POLHEMUS

First in the third dimension ®

PATRIOT™

USER MANUAL

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FCC Statement

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designated to provide reasonable protection against interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause interference to radio communications. Operation of this equipment in a residential area is likely to cause interference in which case the user will be required to correct the interference at the user's own expense.

EC – Declaration of Incorporation

This Product Complies with the following European Community Directives:

> 89/336/EEC as amended by 92/31/EEC
> 73/23/EEC Low Voltage as amended by 93/68/EEC

The following standards were used to verify compliance with the directives:

EMC: IEC 61326-1:1997+A1:1998 / EN 61326-1:1997+A1:1998
CCISPR 11:1990 / EN 55011:1991-Group 1 Class A
IEC 6100-4-2:1995+A1:1998 / EN 61000-4-2:1995 (ESD 4kV CD, 8kV AD)
IEC 6100-4-3:1995 / EN 61000-4-3:1995 (3V/m 80% AM)
IEC 6100-4-4:1995 / EN 61000-4-4:1995 (0.5kV line-line, 1kV line-earth)
IEC 6100-4-6:1995 / EN 61000-4-6:1995 (3V 80% AM, power line)
Australia/New Zealand: AS/NZS 2064.1

Safety Notices

i. Warnings

- This instrument contains no user serviceable parts. Do not attempt to service unit. Return to Polhemus for repair.

- Do not perform any unauthorized modification to the instrument.

- Do not operate the instrument in the presence of flammable gas or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

- Do not use the instrument in a manner not specified by the manufacturer.

ii. To clean the instrument

If the instrument requires cleaning:

1. Remove power from the instrument.

2. Clean the external surfaces of the instrument with a soft cloth dampened with a mixture of mild detergent and water.

3. Make sure that the instrument is completely dry before reconnecting it to a power source.

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

1. Getting Started

Congratulations on buying the latest, most cost-effective 3D tracking system yet! This section of the user manual has been provided to help get your project under way as quickly as possible.

As with any new system, there are two ways to get started with your PATRIOT system: you could "wing it," which involves a great deal of assumptions based on previous experience and/or visual inspection, and hope for the best. Alternatively, you could sit down and read the whole manual, line-by-line, and then start. What we provide here is a middle ground to cover the basics to get you going quickly. However, this approach does not preclude using the manual as a precise guide, reference and final arbiter.

1.1 Set Up the PATRIOT

NOTE: This approach assumes the use of a single sensor, availability of a USB or COM Port on a computer with either Windows 2000 or Windows XP, and that the Polhemus PiMgr GUI is installed on the computer. See Install the Host Software on page 6 for instructions.

1.   Unpack the PATRIOT SEU, source, sensor(s), USB and RS-232 cables, PATRIOT Host Software CD, power supply and cables. See Figure 1-1.

Figure 1-1 PATRIOT System

2.   Set up the PATRIOT system close to your host computer and away from large metal objects like file cabinets, metal desks, etc., and away from the floor and walls.

3.   Identify the source (the two-inch gray cube) and insert the source connector into the source receptacle, being careful to firmly engage it. Using your fingers, tighten the two retaining screws to secure the connector. See Figure 1-2.

Figure 1-2 Source Connection

4.   For getting started, use only one sensor. Identify the sensor and insert it into either of the sensor receptacles as shown below. Firmly engage and lock the sensor connector into place in the same manner as the source connector in step 3. See Figure 1-3.

Figure 1-3 Sensor Connection

5.   For testing purposes, it is convenient to mount both the source and the sensor on a single block of wood (2x4 or equivalent) about 16 inches apart. Exact placement of the source and sensor is not important for this test; just make sure the cables of both devices are **not routed tightly together** and that they come off opposite ends of the wooden block. See Figure 1-4.

Figure 1-4 Sensor/Source Test Setup

6.   Ensure the power switch is in the **OFF** position (logic "0", DOWN). With the separate power supply UNPLUGGED from the wall, connect the power input cable to the PATRIOT. The power supply can now be plugged into a 110/220 VAC outlet. See Figure 1-5.

Figure 1-5 Power Connector

USB or RS-232 Communication

Only one I/O port (USB or RS-232) can be active at a time.
- For USB, continue with step 7.
- For RS-232, skip to step 11.

For USB Communication:

7.   Identify the USB cable and insert it into the receptacle as shown in Figure 1-6. Connect the other end of the USB cable to the host computer.

Figure 1-6 USB Cable Connection

8.   At this point, you may turn on the PATRIOT system using the power switch located on the back panel of the SEU. A system status indicator located on the front panel should flash red for 5 to 10 seconds indicating self-test and set-up. When these routines are completed, the indicator will reflect system status as follows:

• Steady green	System operational – passed startup testing.
• Flashing red	Failed self-test and set-up.

9.   The host should respond with a "Found New Hardware" message. Follow the hardware wizard to install the required drivers from the PATRIOT Host Software CD-ROM. For step-by-step instructions, refer to USB Driver Installation on page 6.

NOTE: Once the USB cable is connected to PATRIOT, it cannot return to RS-232 mode without removing the USB connection and restarting (power OFF/ON).

10.   You may now use the Polhemus PiMgr GUI to exercise the system. If you have not yet installed the Host Software, continue to Install the Host Software on page 6. Otherwise, continue to Use the Polhemus PiMgr GUI on page 6 and Experiment with PATRIOT Data on page 9.

For RS-232 Communication:

11.   Locate the RS-232 cable and insert it into the receptacle as shown in Figure 1-7.

Most PC hosts have a 9 pin, male "D" type connector for COM1. If you are using COM1, plug the remaining end of the cable into the COM1 port of the host PC, engage, and lock as before.

If your host computer has a 25 pin "D" connector for the RS-232 port, you will need a 9 to 25 pin "D" connector adapter with the proper genders. **Note that this adapter must not compromise the NULL MODEM sense of your cable.**
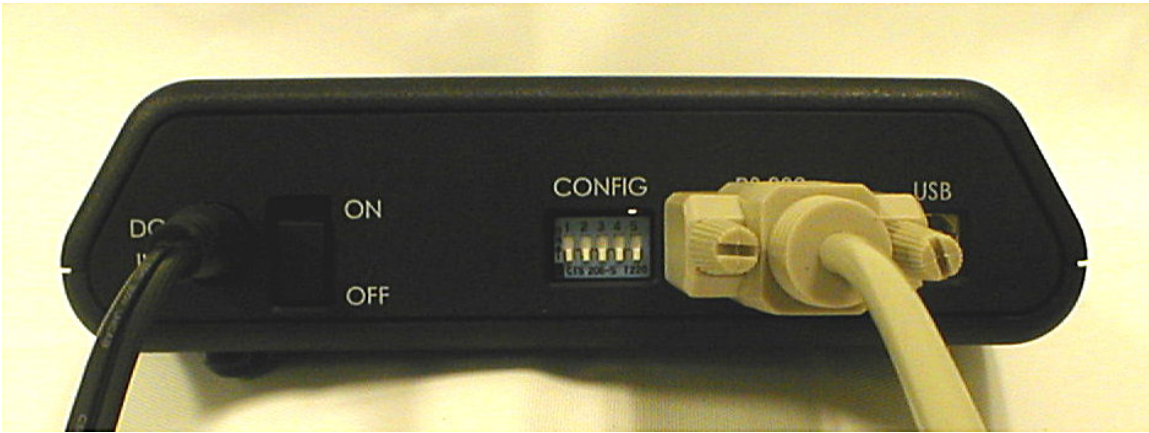
Figure 1-7 RS-232 Cable Connection

12. You may now exercise the system. To use the Polhemus PiMgr GUI, return to step 10. With the RS-232 connection, you may also use PATRIOT's ASCII interface through the Windows HyperTerminal program.

   To do this, first set PATRIOT's "CONFIG" hardware switches to all DOWN as shown in Figure 1-7. (RS-232 switch settings are described in detail in RS-232 I/O on page 78.)

   Next, start the HyperTerminal program and create a serial connection using these switch settings. The steps are as follows:

   - Navigate to HyperTerminal from the Windows Start menu. **Start⇨All Programs⇨Accessories⇨Communications⇨HyperTerminal**.
   - In HyperTerminal, enter a session name, choose an icon, and click OK
   - In the "Connect using" field, select the desired COM port (COM1) and click OK.
   - In the "Bits per second" field, select 115200.
   - In the "Data bits" field, select 8 (default).
   - In the "Parity" field, select None (default).
   - In the "Stop bits" field, select 1 (default).
   - In the "Flow control" field, select None and click OK.

13. You should now have a serial connection opened to PATRIOT. Turn PATRIOT on. In 5 to 10 seconds, you will see "PATRIOT Ready!" in the HyperTerminal screen.

14. Collect a single data record from PATRIOT by typing the 'P' – Single Data Record Output command (see page 63) in the HyperTerminal screen. PATRIOT will respond with a single frame of position and orientation data. The data displayed in the HyperTerminal screen consists of a station number and six columns of data as follows (*these values represent an arbitrary placement of the sensor and source.*):

1	2	3	4	5	6	7
01	16.082	-0.387	0.713	3.051	1.126	-0.674

15. Continue experimenting with the position and orientation data. See Experiment with PATRIOT Data on page 9. If the system fails to produce position and orientation data, carefully go over the above procedure in a systematic fashion, checking connections and switch settings especially. If you still need assistance, refer to Customer Service on page F-1.

1.2 Install the Host Software

NOTE: PATRIOT Host Software is intended to be installed on a computer running Windows 2000 or Windows XP only.

- Insert the PATRIOT Host Software CD-ROM into your computer's CD-ROM drive.

- If the PATRIOT Host Software Installation Panel does not run automatically, then navigate to the CD-ROM drive using Windows Explorer. Run "Setup.exe". The Host Software Installation Panel will appear. Click on "Install Host Software." The installation wizard will walk you through the installation.

- For simplicity, it is recommended that you use the default installation settings suggested by the installation wizard.

- When the installation is complete, if you are planning to use your computer's USB port to connect to the PATRIOT System, leave the CD-ROM in the drive. It will be needed when the initial USB connection is made.

- If you are not planning to use the USB port, you may remove the CD-ROM from the drive now.

1.2.1 USB Driver Installation

- When PATRIOT is connected via USB to a Windows host for the first time, the host will display a "Found New Hardware" message. The host will then launch the "Found New Hardware Wizard" to locate and install the USB drivers for PATRIOT.

- If the CD-ROM is not already in the drive, load it now.

- When the Found New Hardware Wizard displays, select the "Install software automatically" option and click "Next."

- The wizard will install the PATRIOT Loader. When it has completed, click "Finish."

- The same process will be launched again automatically to install the Polhemus PATRIOT USB Driver. Repeat the same selections and the process will be complete.

1.3 Use the Polhemus PiMgr GUI

If you selected the default settings when you installed the PATRIOT Host Software on your computer, you will find a shortcut to the PiMgr application on your Windows 2000 or XP desktop. It looks like this:

Otherwise, navigate to the program through the windows Start menu:

> **Start⇨All Programs⇨Polhemus⇨PiMgr**

The initial PiMgr screen will look like this:
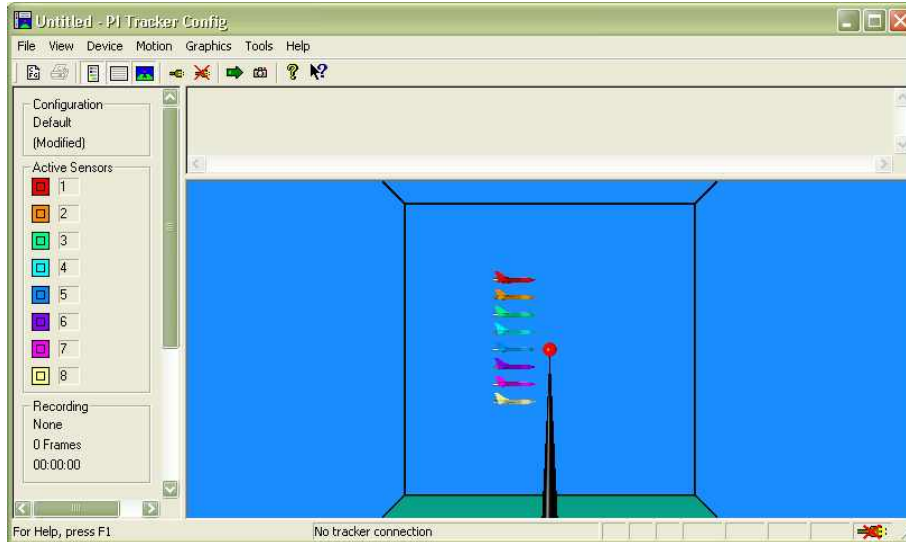
Figure 1-8 PiMgr Screen Display

1. With no PATRIOT system connected, notice that the ![icon] icon appears in the lower right corner. Once connected, the icon will change to ![icon] .

2. If the PATRIOT system is already powered up and connected to the computer, the PiMgr will discover the connection immediately upon startup. If not, you will need to manually create the connection once you have powered up PATRIOT. To do this, first you must select the type of connection you wish to create.

3. If you want to create a USB connection, skip to step 4. PiMgr defaults to a USB connection. If you want to create an RS-232 connection, first configure the serial port settings by opening the Device Configuration dialog. Open this dialog off the Device menu: **Device⇨Device Configuration…,** and select the **Connection** tab. Select the **RS-232** Connection Type on the left, and the appropriate **RS-232 Properties** on the right. Then Click **OK**.
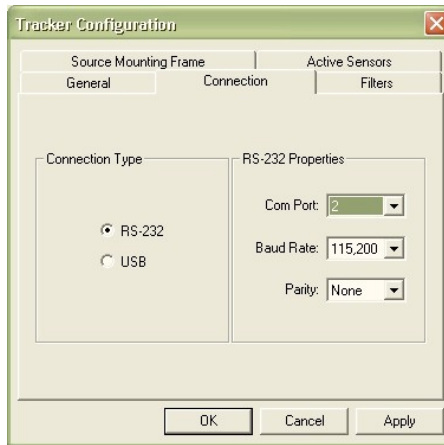
Figure 1-9 RS-232 Configuration Settings

4.   To create a connection, click the **Connect** button on the PiMgr toolbar: ⌐. When the connection has been established, the connection icon at the lower right will change to ⌐.

5.   To collect a single frame of motion data from the PATRIOT system, click the **Single** button on the toolbar: 🖾

6.   You can also do this by typing '**p**' or '**P**' anywhere on the PiMgr window. This will cause PiMgr to request a single data frame from the PATRIOT system. The contents of the frame will be displayed in the text window at the top of the PiMgr display. The airplane image(s) in the graphics portion of the screen will move to the retrieved position and orientation:
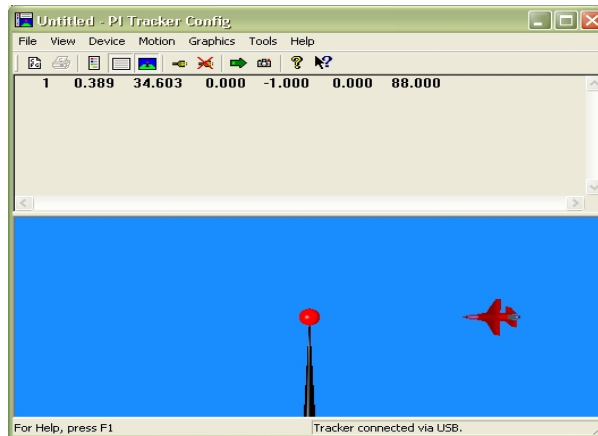
Figure 1-10 PATRIOT Data Record Display

The text portion of the screen will display the retrieved position and orientation:

	Position in inches			Euler Orientation in degrees		
Station Number	X	Y	Z	Azimuth	Elevation	Roll
1	0.389	34.603	0.000	-1.000	0.000	88.000

1.4 Experiment with PATRIOT Data

1. Take some initial samples of data using the <u>'P' – Single Data Record Output</u> command (see page <u>63</u>). Because you have locked the sensor in one position relative to the source (<u>Set Up the PATRIOT</u>, step 5), the data output will not change regardless of the number of data samples you take.

2. Remove the sensor, move it approximately six inches toward the source, secure it in place, and take another single data frame. The value of the X position data will decrease by approximately six inches. The Y and Z values will remain roughly the same as the original data. If you left the attitude of the sensor approximately the same as it was when you started, then the attitude data also will be approximately the same.

3. Again, remove the sensor and without moving its position, try twisting it in azimuth (in the same plane as the wood support) approximately 45 degrees and lock it down with tape. Now collect another data frame. The first four columns will be approximately as they were in step 1, but the Azimuth data in column 5 will have changed by approximately 45 degrees.

4. Continue to experiment with the system as described in step 3 to demonstrate that it measures the position and orientation (six-degree-of-freedom) of the sensor with respect to the source.

5. For a more "hands-on" approach to communicating with PATRIOT, an RS-232 connection is available.

1.5 Terms/Acronyms

Alignment

Obtaining congruence between the axes of the PATRIOT system and the axes of the application. The process whereby the PATRIOT system coordinate reference is brought into coincidence, either physically or mathematically, with other coordinates of the environment. Alignment in an active system is not the same as a boresight operation, which concerns only the sensor; in passive systems, alignment and boresight can be identical.

Alignment Frame

The reference frame in which the position and orientation of the sensor is measured. The default alignment frame is the source frame.

API

Application Programming Interface. Programming library used to develop custom host software for driving the instrument. Sometimes used interchangeably with "SDK."

ASCII

American national Standard Code for Information Interchange defines a certain 8-bit code for display and control characters.

Attitude Matrix

A three-by-three matrix containing the direction cosines of the sensor's X axis in column one, the direction cosines of the sensor's Y axis in column two, and the direction cosines of the sensor's Z axis in column three. The order of the Euler angle rotation sequence is azimuth, elevation, and roll.

X Direction Cosines	Y Direction Cosines	Z Direction Cosines
CA*CE SA*CE -SE	CA*SE*SR - SA*CR CA*CR + SA*SE*SR CE*SR	CA*SE*CR + SA*SR SA*SE*CR – CA*SR CE*CR

where:
  CA = Cos (azimuth)
  CE = Cos (elevation)
  CR = Cos (roll)
  SA = Sin (azimuth)
  SE = Sin (elevation)
  SR = Sin (roll)

Azimuth   The coordinate of orientation tracking in the horizontal plane where an increase in the angle is clockwise when viewed from above. Azimuth is a rotation around the "Z" or vertical axis. The term "yaw" is often substituted for azimuth, especially in the context of flight.

Baud Rate   The signaling rate on a serial line. For example, to convey an 8-bit byte normally requires at least two additional bit times, a start bit and a stop bit so that synchronization is possible without a separate clocking line. For example, such an arrangement implies for a 9600 baud rate conveyance of data at a 9600*8/10 = 7680 bit rate.

Benign Environment   A tracking environment free of the need for special calibration or compensation brought on by the unique features of a particular installation and its environment (e.g. high light levels for optical tracking, high sound levels for sonic tracking, high metallic distortion for magnetic tracking). If not otherwise noted, all measurements and statements pertaining to PATRIOT performance shall be regarded as occurring in such a benign environment.

Binary   Mathematical system based on two digits: 0 and 1.

BIT   <u>B</u>uilt-<u>I</u>n <u>T</u>est features monitoring the status and health of the PATRIOT system, as well as flagging certain preset conditions monitored by the PATRIOT system software. Not to be confused with bit, a contraction of "binary digit."

Boresight   Any procedure that rotates the sensor frame so as to precisely align the sensor to the designated reference frame.

In a PATRIOT system context, the term usually refers to the system software routine that, on command, performs a coordinate rotation, which effectively aligns the sensor frame to a predefined boresight reference orientation.

The boresight routine accomplishes the boresight orientation of the sensor regardless of the sensor's physical orientation at the instant of boresight initiation. For applications that require the orientation tracking of the body (or body member) to which the sensor is attached, a prerequisite to initiating the boresight function is a physical orientation of the body to be tracked to the boresight reference orientation.

bps   Bits per second. Not to be confused with the signaling, or baud rate, which is always equal to or higher than the bit rate. (See baud rate.)

Direction Cosines   The cosines of the angles between the sensor's x, y, z axes and the X, Y, Z axes of the measurement reference (alignment) frame.

Elevation   Coordinate of orientation tracking in the vertical plane where an increase in the angle is upward from the horizontal. A term often substituted for elevation, especially as it concerns flight, is "pitch."

Factory Defaults   The values assigned to certain system variables by the factory. Stored in non-volatile memory, they are used to reinitialize the variables if configuration information is lost.

Firmware   Term used to describe the software programmed into PATRIOT non-volatile memory.

Format   The interchange coding used to present data. PATRIOT outputs either ASCII or BINARY data, but accepts only ASCII inputs from the host.

Hemisphere   Because of the inversion symmetry of the magnetic fields generated by the source, there are two possible mathematical solutions for the X, Y, Z position coordinates for each set of sensor data processed, and PATRIOT is unable to determine which solution is the correct one without additional information. This additional information is provided by the 'H' – Hemisphere of Operation command on page 34, which defines the hemisphere in which the sensors are operating. Therefore, only half of the total spatial sphere surrounding the source can be utilized at any one time for unambiguous position measurement.

The selected hemisphere is referred to as the "current hemisphere." It is defined by an LOS (line-of-sight) vector from the source through a point at the zenith of the hemisphere, and is specified by the direction cosines of the chosen LOS vector.

The orientation coordinates do not have a two-solution spherical ambiguity and are therefore valid throughout the operating sphere centered at the source.

Host	Any device capable of supporting an RS-232C interface or the high speed USB interface and capable of bi-directional data transmission. Devices may range from a dumb terminal to a mainframe computer.
I/O latency	The interval of time needed by the host computer to transfer data from the PATRIOT system into the host application.
Lag	The interval of time between requesting a PATRIOT system data point and receiving it into the host computer.
Latency	The interval of time between when measurement data were collected and when the P&O result is formatted ready for transfer to the host computer. In some systems, namely active PATRIOT systems, there is a time interval between when the data is collected and when the P&O computation can be done. Hence, this definition is intended to correspond to the center point of data collection time so that latency is straightforward and understandable as stated. Other tracking systems (e.g., inertial) may produce raw data continuously or nearly continuously. PATRIOT latency in this case reduces to the computation time for producing the answer ready for transfer to the host computer.
LIBERTY	A generation of flexible and expandable motion tracking instruments after which the PATRIOT is modeled, using the same sources and sensors. The LIBERTY 240/8 allows up to 8 sensors, while the LIBERTY 240/16 allows up to 16 sensors.
Line of Sight (LOS)	1) The orientation angle of the source/sensor pair; 2) in active tracking systems, the angle between the source of stimulation and the sensor; 3) not obscured or blocked from view, such as a clear line of sight for optical uses.
LSB	Least significant bit
LSD	Least significant digit.
MSB	Most significant bit.

Motion Box   The volume in which motion tracking is specified to perform as prescribed. Although this 3D volume usually is cubicle in nature, many of the tracking technologies known as 'active' are dependent on a source of stimulation (e.g., magnetic field, light source) which actually performs equally well at a constant radius from the source so that the "box" actually might be better described as spherical or hemispherical.

Orientation Angles   The azimuth, elevation, and roll angles that define the current orientation of the sensor coordinate frame with respect to the designated reference frame.

The Euler angle coordinates that are output by PATRIOT as one measure of sensor orientation are graphically defined in Figure 1-11. Here, the x, y, z and X, Y, Z tri-axis arrays represent independent, three-dimensional orthogonal coordinate frames. The x, y, z triad represents the sensor frame in its current orientation state. The X, Y, Z triad represents the reference frame against which the relative orientation of the sensor frame is measured. By definition, the X, Y, Z frame also represents the zero-orientation reference state of the sensor frame.

The Euler angles, azimuth, elevation and roll, are designated ψ, θ, and ϕ. These angles represent an azimuth-primary sequence of frame rotations that define the current orientation of the sensor with respect to its zero-orientation state. The defining rotation sequence is an azimuth rotation followed by an elevation rotation followed by a roll rotation.

The azimuth angle ψ is defined in the figure as a rotation of the X and Y reference axes about the Z reference axis. The transition axes labeled X' and Y' represent the orientation of the X and Y axes after the azimuth rotation.

The elevation angle θ is defined as a rotation of the Z reference axis and the X' transition axis about the Y' transition axis. The transition axis labeled Z' represents the orientation of the Z reference axis after the elevation rotation. The current x-axis of the current sensor frame represents the orientation of the X' transition axis after the elevation rotation.

Lastly, the roll angle ϕ is defined as a rotation of the Y' and Z' transition axes about the x-axis of the sensor frame. The y and z-axes of the current sensor frame represent the orientation of the Y' and Z' transition axes after the roll rotation.

In the example of <u>Figure 1-11</u>, the azimuth, elevation and roll rotations are positive, negative and positive respectively.

Legend
X, Y, Z = Alignment (Reference) Frame
x, y, z = Rotated Stylus or Sensor Coordinate Frame

Ψ = Azimuth
θ = Elevation
ϕ = Roll
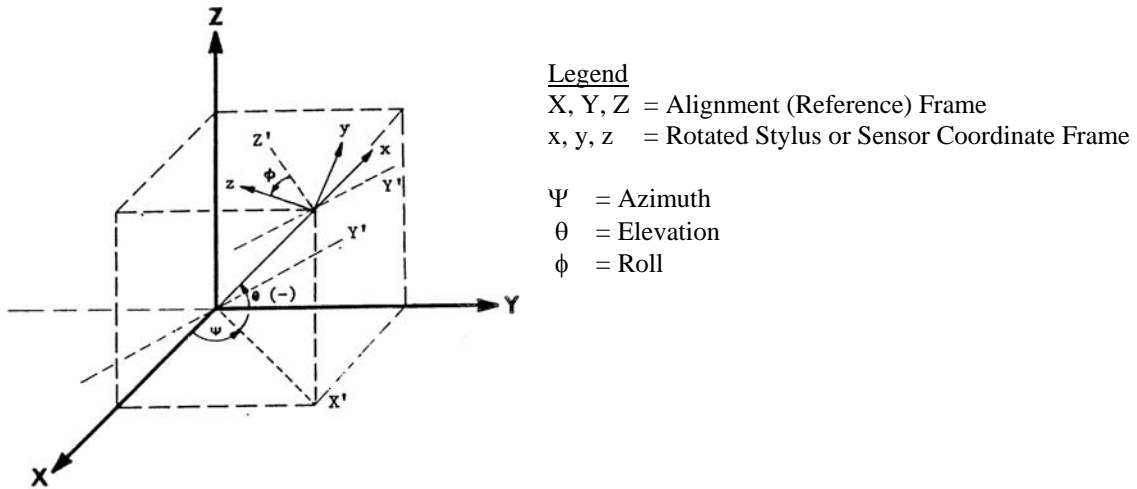
Figure 1-11 Euler Angles

Output List A list of the data items included in a data record.

PATRIOT A two-sensor low cost tracking instrument modeled after LIBERTY.

P&O Acronym for position and orientation, the six pieces of data needed to fully describe tracking of an object in 3D space. Some tracking devices, by virtue of their principle of operation, can produce only position or only orientation whereas others can produce both P&O (although the user usually can opt for only those parameters desired).

Pitch Same as elevation.

Quaternion A four-parameter quantity representing a vector and a scalar. The quaternion $q = q_0 + i\, q_1 + j\, q_2 + k\, q_3$ can be used to represent the sensor's orientation without the need for trigonometric functions. The attitude matrix output from PATRIOT can be equivalently represented by the following matrix using quaternions:

$$
\begin{array}{ccc}
\text{X Directional Cosines} & \text{Y Directional Cosines} & \text{Z Directional Cosines} \\
\end{array}
$$

$$
\begin{bmatrix}
q_0^2 + q_1^2 - q_2^2 - q_3^2 & 2(q_1 q_2 - q_0 q_3) & 2(q_1 q_3 + q_0 q_2) \\
2(q_3 q_0 + q_1 q_2) & q_0^2 - q_1^2 + q_2^2 - q_3^2 & 2(q_2 q_3 - q_0 q_1) \\
2(q_1 q_3 - q_0 q_2) & 2(q_1 q_0 + q_3 q_2) & q_0^2 - q_1^2 - q_2^2 + q_3^2
\end{bmatrix}
$$

Response   The interval of time between a request to the PATRIOT system to collect a data point and when that data is available for input from the PATRIOT system.

Roll   Coordinate of orientation tracking about the azimuth-elevation axis where an increase of the angle is clockwise as viewed from behind or in the same direction as the object is facing.

SDK   <u>S</u>oftware <u>D</u>evelopment <u>K</u>it; software development toolset available for LIBERTY/PATRIOT-based trackers, consisting of programming libraries, help files, and sample code. SDK is sometimes referred to as "API," although API refers specifically to the programming libraries used to interface with the instrument.

Sensor   The sensor measures the low-frequency magnetic field generated by the source. The sensor is used to track both the position and orientation of the object to which it is attached, relative to the measurement reference frame.

Source   The source generates the low-frequency magnetic field measured by the sensor. The source's X, Y, and Z-axes are the default measurement reference frame.

Station   The source-sensor pair. PATRIOT supports up to two sensors, yielding a possible two stations.

Stylus   A pencil-shaped housing for the sensor with an integral switch and used by the operator to indicate and/or select points to be digitized.

Sync   Shorthand for synchronization. For example, "sync signal."

Units   The unit of assumed distance. PATRIOT allows measurement in either inches or centimeters.

Update Rate   The rate at which motion-tracking data can be made available from the PATRIOT system.

Useful Range   The maximum distance at which the resolution and noise performance of the PATRIOT system can be realized.

User Defaults	The values assigned to certain system variables by the user. Stored in non-volatile memory, the system receives these variable values at power-up.
XYZ or X, Y, Z	The Cartesian coordinates of position tracking where normally +X is in the forward direction; +Y is in the right hand direction; and +Z is downward.
XYZAER	The output string of data reporting the position, XYZ, and orientation, AER – azimuth, elevation and roll – of the tracking sensor.
Yaw	Same as azimuth.
<>	Used in text to indicate the "Enter" key.
^	Used in text to indicate the "Ctrl" key.

2. PATRIOT System Commands

2.1 Overview

This section specifies the PATRIOT Command Interface. It defines the structure and function of PATRIOT commands and responses.

The interface is comprised of ASCII commands and binary or ASCII response frames. The ASCII commands are designed to work in a 'dumb terminal' mode, thus keeping the communications protocol simple and easy to use. These commands are the basis of the Polhemus APIs.

Additional information is provided in this document to give the reader some background in the terminology and general science behind the Polhemus tracking technology.

All commands are input on the RS-232 serial port or USB port.

2.2 Command Syntax

2.2.1 Notation

The following notation is used in this manual to describe the PATRIOT command syntax:

[ ]	Items shown inside square brackets are optional. To include optional items, type only the information inside the brackets. Do not type the brackets.
<>	Represents an ASCII carriage return or "enter" ('^M', 0x0d). Whenever shown this value must be present to terminate the command sequence.
...	An ellipsis indicates that you can repeat an item.
,	A comma represents a delimiter in a list of optional parameters. The comma must be present for those parameters which are omitted except for the case of trailing commas. For example: Qs,p1,,,p4<> is the proper command format when omitting parameters p2 and p3. Commas following the parameter p4 are not required if parameters p5 and p6 are omitted.
|	A vertical bar means either/or. Choose one of the separated items and type it as part of the command. For example, "ON|OFF" indicates that you should enter either ON or OFF, but not both. Do not enter the vertical bar.

> ^   A caret in front of a command letter indicates that the control key should be held down while typing the command letter. Control commands produce ASCII values between 0x00 and 0x1F.

For discussion purposes, examples assume that only one sensor is used, in the Sensor 1 position.

2.2.2 Command Format Notes

- Commands and alphabetic parameters are NOT case sensitive.

- Commands that use optional parameters use current system retained values for parameters omitted from the command.

- The term "station" refers to a source-sensor pair. For example, eight sensors paired with the one available source are assigned station numbers one through eight (1-8).

- Unless otherwise noted, commands do not take any punctuation immediately following the command letter. However, if an optional first parameter is to be omitted, a comma is necessary between the command letter and the next parameter.

- A numeric floating point value will be accepted by the machine if any of the following formats are used. For example, 3.0 may be specified as: 3, 3., 3.0 or 3.0E+00.

Station Wildcard

When using a command that requires a station number as the parameter, the user may wish to apply the command to both stations of the PATRIOT system. In such situations a '*' character may be used in place of the station number to apply the settings to both stations in the PATRIOT system.

> e.g. H*,0,0,1<> would change the hemisphere for *every station* to the positive Z hemisphere.

> e.g. H1,0,0,1<> would change the hemisphere for *only station 1* to the positive Z hemisphere.

Default Parameters

Commands that take multiple parameters can be used to change a subset of the parameters and leave the remaining parameter values unchanged.

For example:

- The command G*az,el,roll*<> changes the source mounting frame to *(az, el, roll)*.

- The command G*0,180,0*<> changes the source mounting frame to (0,180,0). By omitting the *el* parameter from the command: G*0,,180*<> the source mounting frame would then change to (0,180,180). The *el* setting remains unchanged.

- Similarly, the *az* parameter can be defaulted by: G*el,roll<>* and the *roll* parameter can be defaulted by G*az,el<>*. The trailing comma is not required when the last parameter(s) are omitted.

2.2.3 Response Format Notes

Depending on the 'F' – Output Format configuration setting (see page 30), frames received from PATRIOT in response to the commands detailed in this document will conform to one of the following format definitions.

ASCII

ASCII response frames are described in this document using the following notation:

> A............... Is an ASCII Character
> B .... Is a Blank or Space
> S .... Is the Sign byte (+,- or a space for (+))
> x .... Is a decimal digit (0-9)
> <>.............Carriage Return + Line Feed (i.e. ^M^J, 0x0d 0x0a)
> *n*() .... Repeat contents of parentheses *n* times

Example: A format 3(Sx.xxxxB), would be output as: -1.1111 2.2222 -3.3333

Except where noted, ASCII mode response includes a standard 5-character response header. The default ASCII response frame format is as follows:

Table 2-1 ASCII Response Format

	Byte Index	Format	Description
HEADER	0	A	First Digit of Station Number
	1	A	Second Digit of Station Number
	2	A	Command Letter
	3	A	Error Indicator
	4	B	ASCII Blank character
	5 thru n	A	Response Body
	n+1, n+2	<>	A P&O response frame may not contain a Carriage Return/Line Feed as specified by the user with the 'O' command

If the Station Number is not applicable to the command, the first two fields will be ASCII zeros '0'.

Error codes presented in the Error Indicator field are detailed in PATRIOT Error Code Summary on page 23. "No Error" is represented by an ASCII blank character ' '.

Binary

Binary response frames are described in this document using the following notation:

> US ....unsigned short, 16 bits
> SH ....signed short, 16 bits
> UC............unsigned char, 8 bits

CH ....char, 8 bits
I ....signed integer, 32 bits
DW ....unsigned double word, 32 bits
FL..............32-bit single-precision floating-point in IEEE format consisting of sign bit, 8-bit exponent, and 23-bit mantissa:
SXXX XXXX XMMM MMMM MMMM MMMM MMMM MMMM
[*n*] ....Array of size *n* of type preceding square brackets (e.g. FL[3])

Binary response frames are composed of an 8 byte frame header followed by a variable-length frame body as follows:

Table 2-2 Binary Response Format

	Byte Index	TYPE	Description
HEADER	0,1	US	Frame Tag, always 'PA' or 0x5041 for PATRIOT HST
	2	UC	Station Number
	3	UC	Initiating command
	4	UC	Error Indicator
	5	UC	Reserved
	6,7	SH	Response size; number of bytes in the response body
	8 - n		Binary Response body

Error codes presented in the Error Indicator field are detailed in PATRIOT Error Code Summary on page 23. "No Error" is represented by NULL (0x00).

Error Responses

When in binary mode, error responses are always prepended by the binary frame header, followed by the ASCII error string. In ASCII mode, error responses have no header. See PATRIOT Error Code Summary on page 23 for a complete listing of error responses.

2.3 *PATRIOT User Command Set Summary*

Command	Description	Decimal	Hexadecimal	Notes	Page
A	Alignment Reference Frame	65	0x41		25
B	Boresight	66	0x42		28
C	Continuous Print Output	67	0x43		62
F	Output Format	70	0x46	0=asc, 1=bin	30
G	Source Mounting Frame	71	0x47		32
H	Hemisphere of Operation	72	0x48		34
L	Stylus Button Function	76	0x4C		37
N	Tip Offsets	78	0x4E		39
O	Output Data List	79	0x4F		41
P	Single Data Record Output	80	0x50		63
Q	FrameCount/Timestamp Reset	81	0x51	0=both;1=FC,2=TS	65
U	Set Units	85	0x55	0=in, 1=cm	43
X	Position Filter Parameters	88	0x58		45
Y	Attitude Filter Parameters	89	0x59		48
^B	UN-Boresight	2	0x02		51
^E	Set Echo Mode	5	0x05	0=off, 1=on	52
^K	Save Operational Configuration	11	0x0B		66
^O	RS-232 Port Configuration	15	0x0F		53
^R	Reset Alignment Frame	18	0x12		55
^T	Built-in-Test Information	20	0x14		67
^U	Active Station State	21	0x15		56
^V	WhoAmI (Software versions)	22	0x16		69
^W	Set Operational Configuration	23	0x17		71
^X	Operational Configuration ID	24	0x18		59
^Y	Initialize System	25	0x19		72
^Z	Read Operational Configuration	26	0x1A		73

2.4 PATRIOT Error Code Summary

The following error codes may appear as binary values in binary mode frame headers.
In ASCII mode, only the text/meaning appears.

Error	Hexadecimal	ASCII Text/Meaning
0	0x00	No Error
1	0x01	Invalid Command
2	0x02	Invalid Station
3	0x03	Invalid Parameter
4	0x04	Too Few Parameters
5	0x05	Too Many Parameters
6	0x06	Parameter Below Limit
7	0x07	Parameter Above Limit
8	0x08	Communication Failure with Sensor Processor Board
9	0x09	Error Initiating Sensor Processor 1
10	0x0a	Error Initiating Sensor Processor 2
11	0x0b	Error Initiating Sensor Processor 3
12	0x0c	Error Initiating Sensor Processor 4
13	0x0d	No Sensor Processors Detected
14	0x0e	Error Initiating Source Processor
15	0x0f	Memory Allocation Error
16	0x10	Excessive Command Characters Entered
17	0x11	You must exit UTH mode to send this command
18	0x12	Error reading source prom. Using Defaults
19	0x13	This is a read only command
20	0x14	Non-fatal text message
21	0x15	Error loading map (N/A for PATRIOT)

The remaining error codes may appear in ASCII and binary frame headers:

Error	Hexadecimal	ASCII Text/Meaning
' '	0x20	No Error (ASCII mode only)
'a'	0x61	Source Fail X
'b'	0x62	Source Fail Y
'c'	0x63	Source Fail XY
'd'	0x64	Source Fail Z
'e'	0x65	Source Fail XZ
'f'	0x66	Source Fail YZ
'g'	0x67	Source Fail XYZ
'u'	0x75	Position outside of mapped area (N/A for PATRIOT)
'A'	0x41	Source Fail X + BIT Errors
'B'	0x42	Source Fail Y + BIT Errors
'C'	0x43	Source Fail X + BIT Errors
'D'	0x44	Source Fail Z + BIT Errors
'E'	0x45	Source Fail XZ + BIT Errors
'F'	0x46	Source Fail YZ + BIT Errors
'G'	0x47	Source Fail XYZ + BIT Errors
'I'	0x49	BIT Errors

2.5 Command Reference

2.5.1 Configuration Commands

Configuration Commands are typically issued during system setup. They affect the overall operation of the PATRIOT system. Once a configuration has been established, PATRIOT will operate in that configuration until power is removed, a reset is issued, or the configuration is changed again through a command. The current configuration may be saved and used at initialization time by commands discussed in this section.

Unless otherwise indicated, the default behavior of the configuration commands will be as follows:

- When no arguments (except station number, where applicable) are supplied with the command, PATRIOT will respond with the current value of the setting in the response frame body.

- When arguments *are* supplied, the command modifies the setting, and PATRIOT sends *no response* to the command. (If '^E' – Set Echo Mode is enabled (see page 52), PATRIOT echoes back the command as verification that the command was received and executed.)

- Station-specific commands have an option to apply the setting to all stations. Refer to Station Wildcard on page 19.

'A' – Alignment Reference Frame

Description:

The alignment command does two things. It defines a reference frame to which all position and orientation output data is referred. In addition, it creates a new origin point where the X, Y, Z measurements would equal (0,0,0) if the sensor were placed there. An example of where this command would be useful is a sloped test surface that the user wanted referenced to the surface. This would obtain congruence between the PATRIOT source and the source frame axes of the sloped surface.

Syntax:

A*station*[,[*Ox*],[*Oy*],[*Oz*],[*Xx*],[*Xy*],[*Xz*],[*Yx*],[*Yy*],[*Yz*]]<>

The Alignment Reference Frame Syntax has these parts:

Part	Description
station	1 or 2, which specifies the relevant source/sensor pair
Ox,Oy,Oz	the Cartesian coordinates of the origin of the new reference frame
Xx,Xy,Xz	the coordinates of the point defining the positive direction of the X-axis of the new reference frame
Yx,Yy,Yz	the coordinates of a third point that is in the positive Y direction from the X-axis

Remarks:

The source reference frame is the default alignment reference frame. (0,0,0,1,0,0,0,1,0) in inches.

Output Record:

Table 2-3 'A' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number
1	A	Second Digit of Station Number
2	A	'A'
3	A	Error Indicator
4	B	ASCII Blank character
5-25	3(Sxxx.xx)	Origin Coordinates
26-27	AA	Carriage Return/Line Feed
28-48	3(Sxxx.xx)	Positive X-Axis Coordinates
49-50	AA	Carriage Return/Line Feed
51-71	3(Sxxx.xx)	Positive Y-Axis Coordinates
72-73	AA	Carriage Return/Line Feed

Table 2-4 'A' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	FL	Ox
12	FL	Oy
16	FL	Oz
20	FL	Xx
24	FL	Xy
28	FL	Xz
32	FL	Yx
36	FL	Yy
40	FL	Yz

Examples:

To perform an alignment on station 1, follow the steps listed below:

Standard Alignment Procedure

1. Send ^R1<>

2. Place the sensor at the proposed origin location

3. Press P and write down the X, Y, Z measurements (these will be Ox, Oy, Oz)

4. Move the sensor along the proposed X axis from the origin defined in step 2 and place it about 24 inches in front of this origin

5. Press P and write down the X, Y, Z measurements (these will be Xx, Xy, Xz)

6. Move the sensor along the proposed Y-axis from the origin defined in step 2 and place it about 24 inches from the source

7. Press P and write down the X, Y, Z measurements (These will be Yx, Yy, Yz)

8. Using all of the data that has been written down in steps 1-7, send the command A1,Ox,Oy,Oz,Xx,Xy,Xz,Yx,Yy,Yz<>

'B' – Boresight

Description:

This command causes the sensor to be electronically aligned in orientation and optionally, position, with the user system coordinates and establishes the boresight reference angles for the station. Azimuth, elevation and roll outputs will equal the boresight reference values at the current orientation. If the "Reset Origin" switch is set, X, Y and Z outputs will equal 0,0,0 at the boresight location. PATRIOT then produces outputs relative to this (these) reference(s). Any sensor orientation can be designated as the zero orientation point.

If all the optional parameters are omitted, the system returns the boresight reference angles for the specified station.

A station may be unboresighted by issuing a ^B command. See the section describing the

Syntax:

B*station*[,*Azref*,*Elref*,*Rlref*,*ResetOrigin*]<>

Part	Description
station	1 or 2, which specifies the relevant source/sensor pair
Azref	The azimuth reference angle
Elref	The elevation reference angle
Rlref	The roll reference angle
ResetOrigin	A switch to enable/disable setting the X, Y and Z origin values to 0,0,0 upon boresight. 0 = disable the origin reset. 1 = reset origin upon boresight. Default is 0.

Remarks:

The system default boresight reference values are: 0, 0, 0

Output Record:

Table 2-5 'B' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number
1	A	Second Digit of Station Number
2	A	'B'
3	A	Error Indicator
4	B	ASCII Blank character
5-12	Sxxx.xxB	Azimuth Reference
13-20	Sxxx.xxB	Elevation Reference
21-28	Sxxx.xxB	Roll Reference
29-30	AA	Carriage Return/Line Feed

Table 2-6 'B' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	FL	Azimuth Reference
12	FL	Elevation Reference
16	FL	Roll Reference

Examples:

The sensor may be mounted on a person's head to measure where it is pointing. When the user's head is looking at a given object, the user may want the system angular outputs to be zero. The user can designate this sensor orientation as the zero orientation by sending the boresight command:

    B1,0,0,0,0<>

This results in azimuth, elevation, and roll outputs of zero at this orientation. As the user's head moves away from the boresight point, the orientation angles are still measured relative to the source, with the zero points shifted to the point where the boresight occurred.

The user may wish to set the boresight reference values to an orientation that corresponds with the application. For example, if the application required an output of 0, -15, 0 following a boresight, reference angles should be included with the B command:

    B1,0,-15,0,0<>

The boresight command will now cause the azimuth, elevation, and roll data output to be 0, -15, 0 respectively.

'F' – Output Format

Description:

This command selects the Binary or ASCII output data format. ASCII format means that the data is generally human readable, while binary format is generally computer readable. Regardless of output data format selected, all input data (commands) to PATRIOT must be in ASCII format.

Syntax:

F[*fmt*] <>

Part	Description
fmt	Defines the type of output from PATRIOT. The choices are:

                    0 …. ASCII output
                    1 …. Binary output

Remarks:

The default output data format is ASCII.

The Polhemus SDK uses binary output exclusively.

As with other configuration commands, if no *fmt* argument is provided, the current value of the setting is returned in the default response frame.

If a software application is written to receive binary data from PATRIOT and there is a requirement to take it off line temporarily to do visual checks, the user would enable the ASCII output data format in order to be able to easily read PATRIOT data on the PC monitor.

The user may wish to write a software application for PATRIOT where a fast update rate is crucial. In order to reduce data throughput size, PATRIOT could be set to output in binary instead of ASCII.

Output Record:

Table 2-7 'F' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number
1	A	Second Digit of Station Number
2	A	'F'
3	A	Error Indicator
4	B	ASCII Blank character
5	A	'0'
6-7	AA	Carriage Return/Line Feed

Table 2-8 'F' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	I	0x00000001

Examples:

The command to enable binary output mode for the system is:

F1<>

'G' – Source Mounting Frame

Description:

This command allows the user to modify the mounting frame coordinates of the source. It is basically a non-physical rotation of the source and becomes the new orientation reference for each sensor's measurements. Source mounting frame is not a sensor-specific setting.

Syntax:

G[[*A*],[*E*],[*R*]]<>

Part	Description
A	Azimuth mounting frame angle
E	Elevation mounting frame angle
R	Roll mounting frame angle

Remarks:

The default mounting frame is 0,0,0.

Issuing a G<> will read the current source mounting frame.

Output Record:

Table 2-9 'G' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number (n/a) '0'
1	A	Second Digit of Station Number (n/a) '0'
2	A	'G'
3	A	Error Indicator
4	B	ASCII Blank character
5-13	Sxxx.xxxB	Azimuth Mounting Frame Angle
14-22	Sxxx.xxxB	Elevation Mounting Frame Angle
23-31	Sxxx.xxxB	Roll Mounting Frame Angle
32-33	AA	Carriage Return/Line Feed

Table 2-10 'G' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	FL	Azimuth Mounting Frame Angle
12	FL	Elevation Mounting Frame Angle
16	FL	Roll Mounting Frame Angle

Examples:

If there was a requirement to mount the source upside down (more mechanically feasible), then the following command should be used:

    G0,0,180<>

The orientation measurements for all stations will now look as if the source had *not* been mounted upside down.

'H' – Hemisphere of Operation

Description:

This command allows the user to set or change the "hemisphere of operation" vector.

Since the sensor(s) can only operate in one hemisphere at a time relative to the source, it is necessary to tell PATRIOT which side of the source they will be on, for each station.

PATRIOT also provides hemisphere tracking, a feature whereby PATRIOT can continuously modify its operating hemisphere, given that it is started in a known, valid hemisphere.

Because of the symmetry of the magnetic fields generated by the source, there are two mathematical solutions to each set of sensor data processed. Therefore, only half of the total spatial sphere surrounding the source is practically used at any one time without experiencing an ambiguity (usually sign flips) in the X, Y, Z measurements. This half sphere is referred to as the current hemisphere. The chosen hemisphere is defined by an LOS vector from the source through a point at the zenith of the hemisphere, and is specified by the LOS direction cosines.

Syntax:

H*station*[,[*p1*],[*p2*],[*p3*]]<>

Part	Description
station	1 or 2, which specifies the relevant source/sensor pair
p1	The initial x-component of a vector pointing in the direction of the operational hemisphere's zenith.
p2	The initial y-component of a vector pointing in the direction of the operational hemisphere's zenith.
p3	The initial z-component of a vector pointing in the direction of the operational hemisphere's zenith.

Remarks:

The arguments *p1-p3* above are the vector components of the operational hemisphere's zenith. The default hemisphere values are: 1,0,0 which is positive X or "forward" hemisphere.

Hemisphere Tracking is enabled by sending H*station*,0,0,0<>. It is not enabled by default. When enabled, PATRIOT modifies the operating hemisphere automatically.

When turning on Hemisphere Tracking, the sensor of the specified station must be initially located in the currently set hemisphere.

NOTE: If Hemisphere Tracking is turned ON when the '^X' – Operational Configuration ID (see page 59) is sent, PATRIOT will save the default hemisphere.

Issuing an H*station*<> returns a record of structure as shown below.

Output Record:

Table 2-11 'H' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number
1	A	Second Digit of Station Number
2	A	'H'
3	A	Error Indicator
4	B	ASCII Blank character
5-11	Sxx.xxx	Current Vector X component
12-18	Sxx.xxx	Current Vector Y component
19-25	Sxx.xxx	Current Vector Z component
26-27	AA	Carriage Return/Line Feed

Table 2-12 'H' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	FL	Vector X component
12	FL	Vector Y component
16	FL	Vector Z component

Examples:

The user may decide to mount the source above the test area in order to be able to move the sensor to the positive and negative sides of X and the positive and negative sides of Y. (**NOTE:** since the default hemisphere value is "forward", the user cannot move the sensor to the negative X side of the source, because the signs will flip and it will appear as if the X measurement never goes negative.) If the source is positioned above the test area, the positive Z or "lower" hemisphere should be selected. This can be accomplished with the following command:

    H1,0,0,1<>

Station 1 of PATRIOT will now be set for the positive Z or "lower" hemisphere.

Although the hemisphere vector is not limited to 1s and 0s, the following table of hemisphere commands may be useful:

Forward Hemisphere (+X)	H1,1,0,0<>
Back Hemisphere (-X)	H1,-1,0,0<>
Right Hemisphere (+Y)	H1,0,1,0<>
Left Hemisphere (-Y)	H1,0,-1,0<>
Lower Hemisphere (+Z)	H1,0,0,1<>
Upper Hemisphere (-Z)	H1,0,0,-1<>

'L' – Stylus Button Function

Description:

This command allows the user to put the PATRIOT stylus into different output modes by controlling the button function.

Syntax:

L*station*[*,fbutton*]<>

Part	Description
station	1 or 2, which specifies the relevant source/sensor pair
fbutton	Defines the function of the Stylus Button. The choices are:

> 0 …. Marker Mode
> 1 …. Point/Track Mode

Remarks:

System default is Marker Mode.

An entry of *fbutton* = 0 defines the output interaction as "marker mode." The pushing of the stylus switch has no effect on system output other than setting an event marker in the output record when the button is pressed. In this case, a 1 is reported in the output record when the switch is pressed and a 0 when it is not pressed. **NOTE:** Output of this marker must be enabled through the 'O' – Output Data List command (see page 41).

An entry of *fbutton* = 1 defines a pseudo "point/track" mode interaction with the switch. In non-continuous mode of output, pressing the stylus switch has the same effect as sending a 'P' – Single Data Record Output command (see page 63) to the system (point mode). In point mode, every time the button is pressed, a data record is sent to the host. [**NOTE:** The host must be aware of this mode. If the stylus button is pressed, the host must be polling for the data frame or monitoring RS232 output in order to capture the output data.]

In continuous output mode, pressing the stylus switch serves as a toggle for continuous output (track mode). The first time the button is pressed, continuous output mode is turned off. The next time the button is pressed, continuous output mode is turned back on again, and so on.

Output Record:

Table 2-13 'L' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number
1	A	Second Digit of Station Number
2	A	'L'
3	A	Error Indicator
4	B	ASCII Blank character
5	A	0 for Marker, 1 for Point/Track
6-7	AA	Carriage Return/Line Feed

Table 2-14 'L' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	I	0x00 for Marker, 0x01 for Point/Track

Examples:

The command to enable Stylus Track mode on station 2 is:

L2,1<>

'N' – Tip Offsets

Description:

This command allows the user to override the factory defaults for the stylus tip offsets. Although changing the tip offsets is not recommended, the ability to do so is available.

Each stylus has been factory calibrated with custom tip offsets. This is the offset of the sensor from the tip of the stylus. The tip offsets allow the tip to act as the measurement reference instead of the sensor coil inside the handle.

Tip Offset settings are not saved in the PATRIOT configuration. They must be re-applied each time PATRIOT is restarted.

Syntax:

N*station*[,[*Xoff*],[*Yoff*],[*Zoff*]]<>

Part	Description
station	1 or 2, which specifies the relevant source/sensor pair
Xoff	X direction Tip offset.
Yoff	Y direction Tip offset
Zoff	Z direction Tip offset

Remarks:

Factory default tip offsets are read from the PROM inside the stylus connector on power-up. As a result, the 'N' command can only override the factory defaults during the current operational session.

Output Record:

Table 2-15 'N' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number
1	A	Second Digit of Station Number
2	A	'N'
3	A	Error Indicator
4	B	ASCII Blank character
5-11	Sx.xxxB	X offset
12-18	Sx.xxxB	Y offset
19-25	Sx.xxxB	Z offset
26-27	AA	Carriage Return/Line Feed

Table 2-16 'N' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	FL	X offset
12	FL	Y offset
16	FL	Z offset

Examples:

If the user created a special stylus tip attachment that extended exactly one inch from the end of the stylus, an adjustment to the tip offsets would have to be made. To do so, the following steps should be taken.

1. Verify that PATRIOT is measuring units in "inches" by sending the 'U' – Set Units command (see page 43).

Read the factory tip offsets from the PROM in the connector by sending the command N1<>. (A typical factory tip offset might be 2.523, 0.004, 0.03.)

2. To add one inch in X to the factory calibration, type N1,3.523,0.004,0.03<>

To verify that the tip offset was entered correctly, type N1<> to read it back.

'O' – Output Data List

Description:

This command allows the user to define the list of variables to be output to the host computer for the specified station. Any combination of up to 20 items that produces a P&O response frame of less than or equal to 1000 bytes is permissible.

NOTE: Due to the high output rate of PATRIOT, caution should be used when defining large output records to prevent overwhelming the host communications' channel.

The output list refers to the subset of data items to be included in a data record.

Syntax:

O[*station*] ,[p1],[p2],...,[pn]<>

Part	Description
station	1 or 2, which specifies the relevant source/sensor pair
p1-pn	Up to 20 parameters that define the list of variables output to the host. The possible parameters are listed below:

Table 2-17 Output Data Types

Parameter Value	Description	ASCII Output Data Format	Binary Output Data Format
0	ASCII space character	A1	A1
1	ASCII carriage return, linefeed	A2	A2
2	X, Y, Z Cartesian coordinates of position	3(Sxxx.xxxB)	FL
3	X, Y, Z Cartesian coords, extended precision	3(Sx.xxxxxxESxxxB)	FL
4	Az, El, Rl Euler orientation angles	3(Sxxx.xxxB)	FL
5	Az, El, Rl Euler angles, extended precision	3(Sx.xxxxxxESxxxB)	FL
6	Direction Cosine Matrix	3(3(Sx.xxxxxB)CRLF)	FL[3]
7	Orientation Quaternion	4(Sx.xxxxxB)	FL[3]
8	Timestamp	A1 ~ A10	DWORD
9	Frame Count	A1 ~ A10	DWORD
10	Stylus Flag ('0' or '1')	A1	I

Remarks:

If the wildcard (*) is specified instead of a *station*, all station output lists will be set to the programmed value. If output list parameters (*p1-pn*) are omitted from the argument list, the current defined output list is returned.

Default is 0*,2,4,1: P&O <cr><lf> for all stations.

Output Record:

Table 2-18 'O' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number
1	A	Second Digit of Station Number
2	A	'O'
3	A	Error Indicator
4	B	ASCII Blank character
5	X	Data Item #1
6	B	
7- .	xB..	Remaining data items separated by blanks

Table 2-19 'O' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	I	Data Item 1
12	I	Data Item 2
16	I	Data Item 3
. . .		
84	I	Data Item #20

NOTE: In the binary output format, the list of valid data items will be terminated with a -1 (0xFFFFFFFF).

Examples:

The user may decide to use X, Y, Z direction cosines instead of the default output format. In order to do so, the following command should be sent:

    O1,5,6,7,1<>
The output data for Station 1 will now be displayed as X, Y, Z direction cosines, plus carriage return/line feed.

    O*,2<>
The output for all stations will be position only.

'U' – Set Units

Description:

This command sets the distance unit to either metric (centimeters) or English (inches). Subsequent input and output lengths will be interpreted as centimeters or inches respectively.

Syntax:

U[*units*] <>

Part	Description
units	Defines the type of input and output Units. The choices are: 0 …. English (Inches) 1 …. Metric (Centimeters)

Remarks:

The system default unit format is inches.

As with all other configuration commands, if the units parameter is not stated in this command, the current units setting will be returned in the default response body.

Output Record:

Table 2-20 'U' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number
1	A	Second Digit of Station Number
2	A	'U'
3	A	Error Indicator
4	B	ASCII Blank character
5	A	0 for inches, 1 centimeters
6-7	AA	Carriage Return/Line Feed

Table 2-21 'U' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	I	0x00 for inches, 0x01 for centimeters

Examples:

Assuming the system units had already been changed to centimeters the following command could be sent to change back to inches:

    U0<>

The system will now output data in inches and interpret input data in inches.

If the operator wanted the system to output its measurements in centimeters, the following command should be sent:

    U1<>

The system will now output data in centimeters.

'X' – Position Filter Parameters

Description:

This command establishes the sensitivity, boundary, and transition control parameters for the adaptive filter that operates on the position outputs of the PATRIOT system. The user can adjust the parameters of this command to fine-tune the overall dynamic response of PATRIOT.

The filter is a single-pole low-pass type with an adaptive pole location (i.e., a floating filter "parameter/variable"). The pole location is constrained within the boundary values *FLow* and *FHigh* but is continuously self-adaptive between these limits as a function of the sensitivity parameter *F* and the sensed (ambient noise plus rotational rate) input conditions. For input "rate" conditions that fall within the adaptive range, the adaptive feature varies the pole location between the *FLow* and *FHigh* limits so as to maximize the output resolution for static inputs while minimizing the output lag for dynamic inputs. Whenever the input conditions cause the filter to make a transition to a narrower bandwidth (i.e., increased filtering), the transition rate of the pole location is constrained to a maximum allowable rate by the parameter *FACTOR*. If all of the optional parameters are omitted the current value of each parameter is returned to the user as an output record of type "X".

Syntax:

X[[*F*],[*FLow*],[*FHigh*],[*Factor*]]<>

Part	Description
F	a scalar value that establishes the sensitivity of the filter to dynamic input conditions by specifying the proportion of new input data to recent average data that is to be used in updating the floating filter parameter/variable.
	Allowable range of values: $0 < F < 1$
FLow	a scalar value that specifies the maximum allowable filtering to be applied to the outputs during periods of relatively static input conditions. Setting this value to 1.0 disables the filter completely.
	Allowable range of values: $0 < FLow < FHigh$ or 1.0 to disable filter

FHigh   a scalar value that specifies the minimum allowable filtering to be applied to the outputs during periods of highly dynamic input conditions.

Allowable range of values: *FLow* < *FHigh* < 1

FACTOR   a scalar value that specifies the maximum allowable transition rate from minimum filtering (for highly dynamic input conditions) to maximum filtering (for relatively static input conditions) by proportionately limiting the decay to the low filter limit whenever the input conditions effect a transition to a narrower bandwidth.

Allowable range of values: 0 < *FACTOR* < 1

When the form of the command is X,0,1,0,0<> the position filter is disabled.

Remarks:

The default mode for all filter parameters is shown below. Although these parameters are a function of the user's particular environment, the following settings may be used as a starting point for determining optimum filtering in your particular environment.

F   Set to 0.2

FLow   Set to 0.2

FHigh   Set to 0.8

FACTOR Set to 0.95

Output Record:

Table 2-22 'X' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number (n/a)
1	A	Second Digit of Station Number (n/a)
2	A	'X'
3	A	Error Indicator
4	B	ASCII Blank character
5-11	Sx.xxxB	Filter Sensitivity
12-18	Sx.xxxB	Filter Low Value
19-25	Sx.xxxB	Filter High Value
26-32	Sx.xxxB	Transition Rate Maximum Value
33-34	AA	Carriage Return/Line Feed

Table 2-23 'X' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	FL	Filter Sensitivity
12	FL	Filter High Value
16	FL	Filter Low Value
20	FL	Transition Rate Maximum Value

Examples:

To select the above filtering, send the following command to the system:

X .2,.2,.8,.95<>

All active stations will now have filtering applied to the position measurements.

To turn off position filters:

X0,1,0,0<>

'Y' – Attitude Filter Parameters

Description:

This command establishes the sensitivity, boundary, and transition control parameters for the adaptive filter that operates on the attitude outputs of the PATRIOT system. The user can adjust the parameters of this command to fine-tune the overall dynamic response of PATRIOT.

The filter is a single-pole low-pass type with an adaptive pole location (i.e., a floating filter "parameter/variable"). The pole location is constrained within the boundary values *FLow* and *FHigh* but is continuously self-adaptive between these limits as a function of the sensitivity parameter *F* and the sensed (ambient noise plus rotational rate) input conditions. For input "rate" conditions that fall within the adaptive range, the adaptive feature varies the pole location between the *FLow* and *FHigh* limits so as to maximize the output resolution for static inputs while minimizing the output lag for dynamic inputs. Whenever the input conditions cause the filter to make a transition to a narrower bandwidth (i.e., increased filtering), the transition rate of the pole location is constrained to a maximum allowable rate by the parameter *FACTOR*. If all of the optional parameters are omitted, the current value of each parameter is returned to the user as an output record of type "Y".

Syntax:

Y[[*F*],[*FLow*],[*FHigh*],[*Factor*]]<>

Part	Description
F	a scalar value that establishes the sensitivity of the filter to dynamic input conditions by specifying the proportion of new input data to recent average data that is to be used in updating the floating filter parameter/variable.
	Allowable range of values: $0 < F < 1$
FLow	a scalar value that specifies the maximum allowable filtering to be applied to the outputs during periods of relatively static input conditions. Setting this value to 1.0 disables the filter completely.
	Allowable range of values: $0 < FLow < FHigh$ or 1.0 to disable filter

FHigh   a scalar value that specifies the minimum allowable filtering to be applied to the outputs during periods of highly dynamic input conditions.

Allowable range of values: $FLow < FHigh < 1$

FACTOR   a scalar value that specifies the maximum allowable transition rate from minimum filtering (for highly dynamic input conditions) to maximum filtering (for relatively static input conditions) by proportionately limiting the decay to the low filter limit whenever the input conditions effect a transition to a narrower bandwidth.

Allowable range of values: $0 < FACTOR < 1$

When the form of the command is Y0,1,0,0<> the attitude filter is disabled. This is the system default configuration.

Remarks:

The default mode for all filter parameters is shown below. Although these parameters are a function of the user's particular environment, the following settings may be used as a starting point for determining optimum filtering in your particular environment.

F	Set to 0.2
FLow	Set to 0.2
FHigh	Set to 0.8
FACTOR	Set to 0.95

Output Record:

Table 2-24 'Y' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number (n/a)
1	A	Second Digit of Station Number (n/a)
2	A	'Y'
3	A	Error Indicator
4	B	ASCII Blank character
5-11	Sx.xxxB	Filter Sensitivity
12-18	Sx.xxxB	Filter Low Value
19-25	Sx.xxxB	Filter High Value
26-32	Sx.xxxB	Transition Rate Maximum Value
33-34	AA	Carriage Return/Line Feed

Table 2-25 'Y' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	FL	Filter Sensitivity Value
12	FL	Filter Low Value
16	FL	Filter High Value
20	FL	Transition Rate Maximum Value

Examples:

To select the above filtering, send the following command to the system:

Y.2,.2,.8,.95<>

All active stations will now have filtering applied to the attitude measurements.

To turn off attitude filters:

Y0,1,0,0<>

'^B' – Un-Boresight

Description:

This command causes the sensor boresight rotation matrix to be reset to the identity matrix for the specified station. If the origin of the station was previously reset using the 'B' – Boresight command (see page 28), the origin will revert back to the source origin.

Syntax:

^B*station*<>

Part	Description
station	1 or 2, which specifies the relevant source/sensor pair

Remarks:

None.

Output Record:

None.

Examples:

^B1<> Resets Station 1

'^E' – Set Echo Mode

Description:

This command enables and disables the communications "echo" mode. In echo mode, Patriot responds to configuration-modifying commands by "echoing" back the command that was received. (Recall that without echo mode, configuration-modifying commands generate no response message from the tracker. See Configuration Commands on page 24.) This allows feedback to the user when modifying configuration settings. In binary mode, the echo is prefixed by the standard 8-byte binary header.

Syntax:

^E[*echo*]<>

Part	Description
echo	Defines the echo mode. The choices are: 0 …. No echo mode 1 …. Echo mode

Output Record:

Table 2-26 '^E' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number
1	A	Second Digit of Station Number
2	A	'e'
3	A	Error Indicator
4	B	ASCII Blank character
5	A	1 = on, 0 = off
6-7	AA	Carriage Return/Line Feed

Table 2-27 '^E' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	I	1 = on, 0 = off

Remarks:

The system default for echo mode is "off."

Examples:

> ^E1<>
> ^E0<>

'^O' – RS-232 Port Configuration

Description:

This command sets the RS-232 port configuration. The system output port settings include RS-232 BAUD rate and parity only.

Syntax:

^O [*rate*],[*parity*]<>

Part	Description

rate　　　　　100 bits per second. Valid arguments include:

Table 2-28 ASCII Baud Rate Values

Rate	Baud Rate
"24"	2,400
"48"	4,800
"96"	9,600
"192"	19,200
"384"	38,400
"576"	57,600
"1152"	115,200

parity

Table 2-29　ASCII Parity Values

Parity	Meaning
"0"	None
"1"	Odd
"2"	Even

Remarks:

See RS-232 I/O on page 78 for reference on the use of RS-232 for communicating with PATRIOT.

By default, the baud rate and parity RS-232 parameters are determined by the state of the RS-232 CONFIG switches (located on the back panel of PATRIOT) upon PATRIOT startup or initialization. See Hardware Switches on page 78 for switch values.

In addition:　　The number of data bits is always eight (8).
　　　　　　　The number of stop bits is always one (1).
　　　　　　　Hardware Handshake is always disabled.

Changes to the RS-232 port settings using ^O will be ignored during the next power up or system initialize ('^Y' – Initialize System, page 72) in deference to the hardware switch settings, even if the new port settings are saved as the startup configuration ('^W' – Set Default Operational Configuration on page 71).

Output Record:

Table 2-30 '^O' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number
1	A	Second Digit of Station Number
2	A	'o'
3	A	Error Indicator
4	B	ASCII Blank character
5-10	A	Baud Rate (See **Table 2-28** above.)
11	B	Blank
12	A	Parity (See Table 2-29 above.)
13-14	A	Carriage Return/Line Feed

Table 2-31 '^O' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	I	Baud Rate (See Table 2-32 below.)
12	I	Parity (See Table 2-32 below.)

Examples:

Suppose there is a requirement to change the baud rate (in software) to 19,200 baud after startup. It can be accomplished with the following command, without turning off and restarting the system.

> ^O192,1,8,0<>

The system serial communication parameters will now be 19200-baud, no parity, 8 data bits, and 1 stop bit. The host communication software may have to be reset to the new baud rate (19,200) in order for communication with PATRIOT to continue.

Table 2-32 Binary RS-232 Codes

Code	Baud Rate	Code	Parity
1	2400	0	None
2	4800	1	Odd
3	9600	2	Even
4	19200		
5	38400		
6	57600		
7	115200		

'^R' – Reset Alignment Frame

Description:

This command resets the alignment reference frame for the specified station to the station reference frame. It provides an easy way to re-align the reference frame to the factory default values. The command parameter is defined as:

Syntax:

^R*station*<>

Part	Description
station	1 or 2, which specifies the relevant source/sensor pair

Remarks:

None.

Output Record:

None.

Examples:

To reset the alignment reference frame for station 2 execute the following:
    ^R2<>

'^U' – Active Station State

Description:

The purpose of this command is to allow the host to turn a station "on" or "off" in software.

A station is defined as a source/sensor port pair. The two sensors paired with the one source are assigned station numbers one and two (1,2). Although stations are enabled simply by plugging the sensors into the ports on PATRIOT, the stations can then be disabled (or enabled again) by using a software command. When a station exists and is enabled, data records for that sensor will be transmitted from that station. If the station is disabled, no data records from that station will be transmitted.

Syntax:

^U[*station*][,*state*]<>
or
^U0[,*bitmap*]<>

Part	Description
station	1 or 2, which specifies the relevant source/sensor pair 0: causes active station bitmap to be retrieved or set.
state	0 … Off 1 … On n/a if station = 0
bitmap	8-bit bitmap reflecting state of each sensor, represented as a hexadecimal number

Remarks:

If a *station* is supplied **without** a *state*, then the current states of all stations are returned. See output record below. The default condition depends on the number of sensors that are currently connected to PATRIOT. The default condition of a station that has a sensor connected to it is a "1" or station "on". The default condition of a station that does not have a sensor connected to it is a "0" or station "off."

If zero '0' is supplied as the station number, this command will take a hexadecimal bitmap to identify ALL the enabled stations:
      E.g.: ^U0,03<> enables all sensors.

NOTE: Do *not* place '0x' in front of the input hex bitmap!

If no bitmap is supplied, the current active sensor bitmap will be returned in the default response body. This bitmap will indicate the detected sensors in the upper 16 bits, and the active sensors in the lower 16 bits. A sensor must be detected AND enabled to be active.

Output Record:

Table 2-33 '^U[*station*]' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number
1	A	Second Digit of Station Number
2	A	'u'
3	A	Error Indicator
4	B	ASCII Blank character
5	X	Station #1 state (1=Active, 0=Inactive)
6	X	Station #2 state (1=Active, 0=Inactive)
7,8	AA	Carriage Return/Line Feed

Table 2-34 '^U0' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number
1	A	Second Digit of Station Number
2	A	'u'
3	A	Error Indicator
4	B	ASCII Blank character
5-8	xxxx	Hex bitmap for detected sensors
9-12	xxxx	Hex bitmap for active sensors
13,14	AA	Carriage Return/Line Feed

Table 2-35 '^U' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	I	Detected and Active Station bitmap

Binary output is the same for both ^U[*station*]<> and ^U0<>

Examples:

A user could connect two sensors to a PATRIOT and then collect a data point from one sensor at a time, after disabling the other one. To do so, the following commands would be sent:

1. Send the command ^U2,0<> to turn station 2 off.

2. Press P to collect a data point from station 1.

3. Send the command **^U2,1<>** to turn station 2 on.

4. Send the command **^U1,0<>** to turn station 1 off.

5. Press P to collect a data point from station 2.

6. Repeat steps 1 through 6 as necessary.

To turn on station 1 while turning off station 2, send:

> ^U0,1<>

where 1 corresponds to:

> 0x01 = 0001

Bits corresponding to station 1 are set and those corresponding to 2 are cleared.

'^X' – Operational Configuration ID

Description:

This command allows a 16 character "ID" to be assigned to the current operational system configuration. This command also allows the user to view the IDs of all valid stored configurations within PATRIOT non-volatile configuration memory.

Syntax:

^X*string<>*

Part	Description
string	A 15 character ASCII string ID that describes the current configuration.

Remarks:

A valid configuration ID is up to 15 characters plus a null-terminator.

If no *string* argument is supplied with this command, PATRIOT will respond with a list of the currently saved configuration IDs.

A string of 15 asterisks followed by the null character indicates an undefined configuration. ("***************\0")

Output Record:

Table 2-36 '^X' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number
1	A	Second Digit of Station Number
2	A	'x'
3	A	Error Indicator
4	B	ASCII Blank character
5-21	16(A)B	Current Configuration Record ID
21-37	16(A)B	Configuration Record ID #1
38-53	16(A)B	Configuration Record ID #2
54-69	16(A)B	Configuration Record ID #3
72-71	AA	Carriage Return/Line Feed

Table 2-37 '^X' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	CH[16]	Current Config ID
24	CH[16]	Default Config ID
40	CH[16]	Config Slot 1 10
56	CH[16]	Config Slot 2 10
72	CH[16]	Config Slot 3 10
88	CH[16]	Startup Config ID

Examples:

To determine what configurations are available in the PATRIOT system issue the following command:

> ^X<>

The returned record could display the following:

Current:	Configuration 1
0	Default
1	Configuration 1
2	Configuration 2
3	***************
Startup	Configuration 1

In this case two unique configurations are stored in PATRIOT configuration memory. The third configuration is not defined.

To set an ID for the third configuration, do the following:

> ^XConfiguration#3<>
> ^K3<>

To make this configuration the startup configuration:

> ^W3<>

2.5.2 Operational Commands

Operational commands are typically executed during normal system operation. They do not affect the current configuration of the PATRIOT system.

'C' – Continuous Print Output

Description:

This command enables the continuous output mode. When the system is in continuous mode, the data points from all stations are requested automatically and are streamed to the host continuously. If more than one station is enabled, then the data from each station will be sent in numerical order (station 1 first, station 2 second).

Output mode refers to whether the system automatically transmits data records to the host (continuous mode), or the host must request data records by polling the system each time (non-continuous mode).

Syntax:

C<>

Remarks:

By default continuous mode is disabled.

If the system is being used in an application where a fast update rate is critical, then the continuous print output configuration should be enabled.

Issuing a 'P' command disables continuous print output mode.

Frames will be received from the PATRIOT at 60 frames/sec.

Output Record:

The format of each frame of continuous output data is identical to that of a single frame generated by the 'P' command. See Table 2-38 on page 63 and Table 2-39 on page 64.

Examples:

To enable continuous output mode, send the command as follows:

    C<>

Data from PATRIOT will now flow continuously to the host computer.

To disable, send a 'P'. Continuous data will stop and the response to the terminating 'P' will be returned.

'P' – Single Data Record Output

Description:

In non-continuous output mode, this command polls PATRIOT for a single data record. If more than one station is enabled, then data from each active station will be sent in numerical order (station 1 first, station 2 second; that is, a complete cycle of active stations will be output).

Output mode refers to whether the system automatically transmits data records to the host (continuous output mode), or the host must request data records by polling the system each time (non-continuous output mode).

Syntax:

P   **NOTE:** This is the *only* PATRIOT command that does *NOT* require a <>.

Remarks:

The system default enables single data record output mode.

Output Record:

The body of each individual frame of output data is comprised of output data types configured by the 'O' command.

Table 2-38 'P' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number
1	A	Second Digit of Station Number
2	A	Error Indicator
3	B	Blank
4-m	See Table 2-17, page 41.	Data Output Item #1 configured by 'O' command (See 'O' – Output Data List on page 41
m+1 - n	See Table 2-17, page 41.	Data Output Item #2
..	See Table 2-17, page 41.	Data Output Item #n

Table 2-39 'P' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8-n	See Table 2-17, page 41.	Data Output Item #1, configured by 'O' command. (See 'O' – Output Data List on page 41.
n+1 - m	See Table 2-17, page 41.	Data Output Item #2
..	See Table 2-17, page 41.	Data Output Item #n

Examples:

If the system is being used in an application where data is only needed a certain number of times, or on command, then the single data record output should be used. To poll the system for a single data record, send the command as follows:

      P

One data record from PATRIOT will be sent to the host computer.

'Q' – Reset Counters

Description:

This command allows the user to zero the frame counting and the frame timestamp feature. The frame counting feature is always enabled; however, it is only output when specified through the 'O' – Output Data List command (see page 41). The framecount is a positive integer value indicating the relative frame number since system start or the last reset. Rollover occurs after 2^{32} frames.

The timestamp feature is always enabled; however, the timestamp is only output if it has been specified in the 'O' – Output Data List command. The timestamp is a positive integer value indicating the number of milliseconds since the last reset operation or system start. Rollover occurs after 2^{32} milliseconds.

Syntax:

Q*counter*<>

Part		Description
counter	0	Reset both framecount and timestamp
	1	Reset framecount only
	2	Reset timestamp only

Remarks:

None.

Output Record:

None.

Examples:

To zero the framecount execute the following:

   Q1<>

'^K' – Save Operational Configuration

Description:

This command allows the user to save an operational configuration to one of three configuration records stored in PATRIOT non-volatile configuration memory. The configuration saved is the configuration currently defined.

Syntax:

^Kslotnum<>

Part	Description
slotnum	1 - 3 = One of three user-definable operational configurations that are stored within PATRIOT.

Remarks:

Configuration slot number 0 is reserved for the factory default configuration.

A 15 character null-terminated ID string should be assigned to the user defined configuration before a ^K is issued. See the '^X' – Operational Configuration ID command (page 59).

Output Record:

None.

Examples:

Assume a user wants to save the current custom operational configuration for use later. The user also wants to make this configuration the default 'power up' configuration for the user's PATRIOT system. The following commands should be issued:

^XNewIDstring<>	Assigns an ID string to current configuration
^K1	Saves current configuration to first config slot
^W1	Sets Config Slot 1 to startup config

'^T' – Read/Clear BIT Errors

Description:

This command allows the user or technician to read and clear any start-up Built-In Test (BIT) errors that occur during system initialization. This command will return 9 integer values that can be decoded as described in APPENDIX C.

Syntax:

^T[*clear*]<>

Part	Description
clear	0 clears all start-up BIT errors.

Remarks:

If no clear command is supplied, this command will display the current start-up errors.

This is a diagnostic command that allows the user or technician to determine the cause of any start-up test failures and to clear those errors. If a start-up test fails, PATRIOT will display a message to the host, and an error code of 'I' (or 'A' – 'G' if run-time errors also exist) will be placed in any P&O frame output header. Once a user clears the errors, the P&O frame output header error will disappear. The user can determine at a glance which sensor channel failed initialization by looking at words 2-9. Any word that does not contain all zeros indicates a failure for that sensor channel. If further information is needed, Appendix C can be used to further decode these BIT results.

This command will not clear run-time BIT errors.

Example:

Word = 0x00000000

Output Record:

NOTE: ^T0 has no output record.

Table 2-40 '^T' ASCII Response

Byte Index	Format	Description
0	A	'0'
1	A	'0'
2	A	't'
3	B	Blank
4	B	Blank
5-14	AAxxxxxxxx	Bitmap of source and global sensor processor errors, sensors 1-8
15,16	AA	Carriage Return / Line Feed
17-27	AAxxxxxxxxB	Bitmap of sensor channel 1 errors
28-38	AAxxxxxxxxB	Bitmap of sensor channel 2 errors
60,61	AA	Carriage Return / Line Feed

Table 2-41 '^T' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	DW	Bitmap of source and global sensor processor errors
12	DW	Bitmap of sensor channel 1 errors
16	DW	Bitmap of sensor channel 2 errors

Examples:

^T<>   Read BIT Errors – Yields the results below when no error

00t   0x00000000
0x00000000 0x00000000 0x00000000 0x00000000
0x00000000 0x00000000 0x00000000 0x00000000

^T0<> Clear BIT errors

'^V' – WhoAmI

Description:

This command returns the basic identification and firmware version of PATRIOT system.

Syntax:

^V[*station*]<>

Remarks:

None.

Output Record:

Table 2-42 '^V' ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number (n/a) 0
1	A	Second Digit of Station Number (n/a) 0
2	A	'v'
3	A	Error Indicator
4	B	ASCII Blank character
5-6	A	Carriage Return/Line Feed
7-22	A	"Polhemus PATRIOT"
23-24	A	Carriage Return/Line Feed
25-26	A	Carriage Return/Line Feed
27-45	A	"Boot Loader Version:"
46-52	A	Boot Version #
53-54	A	Carriage Return/Line Feed
55-79	A	"PATRIOT Firmware Version:"
80-86	A	System Controller Version #
87-88	A	Carriage Return/Line Feed
89-110	A	"I/O Processor Version:"
111-117	A	I/O Processor Version #
118-119	A	Carriage Return/Line Feed

Table 2-43 '^V' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	UC	Sensor count
9	UC	Tracker Type 1=PATRIOT
10	UC	Reserved
11-end	CH[]	Same as ASCII output bytes 5-end

Table 2-44 '^V[*station*] ASCII Response

Byte Index	Format	Description
0	A	First Digit of Station Number ('0')
1	A	Second Digit of Station Number
2	A	'v'
3	A	Error Indicator
4	B	ASCII Blank character
5-17	A	"Station # ID:"
18-n	A	ID
n+1 – n+2	A	Carriage Return/Line Feed
n+24	A	"Station # Serial Number:"
n+24 – m	A	Serial Number
m+1 – m+2	A	Carriage Return/Line Feed

Table 2-45 '^V[*station*]' Binary Response

Byte Index	Format	Description
0-7		Binary Header
8	I	ID
12	CH[16]	Serial Number

Examples:

To determine the firmware version of the System Controller module in PATRIOT issue the following command:

    ^V<>

The record returned will contain the version number of the PATRIOT Firmware, I/O Processor, and Boot Loader.

'^W' – Set Default Operational Configuration

Description:

This command sets the system non-volatile operational configuration to one of four values. This new 'default' configuration will be used upon subsequent system initializations. ***This command does not change the current configuration of the device until the device is restarted.***

Syntax:

^W*slotnum*<>

Part	Description
slotnum	0 = Default Factory configuration 1-3 = User-defined configurations

Remarks:

When using the '^W' command, the '^Y' – Initialize System command (page 72) or system power cycle must be used to make PATRIOT use the operational configuration.

Output Record: None

Examples:

If the PATRIOT system's configuration had been altered (by sending various other commands and saving the result to the configuration non-volatile memory) and the user wanted to return the system to its original factory default settings, then the following commands should be sent:

        ^W0

        ^Y

After initialization, the system non-volatile configuration memory will be set with all of the factory default parameters. This exercise is especially useful when the system has been modified to the point where the user is not sure how to get back to factory defaults. However, care should be taken because ***all*** non-saved custom settings will be lost as a result of the reset.

'^Y' – Initialize System

Description:

This command reinitializes the entire system to an advanced power up state. The user should allow sufficient time for the system to run through its self test and initialization (as signified by completion of LED flashing explained in step 8 of Getting Started) before attempting to send the system additional commands.

Syntax:

^Y<>

Remarks:

None.

Output Record:

None.

Examples:

If the user wanted to set the system configuration back to its original, factory default condition, the following commands should be sent:

    ^W0<>

    ^Y<>

The system will now be in its original factory default condition. The Ctrl Y simulates turning the system power off, then back on again.

'^Z' – Read Operational Configuration

Description:

This command allows the user to view the operational configuration settings for the current, factory default and saved custom configurations.

Syntax:

^Z [*slotnum*]<>

Part	Description
slotnum	0 = factory default configuration
	1 - 3 = One of three User-definable operational configurations that are stored within PATRIOT.

Remarks:

If no *slotnum* is supplied, the current operational configuration will be returned.

Output Record:

The ASCII response to '^Z' will be prepended by only the first 3 characters of the normal 5-byte ASCII header:

Table 2-46 '^Z' ASCII Response Header

Byte Index	Format	Description
0	A	First Digit of Station Number (n/a) '0'
1	A	Second Digit of Station Number (n/a) '0'
2	A	'z'

The body of the response will be a variable length block of text in the format below. Data in italics will vary according to the configuration settings being reported. Table 2-47 describes the text block line-by-line.

The binary response frame is described by Table 2-48.

Table 2-47 '^Z' ASCII Response

Format	Description
00z *Configuration name*<>	3-char ASCII Header Config ID string
<>	
Binary: *Yes/No*<>	
Metric: *Yes/No*<>	
<>	
Frame Rate: 60Hz<>	Fixed at 60 Hz for PATRIOT
<>	
Verbosity Level: 1<>	
Echo Mode: *ON/OFF*<>	
<>	
RS-232 Baud Rate: *baudrate*<>	See Table 2-28 on page 53.
RS-232 Parity: *parity*<>	See Table 2-29 on page 53.
<>	
Position Filter Sensitivity: *Sx.xxx*<>	
Position Filter Low Value: *Sx.xxx*<>	
Position Filter High Value: *Sx.xxx*<>	
Position Transition Rate Maximum Value: *Sx.xxx*<>	
<>	
Attitude Filter Sensitivity: *Sx.xxx*<>	
Attitude Filter Low Value: *Sx.xxx*<>	
Attitude Filter High Value: *Sx.xxx*<>	
Attitude Transition Rate Maximum Value: *Sx.xxx*<>	
<>	
Mounting Frame Angle: *3(Sxxx.xxx)B*<>	Az El Roll
<>	
Compensation: Off<>	
<>	

The following text data will be repeated once for each station on PATRIOT:

Format	Description
Station *x*<>	Station number
Output List: *(xB)..*<>	List of Output Data Items See Table 2-17 on page 41.
Hemisphere: *3(Sxx.xxxB)*<>	Az El Roll
Boresight Reference Angles: *3(xxx.xxB)*<>	Az El Roll
Stylus Function: *Marker/Point/Track* Mode<>	
Alignment Coordinates:<>	
Origin Coordinates: *3(Sxxx.xxB)*<>	Ox Oy Oz
Pos X-Axis: *3(Sxxx.xxB)*<>	Xx Xy Xz
Pos Y-Axis: *3(Sxxx.xxB)*<>	Yx Yy Yz

Table 2-48 '^Z' Binary Response

Byte Index	Format	Description		
0-7		Binary Header		
8	A	Config ID		
24	I	**Bits**	**Meaning**	
		0-2	Baud rate (Table 2-32, on page 53)	
		3-4	Parity (Table 2-32, on page 53)	
		4-31	Reserved	
28	I	**Bits**	**Meaning**	
		0	Continuous Mode (0=Off/1=On)	
		1	Binary Mode (0=ASCII/1=Binary)	
		2	Units Mode (0=Inches/1=CM)	
		3-4	Sync Mode (N/A for PATRIOT)	
		5-7	Reserved	
		8-9	Compensation (N/A for PATRIOT)	
		10-25	Station Bitmap (1=Active)	
		26	Echo Mode (0=Off/1=On)	
		27-31	Reserved	
32	FL	Attitude Filter: Sensitivity		
36	FL	Attitude Filter: FLow		
40	FL	Attitude Filter: FHigh		
44	FL	Attitude Filter: FACTOR		
48	FL	Position Filter: Sensitivity		
52	FL	Position Filter: FLow		
56	FL	Position Filter: FHigh		
60	FL	Position Filter: FACTOR		
64	FL	Source Mounting Frame: Az		
68	FL	Source Mounting Frame: El		
72	FL	Source Mounting Frame: Roll		
76	I	Frame Rate (2 = 60 Hz)		

The following 64 bytes will be repeated once for each station on PATRIOT:

Byte Index	Format	Description
80 + (64 * (station-1))	FL	Alignment Origin: X
84 + (64 * (station-1))	FL	Alignment Origin: Y
88 + (64 * (station-1))	FL	Alignment Origin: Z
92 + (64 * (station-1))	FL	Alignment X-Axis: X
96 + (64 * (station-1))	FL	Alignment X-Axis: Y
100 + (64 * (station-1))	FL	Alignment X-Axis: Z
104 + (64 * (station-1))	FL	Alignment Y-Axis: X
108 + (64 * (station-1))	FL	Alignment Y-Axis: Y
112 + (64 * (station-1))	FL	Alignment Y-Axis: Z
116 + (64 * (station-1))	FL	Hemisphere: X
120 + (64 * (station-1))	FL	Hemisphere: Y
124 + (64 * (station-1))	FL	Hemisphere: Z
128 + (64 * (station-1))	FL	Boresight: Az
132 + (64 * (station-1))	FL	Boresight: El
136 + (64 * (station-1))	FL	Boresight: Roll
140 + (64 * (station-1))	I	Stylus Mode (0=Marker/1=PointTrack)

The following 80 bytes will be repeated once for each station on PATRIOT:

Byte Index	Format	Description
144 + (64 * (station count-1))	I[20]	Output Data List (Table 2-17, page 41)

Examples:

To view the configuration settings for the *current* configuration issue the following command:

^Z<>

To view the configuration settings for the *factory default* configuration issue the following command:

^Z0<>

3. Component Description

3.1 System Electronics Unit (SEU)

The SEU is a stand-alone unit that may be located anywhere that is convenient to the work area, AC power and the host computer. It contains the required input and output connectors and controls to support up to two sensors, a single magnetic source, a USB port, and an RS-232 port. See Getting Started, Figure 1-1 on page 1 for a picture of the SEU. PATRIOT sources and sensors are compatible with, and identical to, LIBERTY sources and sensors.

3.1.1 Source Port

The single source port is a 15 pin plug "D" type connector located on the front of the SEU as shown in Figure 1-2 on page 1. The source should be connected to the SEU before the unit is powered on and disconnected after the unit is powered off. **CAUTION:** Do not disconnect or connect the source while the PATRIOT SEU is powered on. Be sure the source cable is routed separately from the sensor cables.

Source Frequency

The PATRIOT is shipped with a source designed to operate at a standard frequency. It is possible to operate multiple PATRIOT units in close proximity by using sources designed to operate at alternate frequencies. The source frequency is automatically detected, and no operator action is needed. Contact Polhemus Customer Service (see page F-1) for more information.

3.1.2 Sensor Ports

The sensor ports are 15 pin high density receptacle "D" type connectors located on the front of the SEU as shown in Figure 1-3 on page 2. The SEU can be configured to accept up to two sensors. The sensor(s) can be connected or disconnected from the SEU at any time. The sensors are automatically detected and will begin sending data about one second after being connected.

CAUTION: Route the sensor cables separately from the source cable, as there may be some cross-coupling between the sensor cables and the source cable.

3.1.3 LED Indicator

An LED "power on" indicator is located on the front of the SEU. Upon power up, the indicator will blink red for 5 to 10 seconds while the system performs its initialization and self-test routines. When these routines are completed, the indicator changes from blinking read to steady green, indicating that the system is ready for operation. If the LED continues to flash red after 10 seconds, the self-test has failed. Table 3-1 below summarizes the LED condition.

Table 3-1 LED conditions

•	Steady green	System operational – passed startup testing.
•	Flashing red	Failed self-test and set-up.

A malfunctioning sensor or source can cause a poor quality signal that will trigger a solid red LED. This condition should be accompanied by a Built-In Test (BIT) error. See APPENDIX C for a description of BIT errors.

If no sensors are plugged into the SEU and the initialization test passes, the LED will be a solid green.

3.1.4 RS-232 I/O

Serial Connector

The RS-232 I/O serial connector is a standard 9 pin plug "D" type connector located on the rear panel of the SEU as shown in Figure 1-7 on page 5. The pinout identification for this connector is as follows:

Table 3-2 RS-232 Pin Outs

Pin	PATRIOT		Host
1	Not used		Not used
2	RxD	←	TxD
3	TxD	→	RxD
4	Not used		Not used
5	GND	──	GND
6	Not used		Not used
7	Not used		Not used
8	Not used		Not used
9	Not used		Not used

Hardware Switches

NOTE: UP switch position is a logic '1' and DOWN is logic '0.'

The hardware switches located on the rear panel of the SEU to the left of the RS-232 serial port connector as depicted in Figure 1-7 on page 5. PATRIOT reads baud rate and parity RS-232 connection settings from these switches only on power up. If you change the switches to obtain a different setting, you must restart PATRIOT either by using the '^Y' – Initialize System command (page 72) or by cycling the power.

Alternatively, the '^O' – RS-232 Port Configuration command (page 53) may be used to configure the RS-232 connection during operation. However, after using this command and saving the new settings to the startup configuration ('^W' – Set Default Operational

Configuration, page 71), the saved settings will be ignored during the next power up or system initialize ('^Y' – Initialize System) in deference to the hardware switch settings.

The hardware switches are numbered 1 to 5 from left to right. Switch setting definitions are provided in Table 3-3.

Table 3-3 Switch Settings

Baud Rate Switches				**Parity Switches**		
1	**2**	**3**		**4**	**5**	
⇩	⇩	⇩	115,200	⇩	⇩	None
⇩	⇩	⇧	57600	⇩	⇧	Odd
⇩	⇧	⇩	38400	⇧	⇩	Even
⇩	⇧	⇧	19200	⇧	⇧	reserved
⇧	⇩	⇩	9600			
⇧	⇩	⇧	4800			
⇧	⇧	⇩	2400			
⇧	⇧	⇧	reserved			

3.2 Magnetic Source

The Source is the device which produces the electro-magnetic field and is normally the reference for the position and orientation measurements of the sensors. It is usually mounted in a fixed position to a non-metallic surface or stand, which is located in close proximity to the sensors. The standard source is the 2" cube and the specifications in this manual are based on the 2" source, shown in Figure 3-1. Other source sizes are available. Review the Polhemus web site at www.Polhemus.com or contact Polhemus Customer Service on page F-1 for more information.
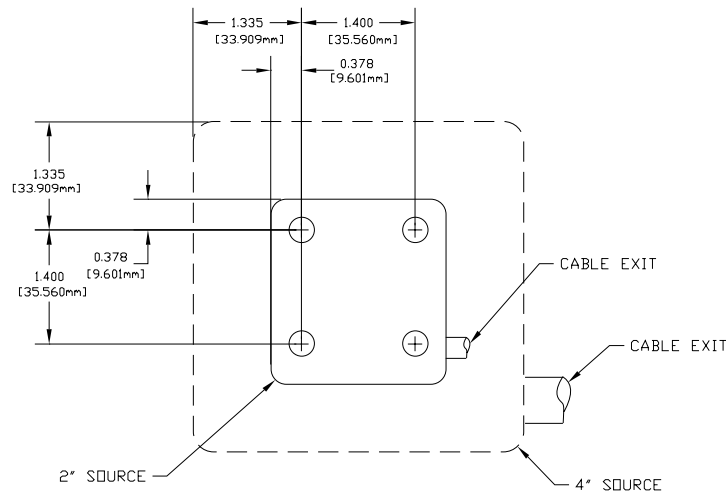
Figure 3-1 Source Diagram

3.3 Sensor(s)

The sensor is the smaller device whose position and orientation is measured relative to the Source. The sensor is dimensionally shown in Fig. 4-1 including the position of the electrical center. The sensor package provides two mounting holes for #4 nylon screws (supplied) in the event that sensor mounting is required.

NOTE: Nylon hardware is only required when the hardware will be **in direct contact with the source or sensor.** A testing surface where the devices will be used (a table for example), could have small metal hardware like screws, nuts, and bolts, which probably would not affect the accuracy of the PATRIOT system.
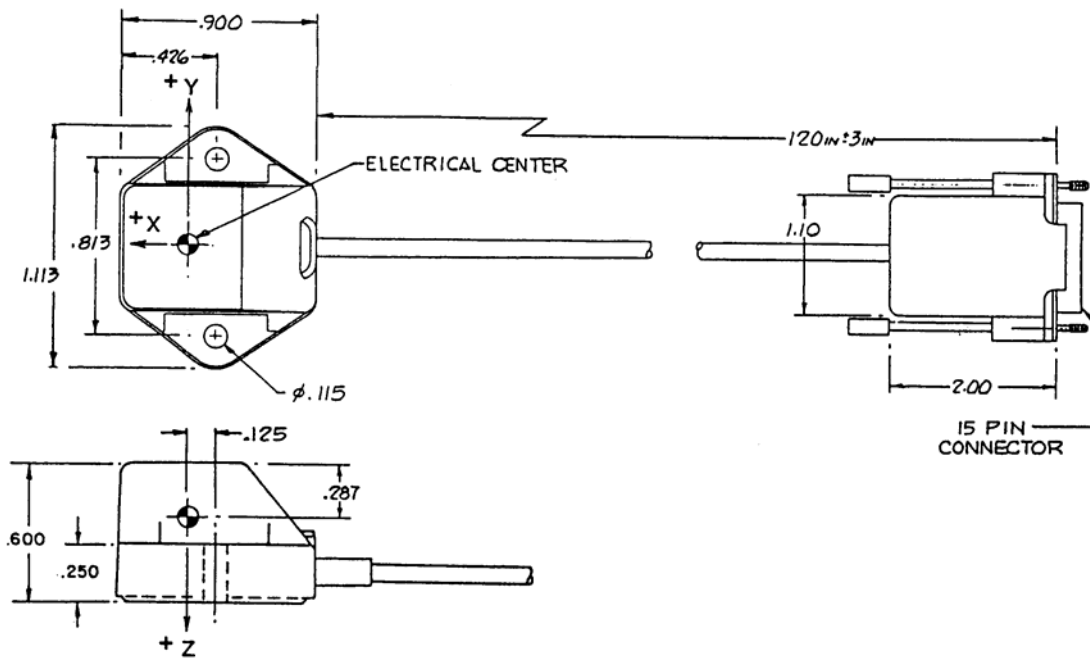
Figure 3-2 Sensor

3.4 Stylus

The stylus is a pen-shaped device with a sensor coil assembly built inside and a push button switch mounted on the handle to effect data output. The position measurements are relative to the tip of the stylus, due to a precise factory calibration. The stylus is dimensionally shown in Figure 3-3 and may be used in any of the sensor ports. The stylus functions as a sensor with the electrical center offset from the tip of the stylus via firmware. Single or Continuous output records may be obtained as a function of the integral switch. See 'L' – Stylus Button Function on page 37 and 'N' – Tip Offsets on page 39 for stylus configuration details.
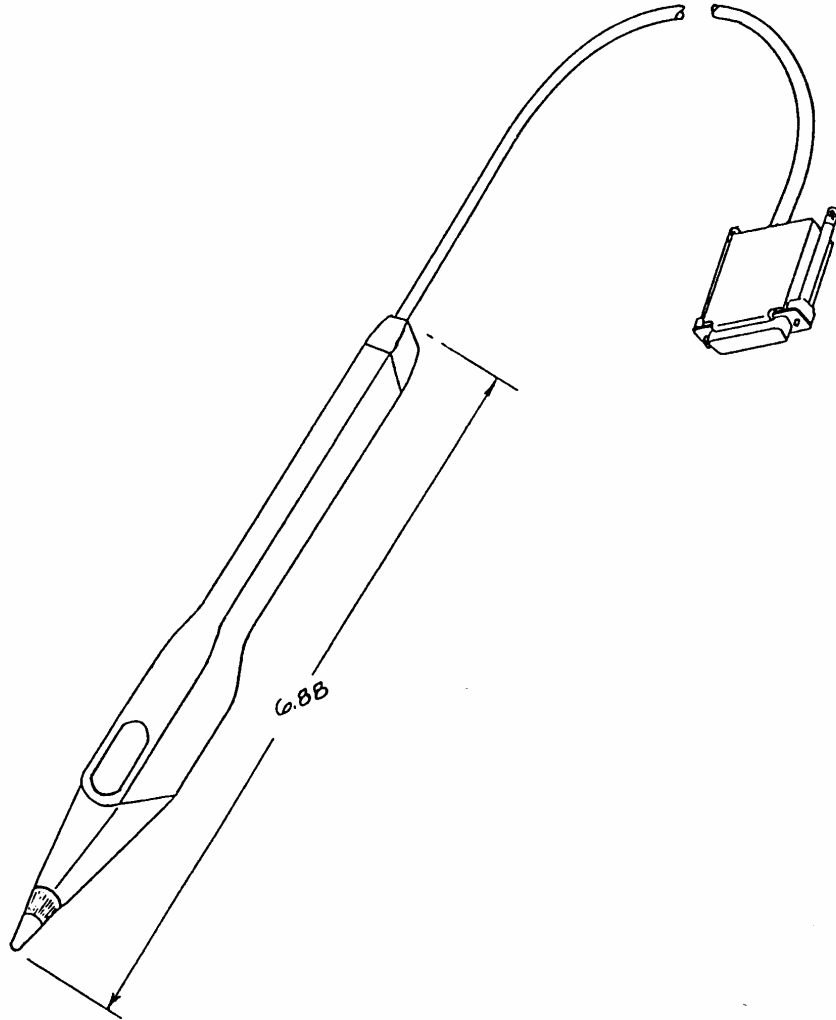
Figure 3-3 Stylus

4. SYSTEM OPERATION

4.1 I/O Considerations

There are two possible communication options available on the PATRIOT system: USB or RS-232. Each option supports either Binary or ASCII formats.

Upon power up or system initialization, if the USB cable is not plugged into the SEU, the PATRIOT will automatically send data to the RS-232 interface. The USB cable can be plugged in at any time and the PATRIOT will shift to USB operation. If the USB is unplugged, the PATRIOT system's power must be recycled to shift back to RS-232 operation.

4.2 Powering Up PATRIOT

To power-up the PATRIOT system, first ensure that the power switch on the back panel of PATRIOT is in the OFF (DOWN) position and that the power supply is not plugged into the AC. Then connect the power cable from the power supply to the power connector on the rear panel of PATRIOT.

Plug in the source and the desired number of sensors.

Plug in the desired I/O cable (USB or RS-232).

Plug the power supply into the AC outlet and turn the Power Switch to the ON (UP) position.

On power up, the power indicator will blink red for 5 to 10 seconds to indicate the system's performance of an initialization and self test routine. During this time, system operation is not possible. At the completion of this routine, the power indicator will change from a flashing red state to a steady green state. See LED Indicator on page 77 for a description of the LED status.

If PATRIOT is connected via RS-232, it will send a "PATRIOT Ready!" text message to the RS-232 port when initialization is complete.

4.3 Configuration Changes

PATRIOT will start up with a default configuration unless otherwise set to a different start-up configuration. Up to three user-defined configuration settings can be stored in the PATRIOT system. Any one of these configurations can be set as the startup configuration. See '^K' – Save Operational Configuration on page 66 and '^W' – Set Default Operational Configuration on page 71 for instructions on how to set and store configurations.

4.4 Output Update Rate

The data output update rate for the PATRIOT is 60 Hz.

4.5 Output Considerations

Most applications of the PATRIOT system involve using its data output to manipulate some type of computer graphics in real time. In this condition, it is extremely important to allow the data to be utilized as quickly as possible and to avoid latency or lag. Lag is defined as the interval of time between requesting a PATRIOT data point and receiving it into the host computer. Factors that could increase this lag are:

- Output Record Length

- Data Format (Binary is more efficient than ASCII)

- Filtering (data are produced at normal times but will show effects of filter lag)

- Background software and applications running on the host computer.

The PATRIOT also contains an adaptive filter that is designed to control noise in the data output. The filter can be applied to Position or Orientation or both. It should be noted that the effect that is seen in the data may have (or appear to have) a slower dynamic response with medium or heavy filtering selected. Although data is transferred at normal time, the filtering gives it the appearance of lag. See 'X' – Position Filter Parameters on page 45 and 'Y' – Attitude Filter Parameters on page 48 for more information on setting the filters.

4.6 Useful Range

An X, Y, or Z position value exceeding PATRIOT's useful range of 60 inches (152 cm) will be output as zero.

APPENDIX A. Alignment Reference Frame
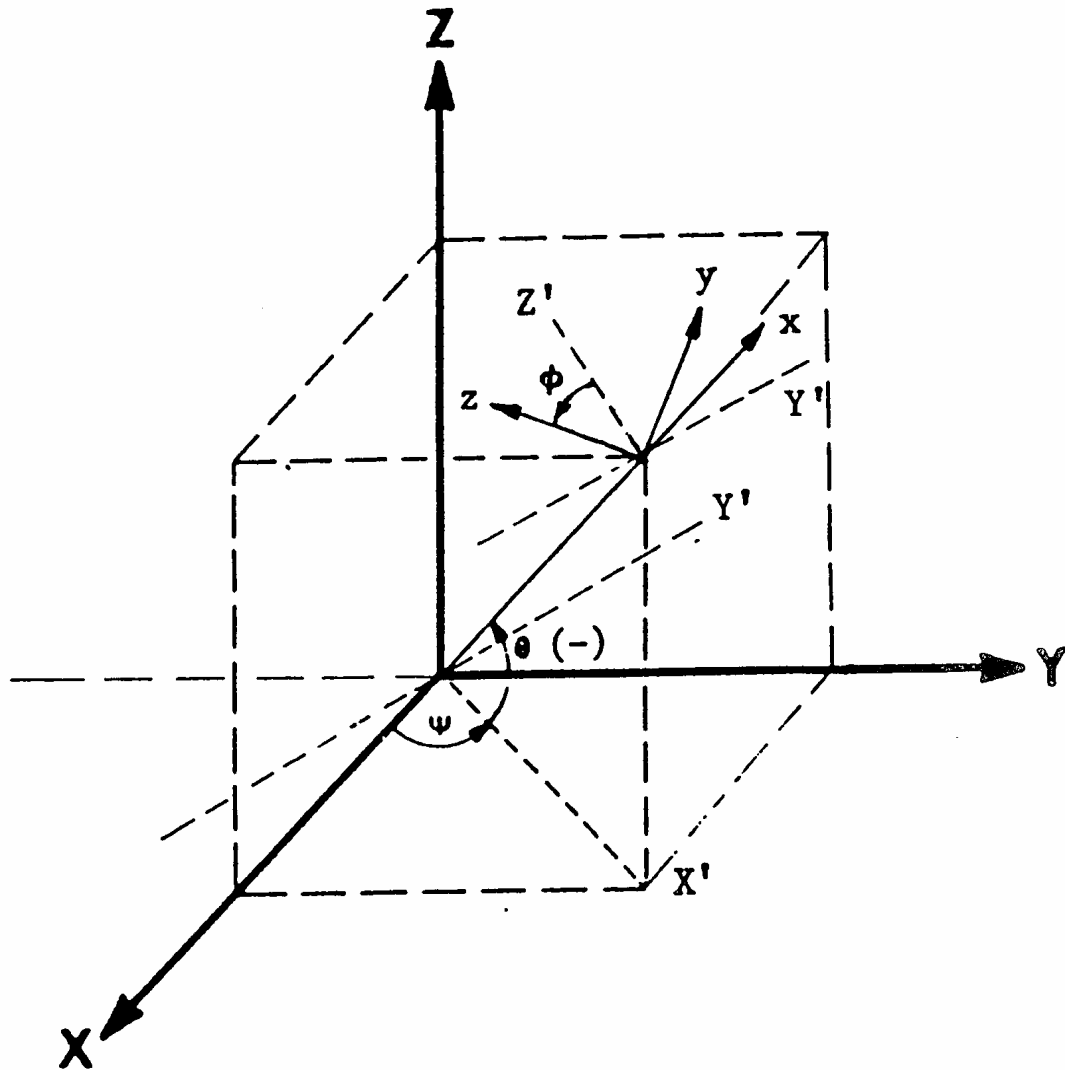
Legend

X, Y, Z = Alignment (Reference) Frame
x, y, z = Rotated Stylus or Sensor Coordinate Frame

Ψ = Azimuth
θ = Elevation
ϕ = Roll

Figure 4-1 Alignment Reference Frame

APPENDIX B. System Output Data Records

ASCII FORMAT

INITIATING COMMANDS .... P or C (continuous mode)

Byte Index	Format	Description
0	A	First Digit of Station Number
1	A	Second Digit of Station Number
2	A	Initiating Command
3	A	Error Indicator
4	B	ASCII Blank character
5-x	Variable	See Possible Formats below
(x+1)-(x+2)	AA	Carriage Return/Line Feed

Original Precision:

?* ..	x,y,z position Cartesian Coordinates	3(Sxxx.xxx)
?* ..	az,el,roll Euler orientation angles	3(Sxxx.xxx)
?* ..	direction cosines of the sensor's x,y,z axis	3(Sx.xxxxx)
?* ..	Orientation Quaternion (Q0-Q3)	4(Sx.xxxxx)
?* ..	Stylus Switch x where:	
	$x = 0$ or 1	

Extended precision:

?* ..	x,y,z position Cartesian coordinates	3(Sx.xxxxxESxxb)
?* ..	az,el,roll Euler orientation angles	3(Sx.xxxxxESxxb)

?* The system data record contents are specified by the user using the 'O' command and may vary from configuration to configuration. Therefore, the specific location of a data item in the output record is not determined until the record contents are defined.

NOTE: Original precision is retained for compatibility with previous Polhemus 3SPACE systems. Also, note that some item values are repeated as extended precision items, although no output difference is made (i.e., space, <cr lf>). Original and extended precision may be freely mixed in an output record, but it is recommended that extended precision be used if compatibility is not required, as the original precision may be deleted in future systems.

BINARY FORMAT

INITIATING COMMANDS ..... P or C (continuous mode)

Byte #	Type	Description
0,1	US	Frame Tag, always 'PA' or 0x5041 for PATRIOT HST
2	UC	Station Number
3	UC	Initiating command
4	UC	Error Indicator
5	UC	Reserved
6,7	SH	Response size – number of bytes in the response body.
8 - n		Binary Response body

?* ..... x,y,z position Cartesian coordinates   FL[3]

?* ..... az,el,roll Euler orientation angles   FL[3]

?* ..... direction cosines of the sensor's x,y,z axes.   FL[3]

?*   The system data record contents are specified by the user using the 'O' command and may vary from configuration to configuration. Therefore, the specific location of a data item in the output record is not determined until the record contents are defined.

The notation FL[3] refers to the ANSI/IEEE Standard for Binary Floating-Point Arithmetic 754-1985 format of data. This is defined in the standard as:

MSB   LSB

Bit 31	Bit 30-23	Bit 22-0	
Sign	Exponent	Fraction	
Byte 3	Byte 2	Byte 1	Byte 0

The IEEE floating-point format uses sign magnitude notation for the mantissa, and an exponent offset by 127. In a 32-bit word representing a floating-point number, the first bit is the sign bit. The next 8 bits are the exponent, offset by 127 (i.e., the actual exponent is e - 127). The last 23 bits are the absolute value of the mantissa with the most significant 1 implied. The decimal point is after the implied 1, or in other words, the mantissa is actually expressed in 24 bits. In the normal case an IEEE value is expressed as:

$(-1)S * (2**(e-127)) * (01.f)$ If $0 < e < 255$

APPENDIX C. Built In Test (BIT)

Initialization Results

Upon startup and initialization, PATRIOT automatically performs a series of Built-In Tests. PATRIOT initialization Built-In Test (BIT) results are read using the '^T' – Read/Clear BIT Errors command on page 67. This command returns initialization BIT results in a series of three bitmapped 32-bit words. When any initialization BIT errors have been detected, the P&O output frame header contains an 'I' (or 'A'–'G' if runtime errors also exist) in the header's error field. See Table 4-5 for more about BIT-related error codes.

The initialization BIT results words contain sub-bitmaps that represent Source, Global Sensor (GS), and individual Sensor Channel BIT results. A SET bit (1) position indicates that a BIT error occurred. If no errors were detected, each bit in all nine or eighteen words will be CLEARED (0). The words and their content are depicted in Table 4-1 below. Shaded areas represent reserved bit fields.

Table 4-1 BIT Results DWORDs

Word	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
												BITMAP																				
0										Source																	GS					
1			Sensor Channel 1																													
2			Sensor Channel 2																													

Source BIT Results

The sub-bitmap representing source BIT results is defined in Table 4-2 below.

Table 4-2 Source BIT Results

Bit	Definition
0	Magnitude X Error
1	Magnitude Y Error
2	Magnitude Z Error
3	Noise X Error
4	Noise Y Error
5	Noise Z Error
6	Source PROM Read Error
7	Reserved
8	Reserved

Global Sensor (GS) BIT Results

The sub-bitmap representing global sensor BIT results is defined in Table 4-3 below.

Table 4-3 Global Sensor BIT Results

Bit	Definition
0	Sensor Errors
1	Sensor 1 PROM Read Error
2	Sensor 2 PROM Read Error
3	Reserved
4	Reserved
5	Reserved
6	Reserved

Sensor Channel BIT Results

If Bit 0 of the global sensor BIT result map is SET, then sensor channel BIT results should be parsed to determine BIT errors for individual sensor channels. If a failed sensor channel is not in use, the initialization BIT errors can be cleared using the '^T' – Read/Clear BIT Errors command on page 67. Table 4-4 below defines sensor channel BIT results.

Table 4-4 Sensor Channel BIT Results

Bit	Definition
0	Gain 0
1	Gain 1
2	Gain 2
3	Noise 0
4	Noise 1
5	Noise 2
6-30	Reserved

Runtime Results

There are only 3 runtime BIT errors defined. These are:

> Source Failure X
>
> Source Failure Y
>
> Source Failure Z

Runtime errors are indicated in the error field of the output P&O frame header. An error code of 'a'–'g' or 'A'–'G' will indicate a combination of runtime and initialization BIT errors as indicated in Table 4-5 below. Note that upper case error codes indicate that uncleared initialization errors also exist. Lower case errors indicate that only runtime errors are present.

NOTE: Because they are updated on a frame-by-frame basis, runtime errors *cannot* be cleared with the '^T' – Read/Clear BIT Errors command on page 67.

Table 4-5 Runtime BIT Error Codes

Error Code		Source Failure X	Source Failure Y	Source Failure Z	Initialization BIT Errors Occurred
ASCII	HEX				
'a'		√			
'A'		√			√
'b'			√		
'B'			√		√
'c'		√	√		
'C'		√	√		√
'd'				√	
'D'				√	√
'e'		√		√	
'E'		√		√	√
'f'			√	√	
'F'			√	√	√
'g'		√	√	√	
'G'		√	√	√	√
'I'					√

APPENDIX D. Limited Warranty and Limitation of Liability

Polhemus warrants that the Systems shall be free from defects in material and workmanship for a period of two years from the date ownership of the System passed from Polhemus to Buyer. Polhemus shall, upon notification within the warranty period, correct such defects by repair or replacement with a like serviceable item at Polhemus' option. This warranty shall be considered void if the System is operated other than in accordance with the instructions in Polhemus' User Manual or is damaged by accident or mishandling. Parts or material, which are disposable or expendable or subject to normal wear beyond usefulness within the warranty period such as lamps, fuses, etc., are not covered by this warranty.

In the event any System or portion thereof is defective, Buyer shall promptly, and within the warranty period, notify Polhemus in writing of the nature of the defect, and return the defective parts at the direction of Polhemus Customer Service to Polhemus. Upon determination by Polhemus that the parts or Systems are defective, in the reasonable opinion of Polhemus, and covered by the warranty set forth above, Polhemus, at its option shall repair or replace the same without cost to Buyer. Buyer shall pay in advance all charges for transportation and delivery costs to Polhemus' factory for defective parts where directed to be sent to Polhemus, and Polhemus shall pay for transportation costs to Buyer's facility only for warranty replacement parts and Systems. Removed parts covered by claims under this warranty shall become the property of Polhemus.

In the event that allegedly defective parts are found not to be defective, or not covered by warranty, Buyer agrees that Polhemus may invoice Buyer for all reasonable expenses incurred in inspecting, testing, repairing and returning the Systems and that Buyer will pay such costs on being invoiced therefore. Buyer shall bear the risk of loss or damage during transit in all cases.

Any repaired or replaced part or System shall be warranted for the remaining period of the original warranty or thirty (30) days, whichever is longer.

Warranties shall not apply to any Systems that have been:

repaired or altered other than by Polhemus, except when so authorized in advance and in writing by Polhemus;

 (a)   used in an unauthorized or improper manner, or without following normal operating procedures; or

 (b)   improperly maintained and where such activities in Polhemus' sole judgment, have adversely affected the Systems. Neither shall warranties apply in the case of damage through accidents or acts of nature such as flood, earthquake, lightning, tornado, typhoon, power surge or failure, environmental extremes or other external causes; or

(c)   used for any purpose without obtaining any applicable regulatory approvals.

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IN NO EVENT SHALL POLHEMUS BE LIABLE UNDER ANY CIRCUMSTANCES FOR SPECIAL INCIDENTAL OR CONSEQUENTIAL DAMAGES, INCLUDING, BUT NOT LIMITED TO LOSS OF PROFITS OR REVENUE OR FOR INJURY TO PERSON. WITHOUT LIMITING THE FOREGOING POLHEMUS' MAXIMUM LIABILITY FOR DAMAGES FOR ANY CAUSE WHATSOEVER, EXCLUSIVE OF CLAIMS FOR PATENT INFRINGEMENT AND REGARDLESS OF THE FORM OF THE ACTION (INCLUDING BUT NOT LIMITED TO CONTRACT NEGLIGENCE OR STRICT LIABILITY) SHALL BE LIMITED TO ACTUAL DIRECT DAMAGES, NOT TO EXCEED THE PRICE OF THE GOODS UPON WHICH SUCH LIABILITY IS BASED.

The systems are not certified for medical or bio-medical use. Any references to medical or bio-medical use are examples of what medical companies have done with the systems after obtaining all necessary or appropriate medical certifications. The end user/OEM must comply with all pertinent FDA/CE and all other regulatory requirements.

APPENDIX E. Specifications

Update Rate
> 60 Hz. per sensor, simultaneous samples

Latency
> Less than 20 milliseconds

Number of Sensors
> 1 or 2

I/O Ports
> USB; RS232 to 115,200 Baud, both standard

Static Accuracy
> 0.1 in. RMS for X, Y or Z position; 0.75° RMS for sensor orientation

Resolution
> 0.0015 in. (0.0038 mm) at 12 in. (30 cm) range; 0.1° orientation

Range
> 36 in. (90 cm) at above specifications; useful operation up to 60 in. (152 cm)

Multiple Systems
> Provision available to operate two separate systems in same environment

Angular Coverage
> All-attitude

Data Format
> Operator selectable ASCII or IEEE 754 binary; English/Metric Units

Physical Characteristics
> *SEU:*
> 6.75 in. (17.1 cm) L x 6.25 in. (15.9 cm) W x 1.75 in. (4.5 cm) H; weight 0.85 lbs. (0.4 kg)
> *Field Source:*
> 2.3 in. (5.8 cm) L x 2.2 in. (5.6 cm) W x 2.2 in. (5.6 cm) H; weight 8.8 oz. (250 gms)
> *Sensor:*
> 0.9 in. (22.9 mm) L x 1.1 in. (27.9 mm) W x 0.6 in. (15.2 mm) H; weight 0.8 oz. (23 gms)

Power Module
> 3.5 in. (8.9 cm) L x 2.4 in. (6.1 cm) W x 1.4 in. (3.6 cm) H; weight 6 oz. (160 gms)

Power Requirements
> 100-240VAC, 50/60 Hz. Nominal (85-264 VAC, 47 – 63 Hz. max rating), single phase 10 W

APPENDIX F. Customer Service

If problems are encountered with the PATRIOT system or if you are having difficulty understanding how the commands work, help is just a telephone call away.

Call Polhemus at the numbers listed below and follow the prompts (select "2" for Customer Service and then "1" for Technical Support). Polhemus is open Monday through Friday, 8:00 AM to 5:00 PM, Eastern Standard Time. For the most part, our customer service representatives are usually able to solve problems over the telephone and get you back into the fast lane right away.

Help is also available on our web page at www.polhemus.com. Simply double-click Technical Support, then click techsupport@polhemus.com to send us an email describing the problem or question.

If a problem requires repair of your system, the customer service representative will issue a Return Merchandise Authorization (RMA) number and you may then return the system to the factory. *Do not return any equipment without first obtaining an RMA number.* Please retain and use the original shipping container, if possible, to avoid transportation damages (for which you or your shipper would be liable). If your system is still under warranty, Polhemus will repair it free of charge according to the provisions of the warranty as stated in Appendix D of this document. The proper return address is:

Polhemus
40 Hercules Drive
Colchester, VT 05446
Attention RMA #_____

From within the U.S. and Canada: (800) 357-4777

From outside the U.S. or Canada: (802) 655-3159

Fax #:(802) 655-1439

INDEX