start of GLONASS day), in seconds	73800
23	Age	Age of data, in days	0
24	Flags	Information flags (see <i>Table 3, Page 46</i>)	13
25	*xx	Checksum	*49
26	[CR][LF]	Sentence Terminator	[CR][LF]

NOTE: ¹ Time offset = 3 hours + GPS UTC offset. See *Page 26* for more information on GLONASS time.

Example:

```
$GEPA,991,496487.00,991,495913.00,10787,4,12,83,0,-2.102581933593754E+007
-1.216645166015627E+007,7.7982763671875110E+006,-9.655075073242192E+002
-5.014476776123048E+002,-3.387468338012698E+003,-1.862645149230957E-006
9.3132257461547851E-007,-9.313225746154785E-007,-3.913920372724533E-004
7.2759576141834267E-012,73800,0,13,*49,[CR][LF]
```

GEPB

Format:

Message ID = 77

Message byte count = 156

Field #	Data	Bytes	Format	Units	Offset
1	Sync	3	char		0
	Checksum	1	char		3
	Message Id	4	integer		4
	Message byte count	4	integer	bytes	8
2	GPS week of log output	4	integer	weeks	12
3	GPS time of log output	8	double	seconds	16
4	Reference week of ephemeris (in GPS time)	4	integer	weeks	24
5	Reference time of ephemeris (in GPS time)	8	double	seconds	28
6	GLONASS time - GPS time	4	integer	seconds	36
7	Slot number	4	integer	ordinal	40
8	Frequency	4	integer	ordinal	44
9	Issue 15 min. reference	4	integer	900s	48
10	Health	4	integer	-	52
11	X position (PZ90)	8	double	meters	56
12	Y position (PZ90)	8	double	meters	64
13	Z position (PZ90)	8	double	meters	72
14	X velocity (PZ90)	8	double	meters/s	80
15	Y velocity (PZ90)	8	double	meters/s	88
16	Z velocity (PZ90)	8	double	meters/s	96
17	X lunisolar acceleration (PZ90)	8	double	meters/s/s	104
18	Y lunisolar acceleration (PZ90)	8	double	meters/s/s	112
19	Z lunisolar acceleration (PZ90)	8	double	meters/s/s	120
20	Tau	8	double	seconds	128
21	Gamma	8	double	seconds/second	136
22	Time of frame start	4	long	seconds	144
23	Age of data	4	integer	days	148
24	Flags (See Table 3 following)	4	integer	-	152



Table 3 GLONASS Ephemeris Flags Coding

N 7 N 6 N 5 N 4 N 3 N 2 N 1 N 0 <- <- Nibble Number																												Bit	Description	Range Values	Hex Value				
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	Isb = 0	P1 FLAG - TIME INTERVAL BETWEEN ADJACENT iISSUE (t _i) VALUES	See Table below	00000001
																																1			00000002
																																2	P2 FLAG - ODDNESS OR EVENNESS OF iISSUE (t _i) VALUE	0 = even, 1 = odd	00000004
																																3	P3 FLAG - NUMBER OF SATELLITES WITH ALMANAC INFORMATION WITHIN CURRENT SUBFRAME	0 = five, 1 = four	00000008
																																4			
																																	RESERVED		
																																31			

Table 3, Bits 0 - 1: P1 Flag Range Values

State	Description
00	0 minutes
01	30 minutes
10	45 minutes
11	60 minutes

OTHER NOVATEL LOGS

RCCA RECEIVER CONFIGURATION

This log outputs a list of all current GPSCard command settings. Observing this log is a good way to monitor the GPSCard configuration settings. See *RCCA* in the *MiLLennium Command Descriptions Manual* for the *RCCA* default list.

The following are the default parameters, for the TESTBEDW receiver, that are different than the standard Millenium WAAS receiver configuration:

CLOCKADJUST DISABLE

EXTERNALCLOCK OCXO

LOG CONSOLE TM1A ONTIME 10 HOLD*

* The logging of the TM1A log is done in order to time synchronize the TESTBEDGLO receiver to the TESTBEDW receiver.

The following are the default parameters, for the TESTBEDGLO receiver, that are different than the standard Millenium Glonass receiver configuration:

CLOCKADJUST DISABLE

EXTERNALCLOCK OCXO

SETTIMESYNC ENABLE*

* The SETTIMESYNC ENABLE allows the TESTBEDGLO receiver to accept the TM1A logs from the TESTBEDW receiver for time synchronization.

E TEST BED RECEIVER - TECHNICAL SPECIFICATIONS

PHYSICAL	
Size	448.8 x 361 x 183.5 mm (without the 19" mounting brackets)
Weight	10.2 kg
ENVIRONMENTAL	
Operating Temperature	-25° C to +55° C with 1 m ³ / minute air flow
Storage Temperature	-40° C to +85° C
Humidity	10-80%
Altitude	3,000 metres [May operate above 3,000 m in a controlled environment, however is not certified as such.]
POWER INPUT	
Connector	3-position chassis jack
Voltage	22-30 V DC
Current	1.5 A continuous; 3.0 A peak
TEST BED RECEIVER SUBSYSTEM PERFORMANCE (Subject To GPS System Characteristics)	
Frequency	GPS: L1(1575.42 MHz), L2 (1227.6 MHz) GLONASS: L1(1602 – 1615.5 MHz)
Code tracked	GPS L1-C/A Code, GPS L2 P Codeless, WAAS GEO C/A Code, GLONASS L1 C/A code, and GEO SVN (PRN 120-138)
Satellite Tracking	GPS GEO 12 GPS L1-C/A (Narrow) / L2 (Codeless) or 10 GPS L1/L2 and 1 GEO (Wide) or 8 GPS L1/L2 and 2 GEO (Wide)
Channels	GPS GLONASS 12 GPS L1-C/A (Narrow) and 6 GLONASS L1-C/A (Narrow)
Position Accuracy Stand-alone	40 metres CEP (SA on), GDOP < 2
Time Accuracy (relative)	50 nanoseconds (SA off) 250 nanoseconds (SA on)
Pseudorange Measurement Accuracy	L1 GLONASS (C/A, Narrow) 20 cm RMS, C/N ₀ > 44 dBHz, BW = 0.05 L1 GPS (C/A, Narrow) 10 cm RMS, C/N ₀ > 44 dBHz, BW = 0.05 L1 GPS (C/A, Wide) 1 m RMS, C/N ₀ > 44 dBHz, BW = 0.05 L2 GPS 50 cm RMS, C/N ₀ > 30 dBHz, BW = 0.05
Single Channel Phase Accuracy	L1 GLONASS 6 mm RMS, C/No > 44 dBHz, Loop BW = 15Hz L1 GPS 3 mm RMS, C/No > 44 dBHz, Loop BW = 15Hz L2 GPS 5 mm RMS, C/No > 30 dBHz, Loop BW = 0.2Hz
Raw Data Availability Rate	GPS GLONASS 1 phase and code measurements per second GPS GEO 1 phase and code measurements per second Almanac data < 15 minutes after reset
Time to First Fix	100 seconds (95%) with stabilized internal and external oscillators. 15 minutes maximum from start of cold receiver. No initial time, almanac or position required.
Re-acquisition	L1 GPS/GLONASS 5 seconds C/No = 44 dB-Hz, 10 seconds C/No = 38 dB-Hz L2 GPS 45 seconds C/No = 41 dB-Hz, 60 seconds C/No = 35 dB-Hz GEO 10 seconds C/No = 44 dB-Hz
Height Measurements	Up to 18,288 metres (60,000 feet) maximum [In accordance with export licensing, the card is restricted to less than 60,000 feet.]

INPUT/OUTPUT DATA INTERFACE			
Serial	Bit rates: 300, 600,1200, 4800, 9600, 19200, 38400, 57600, 115200 bps, user selectable Default: 9600 bps (GPS GLONASS, GPS GEO)		
Connector	DE9P		
Electrical format	RS-232C		
OUTPUT STROBES			
1PPS Output	A one-pulse-per-second Time Sync output. This is a normally high, active low pulse (1 ms) where the falling edge is the reference.		
Measure Out	1 - 10 pulses-per-second output, normally high, active low where the pulse width is 1 ms. The falling edge is the receiver's measurement strobe. (Rate is model-dependent.)		
Connector	DE9S		
Output	Voltage	(High)	> 2.0 VDC
		(Low)	< 0.55 VDC
	Minimum load impedance		1 K Ω
ANTENNA INPUT			
Connector	TNC female		
Frequency	GPS: L1(1575.42 MHz), L2 (1227.6 MHz)		GLONASS: L1(1602 - 1615.5 MHz)
LNA Power Output	Power to the LNA is supplied by the receiver (4.25 - 5.25 V DC @ 0 - 90 mA)		
10 MHz INPUT			
Connector	BNC female		
Sensitivity	0 dBm to +15 dBm into 50 Ω		
RECOMMENDED EXTERNAL FREQUENCY REFERENCE SPECIFICATIONS			
Frequency	10.000 MHz		
Short Term Stability (Allen Variance)	2×10^{-11} , 1 second		
Accuracy Over Operating Temp. Range	$\pm 5 \times 10^{-12}$		
RF Output Power	+13 dBm into 50 Ω		
Output Waveform	Sine wave		
	Harmonics:	-40 dBc	
	Spurious:	-80 dBc	
Phase Noise	@10 Hz:	-120 dBc/Hz	
	@100 Hz:	-140 dBc/Hz	
	@1 kHz:	-150 dBc/Hz	
RF Output Connector	BNC Female		



Default Channel Assignments

Config	Channel	SV Type	Code	DLL Type	Frame	Nav Type	Symbol Rate	FEC	Sky Search
12 L1/L2	0	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	1	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	2	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	3	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	4	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	5	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	6	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	7	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	8	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	9	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	10	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	11	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
Port	Channel	SV Type	Code	DLL Type	Frame	Nav Type	Symbol Rate	FEC	Sky Search
10 L1/L2 + 1 GEO	0	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	1	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	2	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	3	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	4	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	5	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	6	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	7	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	8	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	9	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
		10	GEO	L1 C/A	Wide Corr.	GEO	GEO	500	Yes
Port	Channel	SV Type	Code	DLL Type	Frame	Nav Type	Symbol Rate	FEC	Sky Search
8 L1/L2 + 2 GEO	0	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	1	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	2	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	3	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	4	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	5	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	6	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	7	GPS	L1 C/A, L2 P	Narrow Corr.	GPS	GPS	50	No	Automatic
	8	GEO	L1 C/A	Wide Corr.	GEO	GEO	500	Yes	Automatic
9	GEO	L1 C/A	Wide Corr.	GEO	GEO	500	Yes	Automatic	

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NovAtel Inc.
1120- 68 Avenue N.E.
Calgary, Alberta, Canada T2E 8S5
GPS Hotline: 1-800-NOVATEL (U.S. and Canada only)
Phone: 1-403-295-4900
GPS Fax: 1-403-295-4901
E-mail: support@novatel.ca
Web site: <http://www.novatel.ca>

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