



**3SPACE®**

**FASTRAK®**

**USER'S MANUAL**

**2002 Edition, Rev. C**

Copyright © 2000 by Polhemus Incorporated  
Colchester, Vermont U.S.A.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, mechanical, photocopying, recording or otherwise, without the prior written permission of Polhemus Incorporated. No patent liability is assumed with respect to the use of the information contained herein. While every precaution has been taken in the preparation of this book, Polhemus Incorporated assumes no responsibility for errors or omissions. Neither is any liability assumed for damages resulting from use of the information contained herein.

3SPACE® and FASTRAK® are registered trademarks of Polhemus Incorporated.

### **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 designed 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 his own expense.

### **EC-Declaration of Incorporation**

This product conforms 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:

**EN50081-2, EN50082-1, EN60950, \*EN55022**

\* NOTE: This product complies with the Class A requirements of EN55022.

## Table of Contents

<b>1.0 GETTING STARTED .....</b>	<b>1</b>
COMPLETE FASTRAK SYSTEM .....	1
TRANSMITTER CONNECTION .....	2
RECEIVER CONNECTION .....	2
MOUNTING TRANSMITTER AND RECEIVER ON 2X4 .....	3
POWER CONNECTOR .....	3
DC POWER CABLE INSERTION .....	4
DEFAULT I/O SELECT DIP SWITCH SETTINGS .....	5
RS-232 CABLE CONNECTION .....	5
FASTRAK DATA RECORD .....	6
<b>CONTACTING POLHEMUS CUSTOMER SERVICE .....</b>	<b>8</b>
<b>LATEST FASTRAK VS. PREVIOUS VERSIONS .....</b>	<b>9</b>
<b>FASTRAK COMMANDS INDEX .....</b>	<b>10</b>
<b>2.0 TECHNICAL OVERVIEW .....</b>	<b>11</b>
<b>3.0 SPECIFICATION .....</b>	<b>12</b>
POSITION COVERAGE .....	12
ANGULAR COVERAGE .....	12
STATIC ACCURACY .....	12
RESOLUTION .....	12
LATENCY .....	12
OUTPUT .....	12
UPDATE RATE .....	13
CARRIER FREQUENCY .....	13
RS-232 INTERFACE .....	13
USB INTERFACE .....	13
OPERATING ENVIRONMENT .....	14
OPERATING TEMPERATURE .....	14
PHYSICAL CHARACTERISTICS .....	14
POWER REQUIREMENTS .....	14
<b>4.0 COMPONENT DESCRIPTION .....</b>	<b>15</b>
4.1 SEU .....	15
4.2 TRANSMITTER PORT .....	17
4.3 RECEIVER PORTS (4) .....	17
4.4 POWER INDICATOR .....	17
4.5 I/O SELECT SWITCH .....	17
4.6 EXTERNAL SYNC I/O .....	19
4.7 FREQUENCY SELECT MODULE .....	19
4.8 RS-232 I/O .....	20
4.9 USB I/O .....	20
4.10 OPTIONAL RS-422 I/O .....	21
4.11 VIDEO SYNC INPUT .....	21
4.12 POWER INPUT RECEPTACLE .....	22
4.13 COOLING FAN .....	22
4.14 TRANSMITTER .....	22
4.15 RECEIVER(S) .....	24
4.16 STYLUS .....	25
4.17 3BALL .....	26

4.18 VIDEO SYNC DETECTOR .....	26
4.19 LONG RANGER TRANSMITTER.....	27
4.20 4" TRANSMITTER.....	28
4.21 SHORT RANGER TRANSMITTER.....	28
4.22 MINI RECEIVER.....	28
<b>5.0 SYSTEM OPERATION .....</b>	<b>29</b>
5.1 I/O CONSIDERATIONS.....	29
RS-232 CABLE CONNECTIONS .....	29
RS-422 CABLE CONNECTIONS .....	30
5.2 POWERING UP FASTRAK.....	30
5.3 CONFIGURATION CHANGES.....	30
5.4 USING THE USB INTERFACE .....	31
5.5 INSTALLING USB DEVICE DRIVERS .....	31
5.6 SYNCHRONIZATION .....	38
5.7 INTERNAL SYNC .....	38
5.8 EXTERNAL SYNC .....	38
5.9 VIDEO SYNC.....	38
5.10 MULTIPLE SYSTEMS SYNCHRONIZATION.....	39
5.11 OUTPUT CONSIDERATIONS .....	40
<b>6.0 SYSTEM COMMANDS.....</b>	<b>42</b>
6.1 COMMAND FORMAT NOTATION AND CONVENTION .....	42
6.2 COMMAND FORMAT NOTES.....	43
6.3 COMMAND/OUTPUT LISTING.....	44
ALIGNMENT REFERENCE FRAME A .....	45
*RESET ALIGNMENT REFERENCE FRAME R.....	48
*BORESIGHT B.....	49
BORESIGHT REFERENCE ANGLES G .....	50
*UNBORESIGHT b .....	52
CONTINUOUS OUTPUT MODE C.....	53
DISABLE CONTINUOUS PRINTING c .....	54
ENABLE FIXED METAL COMPENSATION D.....	55
DISABLE FIXED METAL COMPENSATION d .....	56
DEFINE STYLUS BUTTON FUNCTION e.....	57
ENABLE ASCII OUTPUT FORMAT F .....	58
ENABLE BINARY OUTPUT FORMAT f.....	59
HEMISPHERE OF OPERATION H.....	61
DEFINE INCREMENT I.....	65
ACTIVE STATION STATE l.....	67
*DEFINE TIP OFFSETS N.....	70
OUTPUT DATA LIST O.....	71
SYSTEM DATA RECORD, ASCII FORMAT .....	74
SYSTEM DATA RECORD, IEEE FLOATING-POINT FORMAT.....	76
SYSTEM DATA RECORD, 16-BIT BINARY FORMAT.....	77
SET OUTPUT PORT o .....	79
SINGLE DATA RECORD OUTPUT P.....	81
ANGULAR OPERATIONAL ENVELOPE Q.....	82
TRANSMITTER MOUNTING FRAME r.....	84
SYSTEM STATUS RECORD S.....	86
BUILT-IN-TEST INFORMATION T .....	89
ENGLISH CONVERSION UNITS U .....	92
METRIC CONVERSION UNITS u .....	93
POSITION OPERATIONAL ENVELOPE V.....	94
ATTITUDE FILTER PARAMETERS v .....	96
POSITION FILTER PARAMETERS x.....	99
RESET SYSTEM TO DEFAULTS W .....	102

CONFIGURATION CONTROL DATA X.....	103
SET SYNCHRONIZATION MODE y.....	105
* SAVE OPERATIONAL CONFIGURATION CTRL K.....	108
* REINITIALIZE SYSTEM CTRL Y.....	109
* SUSPEND DATA TRANSMISSION CTRL S.....	110
* RESUME DATA TRANSMISSION CTRL Q.....	111
6.4 COMMAND ERROR .....	112
6.5 DEFAULT OPERATION WITH A STYLUS OR 3BALL .....	113
<b>7.0 LIMITED WARRANTY AND LIMITATION OF LIABILITY.....</b>	<b>114</b>
<b>8.0 INDEMNITY AGAINST PATENT INFRINGEMENT.....</b>	<b>116</b>
<b>9.0 TROUBLE SHOOTING.....</b>	<b>117</b>
<b>GLOSSARY .....</b>	<b>119</b>
<b>APPENDIX A: STANDARD/OPTIONAL ITEMS</b>	
<b>APPENDIX B: ‘ACCURACY AND RESOLUTION’ WHITE PAPER</b>	
<b>APPENDIX C: ‘LATENCY’ WHITE PAPER</b>	
<b>APPENDIX D: CABLE DIAGRAMS</b>	
<b>INDEX</b>	



## 1.0 Getting Started

Congratulations on buying the finest 3D tracker system yet! This section of the user manual has been provided to help get your project under way as quickly as possible.

There are two ways to get started with your FASTRAK system, as with any new system. You could "wing it," which involves a great deal of assumptions based on either 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.

**NOTE:** This approach assumes a single receiver, use of the RS-232 serial port at 9600 Baud communicating with a Windows 95/98/NT PC, and use of the Microsoft Windows program HYPERTERMINAL.EXE.

1. Unpack the FASTRAK SEU, transmitter, receiver(s), and power supply.



### Complete FASTRAK System

2. Set up the 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 transmitter (the two-inch gray cube) and insert the transmitter connector into the transmitter receptacle, being careful to firmly engage it. Using your fingers or a small, flat blade screwdriver, lock the connector by tightening the two retaining screws.



### **Transmitter Connection**

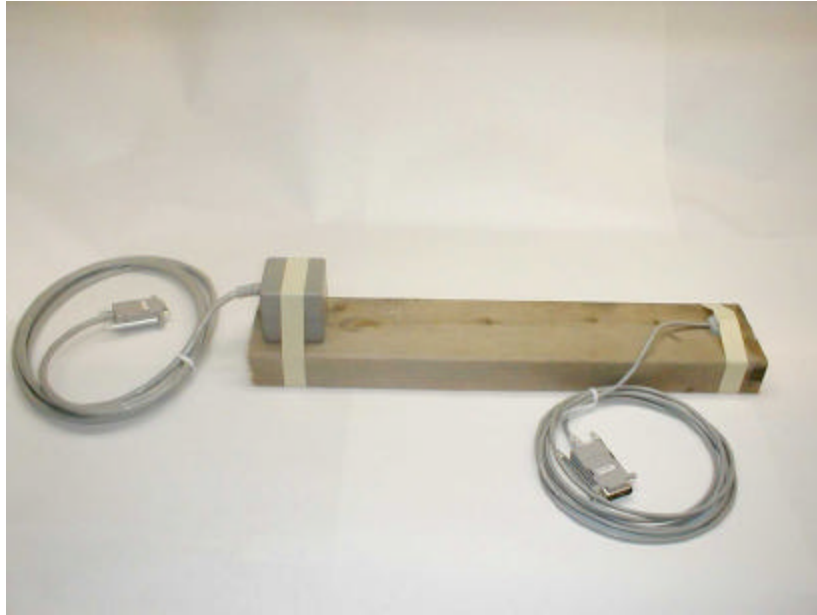
4. For getting started, use only one receiver. Identify the receiver and insert it into the receiver receptacle labeled “one” as shown below. Firmly engage and lock the receiver connector into place in the same manner as the transmitter connector in Step 3.



### **Receiver Connection**



5. For testing purposes, it is convenient to mount both the transmitter and the receiver on a single block of wood (2X4 or equivalent) about 16 inches apart. Exact placement of the transmitter and receiver is not important for this test; just make sure the cables of both devices are not routed together and they come off opposite ends of the 2X4.



**Mounting Transmitter and Receiver on 2x4**

6. Identify the five pin "DIN" type power input connector on the back panel of the electronics unit.



**Power Connector**

With the separate Power Supply ("brick") **UNPLUGGED** from the outlet of the wall, plug the "brick's" DIN connector into the power-input connector on the rear panel of the electronics unit and firmly seat.



### DC Power Cable Insertion

Identify the power ON/OFF rocker switch located on the rear panel of the electronics unit. Ensure this switch is in the OFF position (logic "0", DOWN) before inserting the "brick's" convenience plug into the 110/220 VAC outlet.

7. Identify the I/O Select Switch located on the rear panel of the electronics unit. Set the switches to the following positions:

<u>Switch</u>	<u>Position</u>
1	UP
2	UP
3	DOWN
4	DOWN
5	UP
6	DOWN
7	DOWN
8	UP



### Default I/O Select Dip Switch Settings

As set, these switches provide for RS-232 serial operation (Switch 8), 9600 baud (Switches 1, 2 & 3), 8 bit character width (Switch 5), no parity (Switches 6 & 7), and no hardware handshake (RTS, CTS) functionality (Switch 4).

**8. NOTE: THE FASTRAK SYSTEM BEHAVES AS A TRANSMITTER ON THE RS-232 AND THEREFORE A NULL MODEM CABLE IS REQUIRED.** Obtain a NULL MODEM RS-232 serial interconnection cable with a 9 pin, female "D" connector on the tracker end of the cable. Plug one 9 pin, female "D" connector into the I/O connector located on the rear panel of the electronics unit. Engage and lock this connection in the same manner as the receiver and transmitter connections as indicated in steps 3 & 4.



### RS-232 Cable Connection

9. Most PC hosts have a 9 pin, male "D" type connector for Com 1. If you are using Com 1,

plug the remaining end of the cable into the Com 1 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.**

10. Open a serial connection using the Windows program HyperTerminal. The steps are as follows:

- Click Start, point to Programs, Accessories, and click HyperTerminal
- Double-click the Hyperterminal.exe icon
- Enter a session name, choose an icon, and click OK
- In the "Connect using" field, select Com 1 or Com 2 (depending on the tracker connection) and click OK
- In the "Bits per second" field, select 9600
- 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

11. At this point, you may turn on the FASTRAK using the power switch located on the back panel of the SEU. Note the "power on" indicator located on the front panel of the electronics unit. It should flash for approximately 10 seconds indicating self-test and set-up. When these routines are completed (after the flashing), the indicator will turn to a steady-on state thereby indicating that the system is ready to operate.

12. You may now use the HyperTerminal Program to exercise the system. After sending an upper case "P" command to the system, the six-degree-of-freedom output data will be sent to the host. The data consists of a header (0s, where s equals the station number) and six columns of data as follows: (Note: these values represent an arbitrary placement of the receiver and transmitter.)

<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>
01	16.08	-0.38	0.71	3.05	1.12	-0.67

### **FASTRAK Data Record**

<u>Column</u>	<u>Function</u>
1	01 Header (not shown above)
2	X position in inches
3	Y position in inches
4	Z position in inches
5	Azimuth attitude in degrees
6	Elevation attitude in degrees
7	Roll attitude in degrees

Because you have locked the receiver in one position relative to the transmitter (Step 5), the data output will not change regardless of the number of data samples you take.

13. Remove the receiver, move it approximately six inches toward the transmitter, secure it

in place, and take a data point. 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 receiver approximately the same as it was when you started, then the attitude data will be approximately the same also.

14. Again, remove the receiver and without moving its position, try twisting it in azimuth (in the same plane as the 2 x 4) approximately 45 degrees and lock it down with tape. Now take another data point by pressing "P". The first four columns will be approximately as they were in Step 13, but the Azimuth data in column 5 will have changed by approximately 45 degrees.

15. Experiment with the system as shown in Step 14 to demonstrate that it measures the position and orientation (six-degrees-of-freedom) of the receiver with respect to the transmitter.

16. If the system fails to produce six-degree-of-freedom data, carefully go over the above procedure in a systematic fashion, checking connections and switch settings especially. When all else fails, call us.

## **Contacting Polhemus Customer Service**

If problems are encountered with the FASTRAK system or if you are having difficulty understanding how the commands work, help is just a telephone call away. Call Polhemus at (800) 357-4777 and select “2” for Customer Service and then “1” 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 engineers 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](http://www.polhemus.com). Simply double-click Technical Support, then click [techsupport@polhemus.com](mailto:techsupport@polhemus.com) to send us an email describing the problem or question.

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

**Polhemus Incorporated  
40 Hercules Drive  
Colchester, VT 05446  
Attention RMA #\_\_\_\_\_**

<b>Telephone (From the U.S. and Canada):</b>	<b>(800) 357-4777</b>
<b>Telephone (From outside the U.S. and Canada):</b>	<b>(802) 655-3159</b>
<b>Fax #:</b>	<b>(802) 655-1439</b>

## **Latest FASTRAK vs. Previous Versions**

Congratulations on purchasing our latest FASTRAK system! For our customers who presently own one or more of our tracker products, this recently upgraded version is fully compatible with earlier versions of our FASTRAK system. There are some minor differences, which we believe are an improvement on the previous design. For example, our new FASTRAK design allows the user to connect a stylus into any of the four receiver ports compared to the old FASTRAK design which required the stylus to be connected to port one only. Other improvements include....

- Faster baud rate capability: up to 460.8 Kbps
- No front panel Station Select Switches to set
- Soft download of firmware and distortion compensation maps
- USB interface

## FASTRAK Commands Index

Cmnd.			
<u>Ltr</u>	<u>FASTRAK Command Title</u>	<u>Brief Description</u>	<u>Page</u>
A	Alignment Reference Frame	Defines reference frame and origin	45
B	Boresight	Sets AER to zero or the value set by G	49
b	Unboresight	Removes new reference set by B	52
C	Continuous Output Mode	Enables continuous data output	53
c	Disable Continuous Output	Disables continuous data output	54
D	Enable Fixed Metal Compensation	Turns on compensation (if applicable)	55
d	Disable Fixed Metal Compensation	Turns off compensation (if applicable)	56
e	Define Stylus Button Function	Modifies stylus button function	57
F	Enable ASCII Output Format	Enables ASCII output format	58
f	Enable Binary Output Format	Enables binary output format	59
G	Boresight Reference Angles	Allows B to yield specific AER output	50
H	Hemisphere of Operation	Defines operating side of transmitter	61
I	Define Increment	Control output by receiver movement	65
L	Active Station State	Turns a receiver station off or on	67
N	Define Tip Offsets	Modifies stylus tip offsets	70
O	Output Data List	Changes data output list	71
o	Set Output Port	Modifies output port parameters	79
P	Single Data Record Output	Requests a single data output record	81
Q	Angular Operational Envelope	Sets angular operational envelope	82
R	Reset Alignment Reference Frame	Clears previous alignment for new entry	48
r	Transmitter Mounting Frame	Modifies transmitter mounting frame	84
S	System Status Record	Requests a system status record	86
T	Built-In-Test Information	Clears BIT error and obtains more info	89
U	Set Unit Inches	Sets XYZ measurements to inches	92
u	Metric Conversion Units	Sets XYZ measurements to centimeters	93
V	Position Operational Envelope	Sets XYZ operational envelope	94
v	Attitude Filter Parameters	Modifies AER filter parameters	96
W	Reset System to Defaults	Resets EEPROM to default settings	102
X	Configuration Control Data	Modifies config data in status record	103
x	Position Filter Parameters	Modifies the XYZ filter parameters	99
y	Set Synchronization Mode	Modifies sync mode	105
Ctrl K	Save Operational Configuration	Saves current config. to EEPROM	108
Ctrl Q	Resume Data Transmission	Allows data to be transmitted	111
Ctrl S	Suspend Data Transmission	Restricts data from being transmitted	110
Ctrl Y	Re-initialize System	Invokes start up as if power was cycled	109



## 2.0 TECHNICAL OVERVIEW

The FASTRAK tracking system uses electro-magnetic fields to determine the position and orientation of a remote object. The technology is based on generating near field, low frequency magnetic field vectors from a single assembly of three concentric, stationary antennas called a transmitter, and detecting the field vectors with a single assembly of three concentric, remote sensing antennas called a receiver. The sensed signals are input to a mathematical algorithm that computes the receiver's position and orientation relative to the transmitter.

The FASTRAK consists of a System Electronics Unit (SEU), one to four receivers, a single transmitter, a power supply and a power cord. The system is capable of operating at any of four discrete carrier frequencies. Different carrier frequencies allow operation of up to four FASTRAKs simultaneously and in close proximity to one another. The FASTRAK interfaces to the host computer via RS-232 serial communication. Any single receiver may be operated at the fastest update rate (120 Hz); any two receivers at one half this rate; any three at one-third this rate; or all four at one fourth the fastest rate. Of course, the unit must be set to output at a high enough baud rate to receive these updates. Mixed rates are not permitted meaning that all active receivers operate at the same update rate, i.e. one cannot be operated faster than another. Active receivers are selected by physical receiver cable connections and software configuration commands.

Additionally, the FASTRAK may be used with a stylus or a 3BALL device instead of a standard package receiver. Tip offsets are automatically calculated for the stylus and no special commands are required for this mode of operation. Switch functionality is provided with both the stylus and 3BALL device. The stylus and 3BALL may be used in any of the Receiver Ports. Operation of these devices is covered in Section 6.5.

### 3.0 SPECIFICATION

#### **Position Coverage**

The system will provide the specified accuracy when standard\* receivers are located within 30" (76 cm.) of the standard transmitter. Operation with separations up to 120" (305 cm.) is possible with reduced accuracy.

\*Note: Alternative devices of larger/smaller size are available as options and operate to longer/shorter ranges.

#### **Angular Coverage**

The receivers are all-attitude.

#### **Static Accuracy**

0.03" (0.08 cm) RMS for the X,Y,or Z receiver position, and 0.15° RMS for receiver orientation.

#### **Resolution**

0.0002 inches/inch of range (0.0005 cms/cm of range), and .025°.

#### **Latency**

4.0 milliseconds from center of receiver measurement period to beginning of transfer from output port.

#### **Output**

Software selectable including extended precision. Cartesian coordinates of position and Euler orientation angles are standard. Direction cosines and quaternions are selectable. English or metric units and ASCII or binary outputs also are selectable.

## Update Rate

One receiver: 120 updates/second  
Two receivers: 60 updates/second  
Three receivers: 40 updates/second  
Four receivers: 30 updates/second

## Carrier Frequency

The FASTRAK may be configured with any one of four discrete carrier frequencies to allow simultaneous operation of up to four systems in close proximity. Carrier frequencies are selected via color coded Frequency Select Modules (FSM). These frequencies are:

<u>Reference #</u>	<u>Frequency</u>	<u>Color Code</u>
1	8013 Hz	Black
2	10016 Hz	Red
3	12019 Hz (Std)	Yellow
4	14022 Hz	Blue

A colored dot can be found on the FSM, on the end closest to the connector and on the back panel of the FASTRAK SEU as it comes from the factory. FSMs different from the standard can be specified by the user at time of order or can be purchased for a nominal fee at any time. Field installation of a FSM should prompt user change out of the SEU color dot in order to facilitate easy identification among multiple FASTRAKs.

## RS-232 Interface

RS-232C serial port with software selectable baud rates of 2400, 4800, 9600, 19200, 38400, 57600, 115200, 230400, and 460800; ASCII or Binary formats. The factory default setting is 9600 baud. An RS-422 port is available as an optional serial port in lieu of the RS-232 at the same baud rates.

## USB Interface

USB (Universal Serial Bus) has become the predominant interface standard. It removes transmission speed limitations (due to maximum baud rate) and allows transmission speeds up to 12 Mbps. USB utilizes differential signaling for better signal quality and noise rejection and therefore allows the use of longer communication cables between the host computer and the FASTRAK system.

## Operating Environment

Large metallic objects, such as desks or cabinets, located near the transmitter or receivers may adversely affect the performance of the system. Many walls, floors, and ceilings also contain significant amounts of metal.

## Operating Temperature

10°C to 40°C at a relative humidity of 10% to 95% non-condensing.

## Physical Characteristics

**SEU:** Width 11.38" (28.91 cm.), length 11.06" (28.90 cm.), height 3.63" (9.22 cm.), weight 5.0 lb. (2.26 Kg.).

**Transmitter:** Width 2.1" (5.3 cm.), length 2.1" (5.3 cm.), height 2.3" (5.8 cm.), weight 0.6 lb. (0.27 Kg.) excluding attached cable. The Transmitter may be purchased with either 10' or 20' cables.

**Receiver:** Width 1.1" (2.83 cm.), length 0.90" (2.29 cm.), height 0.60" (1.52 cm.), weight 0.6 oz. (17.0 gm.) excluding attached cable. Receivers may be purchased with either 10' or 20' cables.

**Stylus:** Length 7.00" (17.78 cm.) including tip, or the shorter version Stylus, length 3.5" (6.04 cm.), maximum barrel diameter 0.75" (1.9 cm.), handle diameter 0.375" (0.95 cm.), tip length 0.8" (2.03 cm.), tip diameter 0.156" (0.4 cm.), weight 2.5 oz. (28.3 gm.) excluding attached cable. Either stylus may be purchased with either 10' or 20' cables.

**3BALL:** A standard receiver mounted in an official #3 billiard ball fitted with an integral switch. The 3BALL has a standard 10' cable.

## Power Requirements

International Power Sources Supply: Input power is 85-264 VAC, 47-440 Hz, and single phase at 30 watts.

## 4.0 COMPONENT DESCRIPTION

### 4.1 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 four receivers, a single transmitter and the RS-232 output port. Receiver Input(s), Transmitter Input, I/O Cables, I/O Select Switch, External Sync I/O, Video Sync Input, and Power Input connections are located on the SEU as shown in Figure 4.1A and Figure 4.1B.



Figure 4.1A FASTRAK SEU, Front View



Figure 4.1B FASTRAK SEU, Rear View

## 4.2 Transmitter Port

The single Transmitter receptacle port is a 15 pin, male "D" type connector located on the front of the SEU as shown in Figure 4.1A. The transmitter should be connected to the SEU before the unit is powered on and disconnected after the unit is powered off. **Caution:** Do not disconnect the transmitter while the FASTRAK SEU is powered on. Also, do not power on the SEU without a transmitter connected. When routing cables, please be sure the transmitter cable is routed separately from the receiver cables.

## 4.3 Receiver Ports (4)

The four Receiver receptacle ports are 15 pin, female "D" type connectors located on the front of the SEU as shown in Figure 4.1A. The receiver(s) should be connected to the SEU before the unit is powered on and disconnected after the unit is powered off. It is permissible to disconnect and re-connect receivers while the SEU is powered on, however, it is necessary to send the Ctrl Y reset command after doing so. This will allow the receiver's precise characterization matrix to be loaded into the FASTRAK memory. Again, rout the receiver cables separately from the transmitter cable.

## 4.4 Power Indicator

A green LED power on indicator is located on the front of the SEU as shown in Figure 4.1A. Upon power up, the indicator will blink for several seconds while the system performs its initialization and self-test routines. When these routines are complete, the indicator changes from blink mode to steady-on mode indicating that the system is ready for operation.

## 4.5 I/O Select Switch

The I/O Select Switch is an 8 position switch located on the rear panel of the SEU as shown in Figure 4.1B, Rear View and is only read on power up or system re-initialization (Ctrl Y command). The purpose of these switches is to select the RS-232 serial port parameters including baud rate, character width, and parity. The modes with switch positions and their corresponding functions are as follows:

Note: **UP** position is a logic "1" and **DOWN** is a logic "0".

<u>Switch Position</u>	<u>Function</u>
1	Baud rate select
2	Baud rate select
3	Baud rate select
4	Hardware Handshake select
5	Character width: "0" = 7 bits

"1" = 8 bits

- 6 Parity select
- 7 Parity select
- 8 I/O Select -- **UP** for **RS-232**

The Baud rate select logic for switches 1, 2 and 3 is as follows: (Again, 1=Up and 0=Down)

<u>Baud Rate</u>	<u>1</u>	<u>2</u>	<u>3</u>
1200	0	0	0
2400	1	0	0
4800	0	1	0
9600	1	1	0 (factory setting)
19200	0	0	1
38400	1	0	1
57600	0	1	1
115200	1	1	1

The system reads the baud rate switches only on power up or system re-initialization. Therefore, if you change the switches to obtain a different baud rate, you must restart the system either by recycling the power or by using the Ctrl Y command.

The "o" command may be used to override the switch settings during operation and select faster baud rates. The FASTRAK is capable of running at additional speeds of 230,400 and 460,800 bits per second. However, even though it is possible to save the new baud rate with the Ctrl K command, the next time you power up (or re-initialize the system with the Ctrl Y command), the system will ignore the EEPROM baud rate setting and read the dip switch settings to operate at that baud rate.

**Note:** High baud rates such as 115.2K and above generally require a short, well-made RS-232 cable in order to achieve error-free performance. The Hardware Handshake function has been discontinued in the new FASTRAK. Switch #4 has no effect.

The Parity select logic for switches 6 and 7 is as follows:

<u>Parity</u>	<u>6</u>	<u>7</u>
None	0	0
Odd	1	0
Even	0	1
not used	1	1 - if selected, system defaults to Even parity.



## 4.6 External Sync I/O

The External Sync I/O module is located on the rear panel of the SEU as shown in Figure 4.6A. The connector contains two modular telephone sockets with the one closest to the I/O Select Switch being "Sync In". The input signal must be a single-ended TTL signal. If the output is employed in the user's system, it should be interfaced with differential TTL circuitry. The Sync Out signals are also compatible with RS-422 specifications. The signal logic is as follows:

Input: START = Logic LOW to HIGH transition, 50  $\mu$ sec. pulse, min.

Output: START = Logic LOW to HIGH transition, 50  $\mu$ sec. pulse, min.

**CAUTION:** Do not attempt to synchronize an older FASTRAK with the new version of FASTRAK. The synchronization circuits between the two systems are incompatible.

The pin assignments for each plug are as follows and their numbering is shown in Figure 4.6A:

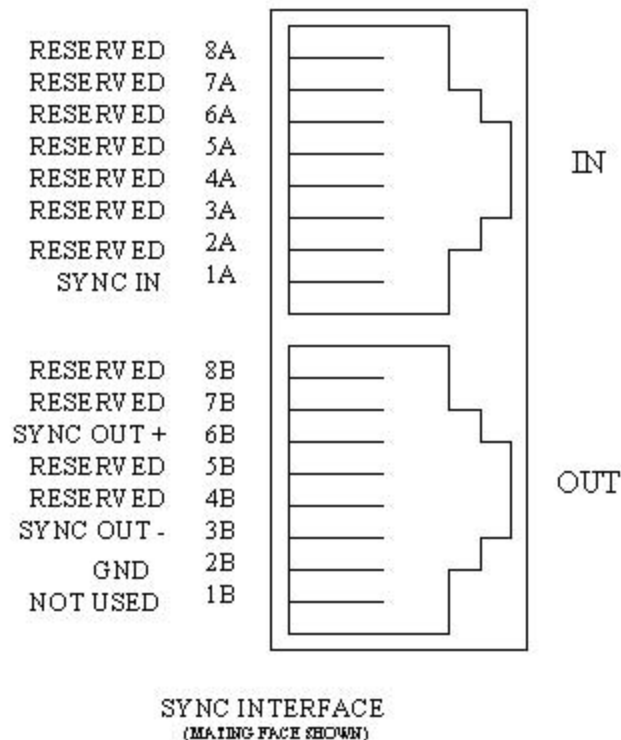


Figure 4.6A. Sync Connector Identification (Input & Output)

**Note:** If a ground is required, use a shielded cable and use the shield as the ground reference.

## 4.7 Frequency Select Module

The Frequency Select Module is used to select the operating carrier frequency of the FASTRAK system. It is located inside the SEU, directly behind the Transmitter input connector. The alternate carrier frequencies are produced by inserting the required tuning module in the socket provided. The Frequency Select Modules are color coded for carrier frequency identification as described in Section 3.0 of this document.

**Important Note:** As with any handling of an electronics printed circuit board (PCB), when inserting other frequency select modules to change the carrier frequency, static electricity precautions must be observed. Do not remove and replace frequency select modules with power applied to the SEU. Also, do not handle or touch the main PCB without first being grounded at an “ESD-safe” workstation.

#### 4.8 RS-232 I/O

The RS-232 I/O serial connector is a standard, 9 pin, male, "D type" connector located on the rear panel of the SEU as shown in Figure 4.1B. The pinout identification for this connector is as follows:

<u>FASTRAK End</u>	<u>User End</u>
1 Not used	
2 RxD (Receive Data) -----	TxD (Transmit Data to the FASTRAK)
3 TxD (Transmit Data) -----	RxD (Receive Data from the FASTRAK)
4 Not used	
5 GND -----	GND
6 Not used	
7 Not used	
8 Not used	
9 Not used	

**Note:** Many commercially available cables do not include connections for all pins, so do not assume that these connections are made. Please refer to Appendix D to find the specific interconnection scheme for your host computer in order to obtain a reliable serial interface.

If you do not find your particular host's RS-232 I/O interconnection scheme in Appendix D, call Polhemus and FAX a copy of your host computer's pin out identification from its user's manual. Polhemus will respond with advice on how to make the serial connection between your FASTRAK and your host computer. (Our Telephone and FAX numbers and email address can be found in Section 1.)

#### 4.9 USB I/O

The USB I/O connector is a standard Series B connector located on the rear panel of the

FASTRAK SEU as shown in Figure 4.1B. The connector on the FASTRAK is a square shaped connector with two corners shaved off for correct orientation upon insertion. The connector on the host PC is a Series A connector and is rectangular shaped. Since the connectors on each end of the USB cable are different, it is impossible to connect the cable incorrectly. The signals on the FASTRAK USB connector conform to the USB standard. The USB communication cable used to connect the FASTRAK to the host computer is a standard cable that is commercially available.

#### 4.10 Optional RS-422 I/O

The optional RS-422 connector is identical to the RS-232 connector in form, fit, function, and location on the rear of the SEU.

**Important Note:** In order to use this interface, the FASTRAK system must be ordered from the factory configured for RS-422 communication. A system can be configured for RS-422 **or** RS-232 communication, but not both. Once ordered, a system can be returned to the factory to have its interface configuration changed for a nominal fee.

RS-422 is a differential transmit and receive I/O standard with a maximum error-free speed of 10 Megabits/second (technical specifications for RS-422, not FASTRAK) with operation possible at a distance of 1200 meters with a speed of 100Kbits/second. The RS-422 does not use Handshake functions for transmission and reception. The RS-422 transfer rate on a FASTRAK is the same as for RS-232, but larger communication cables can be used, which is very important at higher baud rates. The pinouts for this connector are as follow:

<u>FASTRAK End</u>	<u>User End</u>
1 TxB -----	RxB (Non-inverting receive input)
2 Not used	
3 Not used	
4 RxB -----	TxB (Non-inverting transmit output)
5 Not used	
6 TxA -----	RxA (Inverting receive input)
7 Not used	
8 Not used	
9 RxA -----	TxA (Inverting transmit output)

#### 4.11 Video Sync Input

The Video Sync Input is a subminiature telephone receptacle that mates with the video pickup coil assembly (Video Sync Detector, optional). The Video Sync Input is located on the rear of the SEU as shown in Figure 4.1B. Video sync is available to minimize noise generated by computer monitors, detected by the receivers. In order to use the video sync capability, the Video Sync Detector cable must be connected to the video sync input connector on the FASTRAK. The detector can then be positioned on the monitor surface where it will detect a sync pulse. After sending the y2 external sync. command to the FASTRAK, it will be synced to the monitor. See section 5 for more information on synchronization.

#### 4.12 Power Input Receptacle

The Power Input is a 5 contact, female, shielded DIN type receptacle located on the rear panel of the SEU as shown in Figure 4.1B. Pin outs for this receptacle are as follows:

<u>Pin #</u>	<u>Function</u>
1	GROUND (Digital)
2	GROUND (Analog)
3	+5 VDC
4	-15 VDC
5	+15 VDC

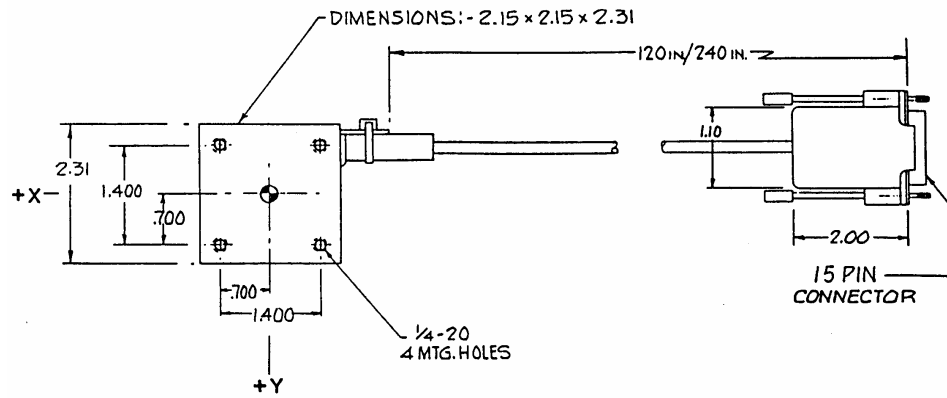
**Note:** Digital ground, pin 1 is **not** electrically shorted to analog ground, Pin 2 on the PCB. (They are electrically connected in the power supply.)

#### 4.13 Cooling Fan

A small cooling fan is located on the rear panel of the SEU as shown in Figure 4.1B. The fan is powered from the 5 VDC supply and will only operate when the system is powered up.

#### 4.14 Transmitter

The Transmitter is the device which produces the electro-magnetic field and is the reference for the position and orientation measurements of the receivers. It is usually mounted in a fixed position to a non-metallic surface or stand, which is located in close proximity to the receivers. The Transmitter is dimensionally shown in Figure 4.13A including the position of the electrical center. There are 4, 1/4" - 20 NC tapped holes provided on the bottom surface for mounting. Nylon hardware (supplied) should be used when locating the Transmitter in a fixed position. **Note:** Please be sure to route the transmitter cable separate from the receiver cables in order to avoid possible noise problems.



+Z DIRECTION IS OUT OF PAPER (TOWARDS VIEWER)

Figure 4.14A Transmitter Dimensions (In Inches)

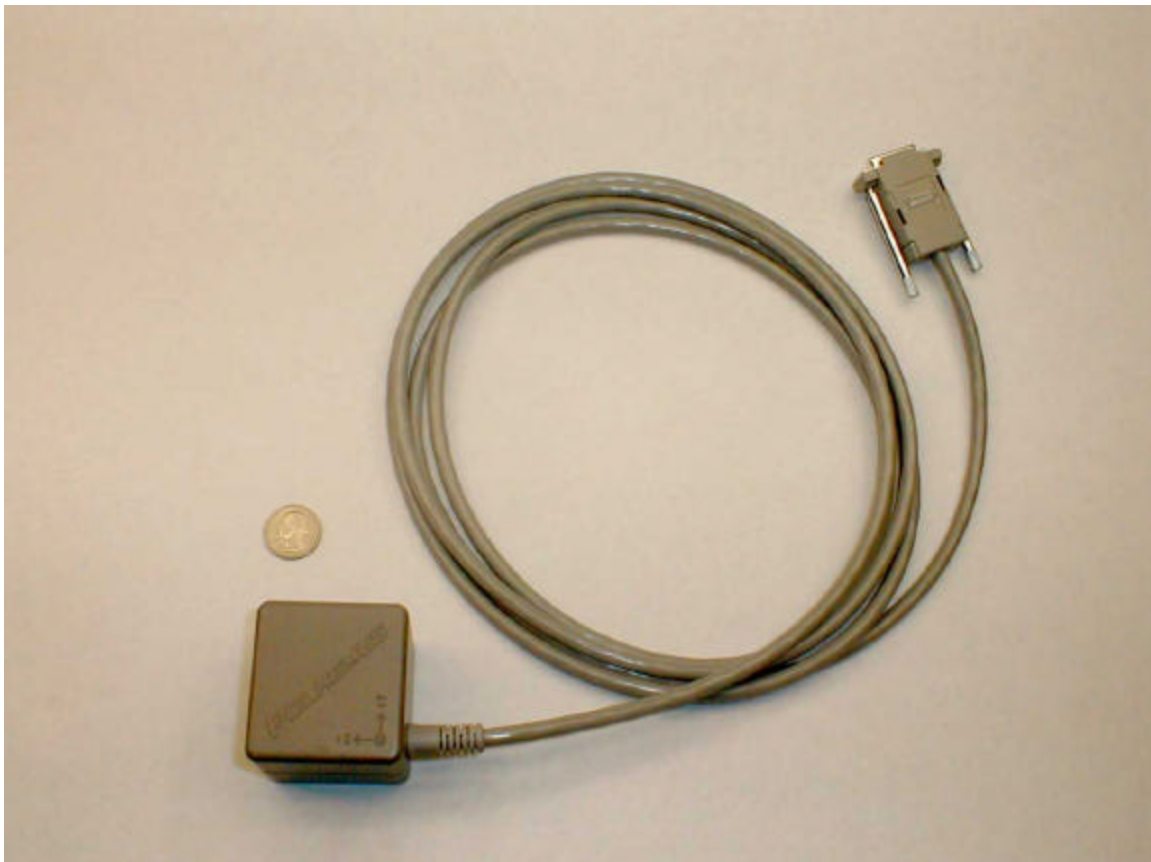


Figure 4.14B Transmitter

#### 4.15 Receiver(s)

The receiver is the smaller device whose position and orientation is measured relative to the Transmitter. The Receiver is dimensionally shown in Figure 4.14A including the position of the electrical center. The Receiver package provides 2 mounting holes for #4 nylon screws (supplied) in the event that Receiver mounting is required.

**Note:** Nylon hardware is only required when the hardware will be **in direct contact with the transmitter or receiver**. 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 system. Again, please be sure to route the receiver cables separate from the transmitter cable.

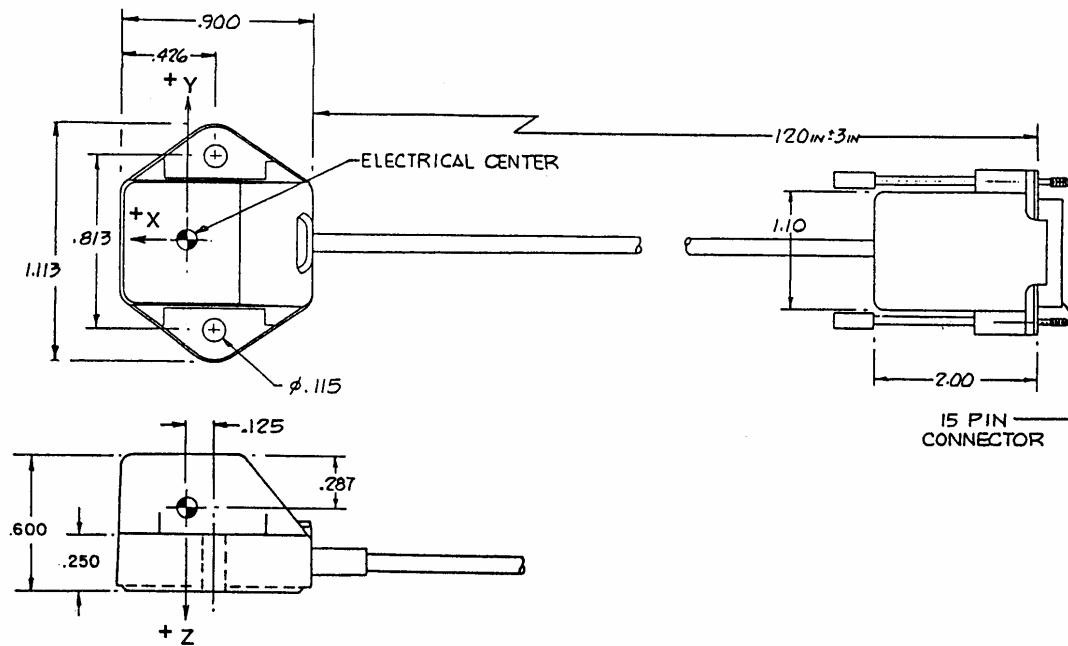


Figure 4.15A Receiver Dimensions (in Inches)



Figure 4.15B Receiver

#### 4.16 Stylus

The stylus is a pen shaped device with a receiver 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 4.15A and may be used in any of the receiver ports. The stylus functions as a receiver with the electrical center offset from the tip of the stylus via software. Single or Continuous output records may be obtained as a function of the integral switch. See Section 6.5 for operation with a stylus.

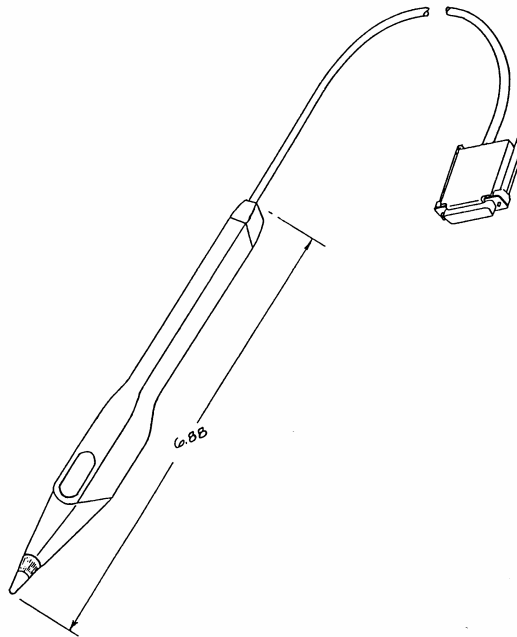


Figure 4.16A Stylus Dimensions

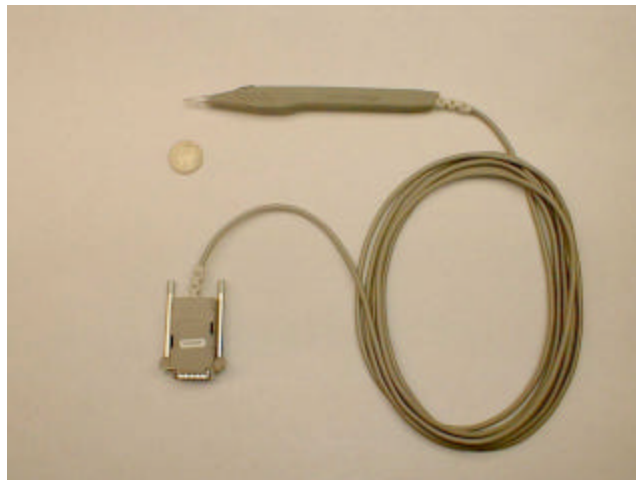


Figure 4.16B Stylus

#### 4.17 3BALL

The 3BALL is a #3 billiard ball with a receiver coil assembly built inside and an integral push button switch to effect data output. The 3BALL is shown in Figure 4.16A. It may be used in the same manner as a stylus where single or continuous data output records may be obtained as a function of the switch. The data are referenced to the center of the ball. Like the stylus, the 3BALL may be used in any of the receiver ports. See section 6.5 for operation with the 3BALL device.



Figure 4.17A. 3BALL

#### 4.18 Video Sync Detector

The Video Sync Detector consists of a suction cup pickup coil with a 3' cable terminated with a subminiature telephone plug. The Video Sync is used when the system's data exhibits objectionable noise when operating a receiver in close proximity to any CRT monitor. If this condition occurs, then Video Sync may be employed using the Video Sync Detector through the software command "y2".

The pickup coil of the Video Sync Detector is attached to the CRT (Monitor) case and the connector inserted into the Video Sync Detector input. After issuing the "y2" command, the system checks for sufficient signal level from the video pickup coil. If the signal level from the pickup coil is below a preset threshold, the message **"no video sync available"** will be displayed. If this condition exists, move the pickup coil to another part of the Monitor case. This procedure should be



repeated until the message **"no video sync available"** ceases to occur. The video synchronization mode may be exited at any time by selecting another type of synchronization mode using the "y" command.



Figure 4.18A Video Sync Detector

#### 4.19 Long Ranger Transmitter

The Long Ranger Transmitter is an optional device which produces a larger electro-magnetic field and therefore enables greater range capabilities. The 18" acrylic sphere is attached to a pedestal, which is typically mounted on the optional tripod assembly, or suspended from the ceiling. The advantage besides longer range, when using the Long Ranger Transmitter in lieu of the standard transmitter, is a better signal to noise ratio (less noise) so that whole body tracking can easily be done.

#### **4.20 4" Transmitter**

The 4" Transmitter is an optional device which allows up to 40% more range than the standard 2" Transmitter. The 4" Transmitter can be employed in virtually the same environments as the standard transmitter, and even uses the same mounting hole pattern—allowing increased range without degradation in the data.

#### **4.21 Short Ranger Transmitter**

The Short Ranger Transmitter is an optional device, which produces a smaller electro-magnetic field for precision work in a restricted space. It is dimensionally the same as the receiver and is shown in Figure 4.14A. There are two advantages of using the Short Ranger Transmitter in lieu of the standard transmitter. A small volume: 1) less susceptibility to field distortions with metals nearby and 2) no concern about transmitter aperture when closely approaching the device.

#### **4.22 Mini Receiver**

The Mini Receiver is an optional device; 10-12 mm in size, whose position and orientation is measured relative to the transmitter, like all receivers. Because of its small size, its maximum range from the transmitter is reduced to 35% -40% that of a standard receiver.

## 5.0 SYSTEM OPERATION

### 5.1 I/O Considerations

Currently, there are two possible interface configuration options available on the FASTRAK system; the standard RS-232 serial configuration or the optional RS-422 parallel configuration. Each configuration supports either Binary or ASCII formats.

**RS-232** The RS-232 is the most commonly used port both in binary and ASCII formats because of its commonality and the fact that it supports high baud rates. The RS-232 port should be used where host to FASTRAK physical separation distances are no greater than 50 feet and baud rates can be kept low. (Higher baud rates will require shorter cable lengths for reliable operation.) There are two modes of operation with the RS-232; with Hardware Handshake (HH) and without HH.

Ensure that your RS-232 cable connects the **FASTRAK TRANSMIT** data pin (pin 3) to the **HOST'S RECEIVE** data pin and that the **FASTRAK RECEIVE** data pin (pin 2) is connected to the **HOST'S TRANSMIT** data pin. Also ensure that the RS-232 cable connects the **FASTRAK GROUND** (pin 5) to the **HOST'S GROUND** pin. Note that the host computer's ground pin may be designated as "Signal Ground" or some other comparable phrase.

#### RS-232 Cable Connections

<u>FASTRAK</u>	<u>HOST</u>
Transmit (pin 3) -----	Receive
Receive (pin 2) -----	Transmit
Ground (pin 5) -----	Ground

**RS-422** The optional RS-422 port is used where large separation distances between the FASTRAK and the host are anticipated. If high baud rate operation over a long communication cable is required but the host computer does not have an RS-422, inexpensive RS-422/RS-232 conversion modules are available commercially. Please contact Polhemus Customer Service should you need suggestions on where to locate these modules.

As with the RS-232 port, the RS-422 Transmit signals from the FASTRAK must be connected to the Host's Receive signals and the FASTRAK's Receive signals must be connected to the Host's Transmit signals. Signal polarity conventions must be strictly observed. See diagram below for connections.

## RS-422 Cable Connections

### FASTRAK

### HOST

RxB; receive high (pin 1)	-----	TxB; transmit high
TxB; transmit high (pin 4)	-----	RxB; receive high
RxA; receive low (pin 6)	-----	TxA; transmit low
TxA; transmit low (pin 9)	-----	RxA; receive low

## 5.2 Powering Up FASTRAK

To power-up your FASTRAK system, first ensure that the power switch on the back panel of the FASTRAK is in the "off" position and the power supply brick is not plugged into the AC wall outlet. Then connect the power cable from the power supply to the DIN power connector on the rear panel of the FASTRAK. Connect the power cord to the power supply brick and plug it into the AC wall outlet. Configure the dip switch settings on the I/O select switch. Plug in transmitter, receivers and RS-232 cable and turn the power switch to the ON position. On power up, the power indicator will blink for several 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 "blink" state to "steady-on" which indicates that the system is now operational.

**Important Note:** Do not connect or disconnect the power cable to the FASTRAK while it is powered on or while the power supply brick is energized. Internal component damage could result.

### Initial Power Up Procedure

- Verify FASTRAK power switch is off
- Verify power supply brick is not energized (plugged into the wall outlet).
- Connect power cable from the brick to the power connector on rear panel of FASTRAK
- Plug power supply brick into AC wall outlet
- Configure switch settings on I/O select switch
- Plug in transmitter, receivers, and RS-232 cable
- Turn on FASTRAK power switch

## 5.3 Configuration Changes

Although receivers can be connected or disconnected while the unit is powered on, it is not normal operating practice. However if it is necessary to do this, it is important to either cycle the system power or send the Ctrl Y reset command. This allows the device characterization data for the receiver to be read and applied to future measurements. Normal system accuracy cannot be achieved unless the receiver characterization data has been read properly.

**Important note:** Do not connect or disconnect the transmitter while the FASTRAK system is

powered on.

#### 5.4 Using the USB Interface

When the FASTRAK is powered on, it is enabled for RS-232 communication. As soon as the USB cable is plugged in, the FASTRAK will shift to USB operation. (See figure 5.4 below.) It takes the FASTRAK approximately 3-4 seconds to shift to USB mode. Since the FASTRAK can not communicate over the RS-232 port and the USB port simultaneously, the user needs to choose which interface will be used and cease communication over the other port. Once the FASTRAK is in the USB mode, simply disconnecting the USB cable will not put the FASTRAK back in RS-232 mode. In order to switch the FASTRAK back to RS-232 mode, the user must disconnect the USB cable and then cycle the power on the FASTRAK (turn it off, then turn it back on again.) Note that anytime during RS-232 operation, the USB cable can be plugged into the FASTRAK and it will switch to USB mode, without having to cycle the power. However, it is best to disable continuous output mode and close any programs communicating with the FASTRAK via RS-232 first, in order to avoid error messages or program lock-ups while switching to the USB mode.



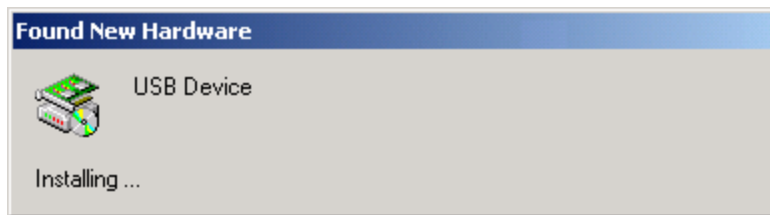
Figure 5.4 Connection of USB Cable to Switch to USB Mode

#### 5.5 Installing USB Device Drivers

**Note: The following USB Device Driver was designed to run on Windows 2000 and Windows XP.**

The first time the FASTRAK is connected to a new host computer (via USB), a device driver must be installed on that computer before USB communication can be established. This process is somewhat automatic, but requires occasional key strokes by the user during the installation process. (Please note that the FASTRAK USB port was designed to operate in accordance with the USB 1.0 standard.)

When the USB cable is connected from the FASTRAK to the host computer for the first time, the following message will appear:



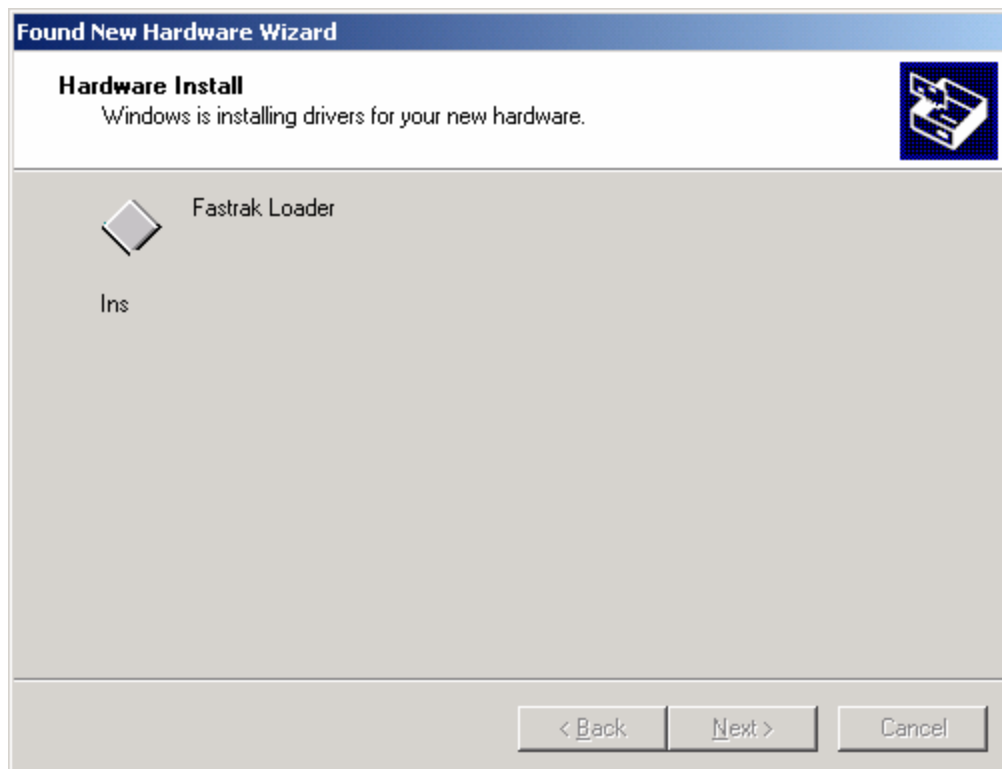
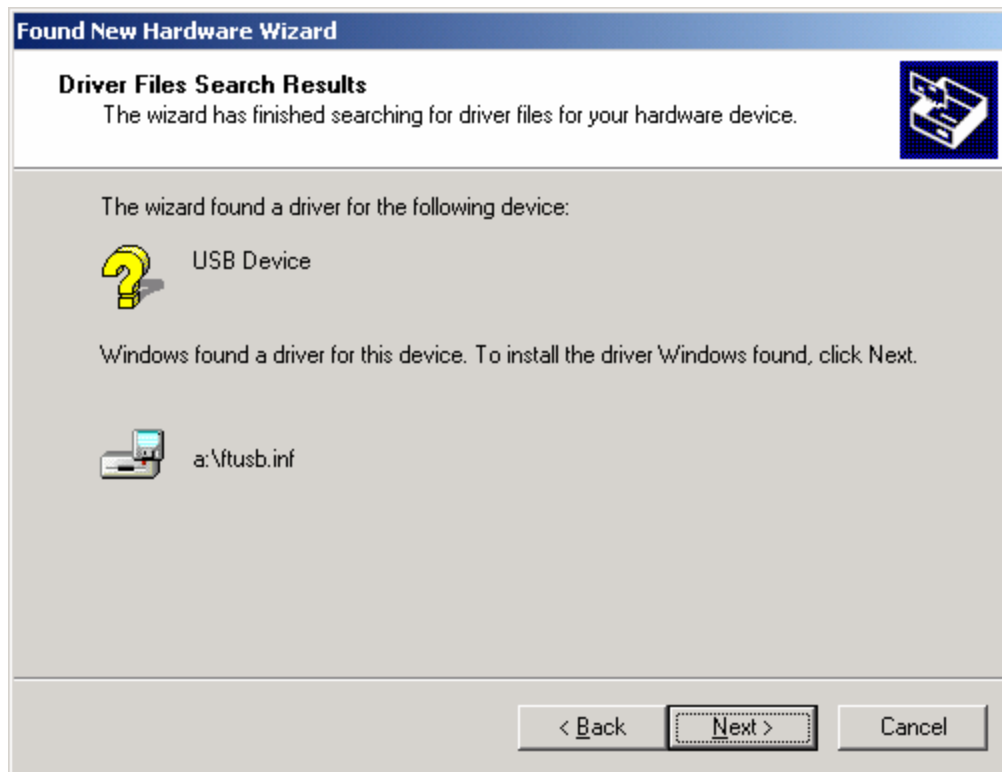
Shortly after the message, the 'Found New Hardware Wizard' will be launched.





Make sure the Floppy disk or CD containing the USB device driver is inserted into the drive before pressing 'Next' in the following window.



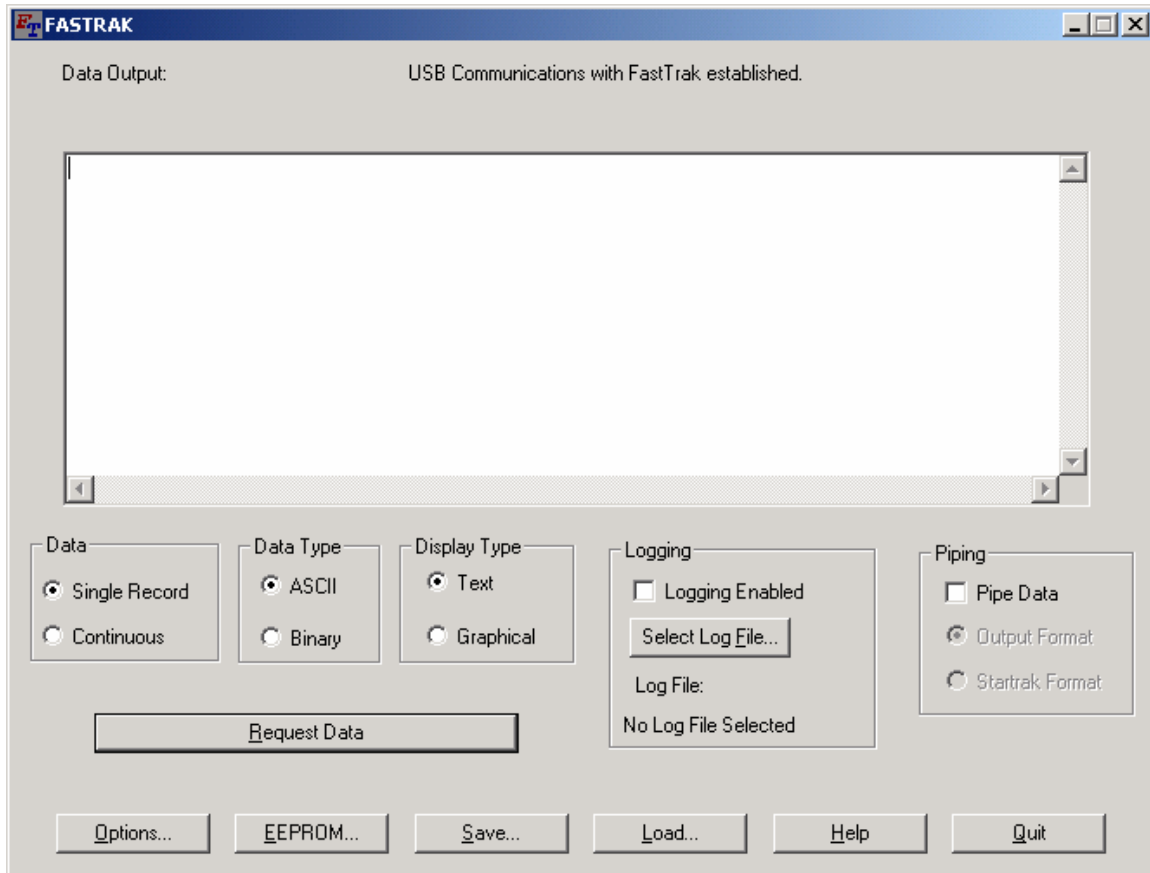




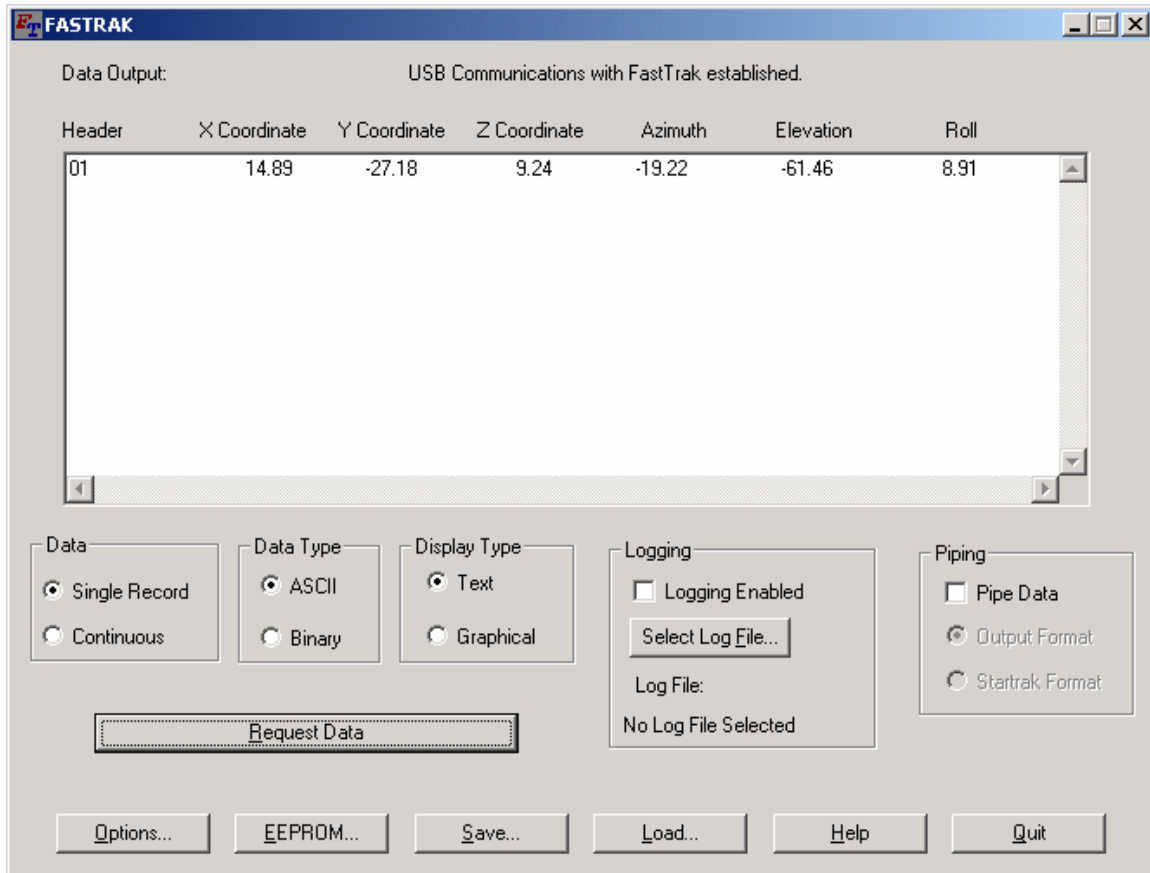


At this point, the device driver installation is complete and the host computer should be ready to communicate with the FASTRAK over the USB port with the user's application software.

To verify USB communication using the Polhemus GUI, double-click on the FASTRAK GUI icon (FT GUI). In the 'Data Output' field, the message 'USB Communications with FASTRAK established' should be displayed as shown below:



Click the 'Request Data' button to get data from the FASTRAK over the USB port.



Receiving data from the FASTRAK using the GUI confirms that the USB device drivers have been successfully installed on the host computer and the FASTRAK should now be able to communicate with the host application over the USB port. For subsequent utilization of the USB I/O, simply make sure that the USB communication cable is connected to the FASTRAK and the host computer, before turning on the FASTRAK power.

To return to RS-232 communication, disconnect the USB cable and cycle the power on the FASTRAK system. (Make sure the RS-232 cable is connected and that the host communication software settings are set correctly, i.e. com port selection, baud rate, parity, etc.)

## 5.6 Synchronization

Synchronization defines and controls the precise time that a FASTRAK system measurement cycle will start and thereby controls the tracking output from an application system point of view. The FASTRAK system has three distinct synchronization modes that are controlled by the "y" commands and are defined as:

<u>Command</u>	<u>Synchronization Mode</u>
y0<>	Internal Sync. (Default)
y1<>	External Sync.
y2<>	Video Sync.

## 5.7 Internal Sync

In the Internal Sync mode, each measurement cycle of the FASTRAK system starts immediately after the previous cycle ends. The system update rate is slightly greater than 120 Hz, and cycle-to-cycle variations on the order of microseconds are possible in this mode. Only the "y0" command is required to initiate the Internal Sync mode and no input is required for the system's SYNC IN port.

## 5.8 External Sync

The External Sync mode allows the user to define when the FASTRAK system measurement cycle will start, by means of a user supplied external sync pulse. This mode may be used to synchronize other peripheral instrumentation to the FASTRAK data collection cycle or to slow the FASTRAK to a known and desired rate. To initiate the External Sync mode an external signal as detailed in Section 5.5 must be input to the SYNC IN port and the "y1" command issued.

## 5.9 Video Sync

The Video Sync mode should be used when a receiver will be operating in close proximity to a CRT monitor and the FASTRAK measurements appear noisy. (The amount of noise detected will ultimately determine the definition of "close proximity," but it is usually when the receiver is less than 24 inches away from the monitor.) The reason this can occur is that all CRT monitors produce a magnetic field during the vertical refresh cycle. After connecting the video sync detector and sending the "y2" command, the detector will sense the magnetic field and cause the FASTRAK to begin each measurement cycle after a slight pause for settling time. This ensures that the FASTRAK measurement cycle will not occur during the monitor refresh cycle and eliminate noisy data.

## 5.10 Multiple Systems Synchronization

When using more than one FASTRAK in the same area, it is important to ensure that each unit have a different Frequency Select Module and to sync the units together so that they will not interfere with each other and produce noisy data. Additionally, system synchronization ensures that each FASTRAK will operate at the fastest possible update rate while operating at reasonable separation distances from the other FASTRAKs. If they are not synchronized, then greater separation distances between systems is required.

**Separation distance is defined as the distance between the transmitter of one system and the receiver of another system when both systems are operating.**

Without changing the frequency module or synchronizing systems together, the minimum separation distance is 23 feet or 7 meters. If **only** the Frequency Select Modules are changed and the systems are **not** synchronized together, then the minimum separation distance is 16 feet or 5 meters. If the Frequency Select Modules **and** the systems are synchronized, then the minimum separation distance is 15 inches or 38 centimeters. Clearly, the last option offers the greatest set up flexibility and user freedom. The separation distance guidelines are restated below for further clarification:

**If systems have identical Frequency Select Modules and they are not synchronized:**

- Separation distance should be 23 feet or 7 meters

**If systems have different Frequency Select Modules and they are not synchronized:**

- Separation distance should be 16 feet or 5 meters

**If systems have different Frequency Select Modules and they are synchronized:**

- Separation distance should be 15 inches or 38 centimeters, with transmitter-to-transmitter adjacent spacing no closer than 6 inches or 15.2 centimeters

Again, separation distance is defined as the distance between the transmitter of one system and the receiver of another system. **Note:** These separation distances assume FASTRAK systems using standard 2-inch transmitters and standard receivers.

Synchronizing multiple systems involves sending each system the appropriate “y” command and the interconnection of the SYNC IN/SYNC OUT ports of up to four systems to be operated in the same area. The interconnection is accomplished by using a “daisy chain” configuration where one system is arbitrarily designated as the “Master” and the remaining systems are designated as “Slaves.” The SYNC OUT port of the “Master” is connected to the SYNC IN port of the first “Slave” and this “Slave’s” SYNC OUT port is connected to the next “Slave’s” SYNC IN port and so on for a maximum of four systems (1 master and 3 slaves).

When synchronizing multiple systems, the “Master” system may be synchronized in any mode desired (Internal, External, or Video) using the appropriate “y” command corresponding to the chosen mode. However, each of the remaining systems (Slaves) must be configured in the External Sync mode using the “y1” command.

#### Procedure for Synchronizing Multiple Systems

- Ensure that each FASTRAK system has a different color Frequency Select Module installed
- Arbitrarily choose one of the FASTRAKs to be the Master
- Connect one end of the Sync cable to the SYNC OUT port of the Master
- Connect the other end of the Sync cable to the SYNC IN port of the first Slave
- Connect one end of another Sync cable to the SYNC OUT port of the first Slave
- Connect the other end of the Sync cable to the SYNC IN port of the second Slave and continue hooking up Sync cables in this fashion until all slaves are connected
- Send the Master the appropriate “y” command (Internal, External, or Video Sync), usually internal unless the user system can supply a sync input
- Send each Slave the “y1” command
- Maintain the proper separation distance of 15 inches or 38 centimeters and transmitter-to-transmitter adjacent spacing of 6 inches or 15.2 centimeters.
- Ensure that all FASTRAK SEUs have the same part number since the original and new designs cannot be intermixed.

### **5.11 Output Considerations**

Most applications of the FASTRAK 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 tracker data point and receiving it into the host computer. Factors that could increase this lag are:

- Baud Rate
- Output Record Length
- Data Format (binary is more efficient than ASCII)
- Filtering

The FASTRAK baud rate should be set to the highest setting that is compatible with the host computer and the communication software. Although the FASTRAK system runs at 120 Hz, it may appear that it is running slower if the output is constrained by a slow baud rate. The FASTRAK is capable of running at speeds of up to 115,200 as selected by the I/O Select Switches on the back panel or speeds up to 460,800 as selected by the software command “o” (see section 6 for full description).

The FASTRAK default output record contains measurements for X, Y, Z in inches and Azimuth, Elevation, and Roll in degrees. This output format can be easily modified with “O” command (see section 6). Although the FASTRAK offers a variety of output selections, it is best to keep the output record length constrained only to the data that is needed. Excessive data in the output record can slow down the transmission and not allow the system to output data to the host at

the maximum update rate.

The FASTRAK 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 and can be activated with “simple” commands that select “low”, “medium”, or “heavy” filtering. 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.

## 6.0 System Commands

There are two classes of system commands: one class for configuring the state of the system, and the other for controlling its operation. The commands are presented in functional, alphabetical order. Where applicable, examples of the command in use will be given. All commands are input on the RS-232 serial port and consist of ASCII characters. Additionally, format notations and conventions for commands and outputs are presented first.

### 6.1 Command Format Notation and Convention

Use the following format notation to enter commands:

- [ ] 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”. 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.*



## 6.2 Command Format Notes

- (1) All commands and alphabetic parameters are case sensitive. They must be entered in upper or lower case as defined in the syntax.
- (2) Any command with a \* next to it means that it cannot be stored in EEPROM i.e. if a Ctrl K command (save machine state) is executed, the information will not be saved after the system power is turned off.
- (3) For those commands involving an optional list of parameters, if some of the parameter values are omitted the current system retained value of that parameter is used in its place.
- (4) The RELATIVES field contains a list of those commands which provide related information to the system. For example, the unboresight command "b" is a relative to the boresight command "B".
- (5) The term station is a transmitter-receiver pair. The four receivers paired with the one available transmitter are assigned station numbers one through four (1-4).
- (6) FASTRAKs are shipped configured in one of four (4) possible frequencies. The frequencies are referenced as follows:

<u>Ref. Number</u>	<u>Frequency</u>
1	8013 Hz
2	10016 Hz
3	12019 Hz (Standard)
4	14022 Hz

- (7) A numeric floating point value will be accepted by the FASTRAK if any of the following formats are used. For example: 3.0 may be specified as:

3  
3.  
3.0 or  
3.0 E+00

See each command's format for generally accepted accuracy range.

- (8) The notation R(Sxx.xxxB) represents the ASCII output format for the specific data element, where:

R	is the repeat count and what follows in parenthesis is repeated R times
S	is the sign byte, either +, -, or space (for +)
X	is a decimal digit (0...9)
.	is a decimal point
B	is a blank
H	is a hexadecimal digit (0...F)

Example: A format 3(Sx.xxxxB), would be output as:

-1.1111 2.2222 -3.3333

- (9) For discussion purposes, all “Examples” assume only 1 receiver is used, connected to the station 1 receptacle.

### 6.3 Command/Output Listing

See pages that follow.

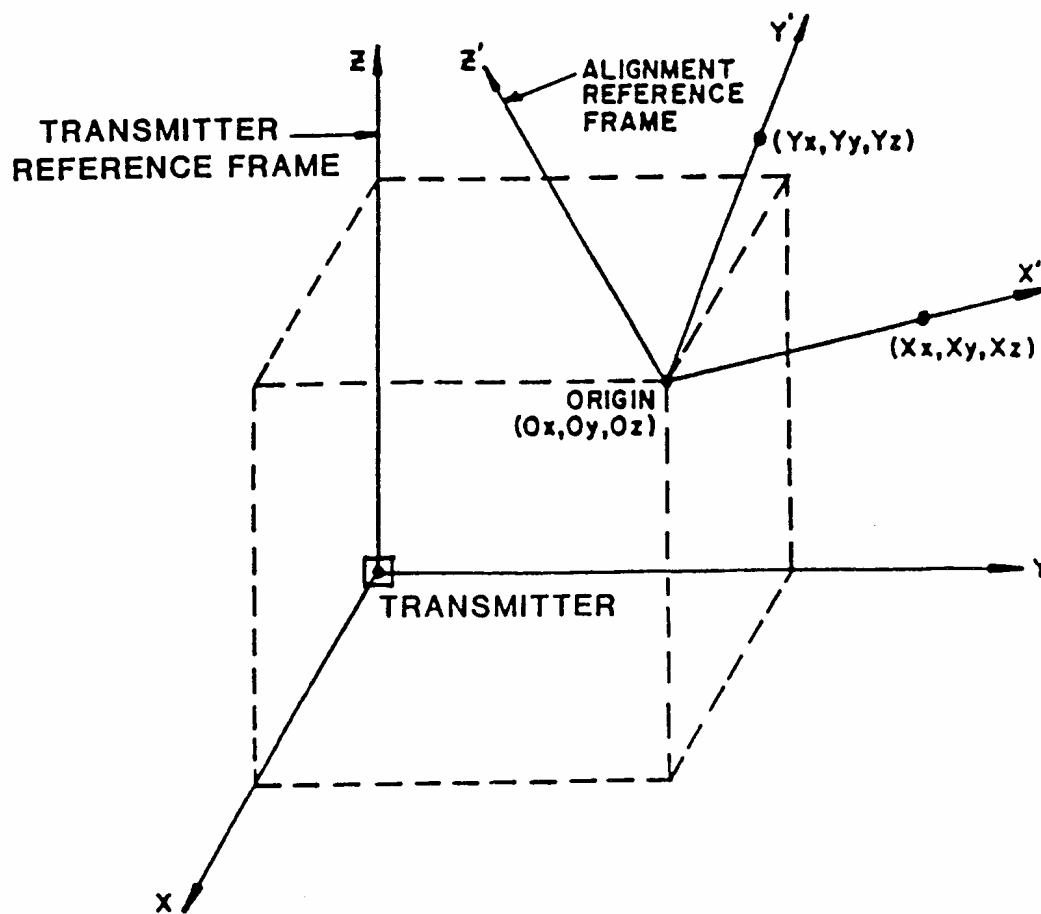


Figure 6.3A System Alignment

## ALIGNMENT REFERENCE FRAME      A

---

**Syntax:**      Astation,[Ox],[Oy],[Oz],[Xx],[Xy],[Xz],[Yx],[Yy],[Yz]<>

or

Astation<> to read back the current alignment

**Purpose:**      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 receiver were placed there. See figure 6.3A on previous page. An example of where this command would be useful is a sloped test surface that the user wanted referenced to the transmitter. This would obtain congruence between the FASTRAK and the axes of the sloped surface.

**NOTE:** This command operates incrementally. If the command is entered and the user then changes his/her mind, the 'R' command must be used to reset the alignment reference frame BEFORE the command is re-entered. This is **ESPECIALLY IMPORTANT** to remember if the user makes an error and wants to correct the erroneous input because the new alignment would be additive to the mistake. The command parameters are:

station	1 to 4, which specifies the relevant transmitter/ receiver 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.

**Relatives:**      R

**Range:**      No Range Restriction Enforced

**Default:**      The transmitter reference frame is the default alignment reference frame.  
(0,0,0,200,0,0,0,200,0) in centimeters

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

### **Standard Alignment Procedure**

1. Send the command R1<>
2. Place the receiver 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 receiver 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 receiver along the proposed Y-axis from the origin defined in step 2 and place it about 24 inches from the transmitter.
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<>

### **Enhanced Alignment Procedure**

A new capability of the alignment command is called the Enhanced Alignment. The Enhanced Alignment feature allows the user to perform an alignment quickly and easily. The procedure is as follows:

1. Select the lowest station number receiver selected. (Usually station 1).
2. Issue the command A0<>. Sending this command prepares the system for collection of alignment data (3 data points) and resets previous alignments by sending the commands R1<>, R2<>, R3<>, and R4<>.
3. Place the receiver at the proposed origin location and press P once.
4. Move the receiver along the proposed positive X axis from the origin and place it about 18" to 24" from the transmitter and press P once.
5. Move the receiver along the proposed positive Y-axis from the origin and place it about 18" to 24" from the transmitter and press P once.
6. The system then composes the alignment coordinates and prints the new alignment parameters to the screen.

## ALIGNMENT REFERENCE FRAME

---

SUB-RECORD IDENTIFIER .... A  
INITIATING COMMAND ..... A

---

<u>byte(s)</u>	<u>Identification</u>	<u>Format</u>
1	Record type, "2"	A1
2	Station Number	A1
3	Sub-record type "A"	A1
4-24	Origin coordinates	3(Sxxx.xx)
25-45	Positive X-axis coordinates	3(Sxxx.xx)
46-66	Positive Y-axis coordinates	3(Sxxx.xx)
67-68	Carriage return, line feed	

## **\*RESET ALIGNMENT REFERENCE FRAME    R**

---

**Syntax:**        Rstation<>

**Purpose:**        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:

station            the number of the station to be reset.

**Relatives:**     A

**Example:**       Any time the alignment command (A1...) used, it is best to send the reset alignment command (R1<>) first. That way, there is no risk of building one alignment on top of another. See Standard Alignment Procedure listed under Alignment Reference Frame.

**\*BORESIGHT                      B**

---

**Syntax:**                      Bstation<>

**Purpose:**                      This command causes the tracking receiver to be electronically aligned in orientation with the user system coordinates. This results in azimuth, elevation and roll outputs equal to the boresight reference values (usually 0,0,0 which is the system default) at the current orientation. The tracker then produces outputs relative to this reference. Any receiver orientation can be designated as the zero orientation point. The command parameter is defined as:

station                      the number of the station to be boresighted.

**Relatives:**                      b, G

**Default:**                      The zero orientation condition occurs when the receiver orientation corresponds to the transmitter orientation.

**Example:**                      The receiver 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, he may want the system angular outputs to be zero. The user can designate this receiver orientation as the zero orientation by sending the boresight command:

B1<>

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 transmitter, with the zero points shifted to the point where the boresight occurred.

## BORESIGHT REFERENCE ANGLES      G

---

**Syntax:**      Gstation,[Azref],[Elref],[Rlref]<>

or

Gstation<> to read back the current boresight reference angles

**Purpose:**      This command establishes the bore-sight reference angles for a particular station. When the system is boresighted with the "B" command, the line-of-sight vector (Azimuth, Elevation, and Roll angles) will assume these values. If all the optional parameters are omitted, the system returns the boresight reference angles for the specified station as an output record of type "G". The command parameters are defined as:

station    the number of the station whose reference angles are to be fixed.

Azref    the azimuth reference angle.

Elref    the elevation reference angle.

Rlref    the roll reference angle.

**Relatives:**    B, b

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

**Example:**      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 applied with the G command:

G1,0,-15,0<>

The boresight command (B1<>) will now cause the azimuth, elevation, and roll data output to be 0, -15, 0 respectively.



## BORESIGHT REFERENCE ANGLES

---

SUB-RECORD IDENTIFIER .... G  
INITIATING COMMAND ..... G

---

byte(s)	Identification	Format
1 ...	Record type, "2"	A1
2 ...	Station Number	A1
3 ...	Sub-record type "G"	A1
4-10 ...	Azimuth reference angle	Sxxx.xx
11-17 ...	Elevation reference angle	Sxxx.xx
18-24 ...	Roll reference angle	Sxxx.xx
25-26 ...	Carriage return, line feed	

**\*UNBORESIGHT    b**                      (Note: \* = not saved by Ctrl K command)

---

**Syntax:**            bstation<>

**Purpose:**            This command removes the current boresight. The system boresight rotation matrix is reset to the identity matrix for the specified station. The command parameter is defined as:

station    the number of the station to be boresighted.

**Relatives:**        B, G

**Example:**            If the user issued the Boresight command while the receiver was at a particular orientation and then later decided that it would be best not to use a Boresight, or there was a need to see what the system reads without the Boresight, then the Unboresight command could be used as follows:

b1<>

(P, the command to request a single data record, could then be used to read the default orientation angles.)

## CONTINUOUS OUTPUT MODE C

---

**Syntax:** C

**Description:** Output transmit mode refers to whether the system automatically transmits data records to the host (continuous mode), or the host must request data records by sending a command to the system each time (non-continuous mode).

**Purpose:** This command enables the continuous print output mode. When the system is in continuous mode, the data points from all stations are requested automatically and are scrolled one after the other in a continuous “stream”. If more than one station is enabled, then the data from each station will be displayed in numerical order (station 1 first, station 2 second, etc).

**Relatives:** c, P

**Default:** Continuous output mode is disabled.

**Example:** If the system is being used in an application where a fast update rate is critical, (driving real-time computer graphics, like an animated character for example) then the continuous output configuration should be enabled. To enable continuous output mode, send the command as follows:

C

Data from the FASTRAK will now scroll continuously across the serial port to the host computer.

## DISABLE CONTINUOUS PRINTING      c

---

**Syntax:**            c

**Purpose:**            This command disables the continuous print output mode. After sending this command, the continuous data stream from the FASTRAK to the host computer will stop.

**Relatives:**        C, P

**Default:**           Continuous output mode is disabled

**Example:**           If the system is set to continuous output mode with the “C” command, the user may wish to stop the data stream to adjust other system parameters. This can be accomplished by sending the command:

c

The continuous data output mode will be disabled and the data stream will stop.

## ENABLE FIXED METAL COMPENSATION      D

---

**Syntax:**            D

**Description:**            Compensation refers to programmed offsets that allow system computations to be accurate, while the system is used in an environment containing metal within close proximity of the transmitter and receiver. (Generating compensation requires the use of special fixtures and proprietary software and is usually performed by a Polhemus technician.)

**Purpose:**            This command is used to turn on compensation offsets. If a custom calibration has not been performed by a Polhemus technician at the user location, then enabling this command will yield no change in the system outputs.

**Relatives:**            D, d

**Default:**            The default condition is compensation disabled.

**Example:**            In most cases, the user is able to locate a test set up where compensation is not required. If it is required and Polhemus is contracted to perform a calibration, then the system will be left with compensation enabled. The command to enable compensation on all active stations is simply:

D

The compensation offsets will now be applied to all position and orientation measurements.

## DISABLE FIXED METAL COMPENSATION     d

---

**Syntax:**         d

**Purpose:**         This command disables fixed metal compensation. If a custom calibration has been performed by a Polhemus technician at the user location, then issuing this command will disable the compensation offsets in the system outputs.

**Relatives:**       D

**Default:**         The default condition is compensation disabled.

**Example:**         A system could be calibrated (by Polhemus) at a particular user location and then later moved to a different location where the calibration is no longer required. The user should then disable the calibration that is no longer applicable. This could be accomplished with the command:

d

System measurements would no longer contain the compensation offset.

## DEFINE STYLUS BUTTON FUNCTION e

---

**Syntax:** e[station],fbutton<>

**Purpose:** This command allows the user to put the FASTRAK stylus into different output modes by controlling the button function. The command parameters are defined as:

station - the number of a station.

fbutton - defines the function of the stylus button.

An entry of fbutton = 0 defines the output interaction as "mouse mode." The pushing of the stylus switch has no change on system output except that if the user has defined (by use of the "O" command) an output with item 16 (switch status), then the status of the switch is reported in the output record. In this case, a 1 is reported in the output record when the switch is pressed and a 0 when it is not pressed.

An entry of fbutton = 1 defines a pseudo "point" or "track" mode interaction with the switch. In non-continuous mode of output, pressing the stylus switch has the same effect as sending a "P" command to the system (point mode). In point mode, every time the button is pressed, a data record is sent to the host. 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.

**Default:** System default is fbutton = 1 (point and track mode stylus interaction)

**Relatives:** None

## ENABLE ASCII OUTPUT FORMAT F

---

**Syntax:** F

**Purpose:** This command enables the 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 the FASTRAK system must be in ASCII format.

**Relatives:** f

**Default:** The default output data format is ASCII

**Example:** If a software application is written to receive binary data from the FASTRAK system and there was 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 the FASTRAK data on the PC monitor. To do so, the following command should be sent:

F

The system will now be in ASCII output data format and can be read by the user.



## ENABLE BINARY OUTPUT FORMAT    **f**

---

**Syntax:**        **f**

**Purpose:**        This command enables the binary output data format. Binary format is generally computer readable while ASCII format is human readable. This format is a 32 bit, floating point output that is in accordance with the format specified by ANSI/IEEE Std 754-1985 Specification for Binary Floating Point Arithmetic.

**Relatives:**    **F**

**Default:**        The default output data format is ASCII.

**Example:**        The user may wish to write a software application for the FASTRAK where a fast update rate is crucial. In order to reduce data packet size, the FASTRAK could be set to output in binary instead of ASCII. This can be accomplished with the command:

**f**

The FASTRAK will now output binary data.

The notation SingleFP 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	
<u>S</u> ign	<u>E</u> xponent	<u>F</u> raction	
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 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:

$$(-1)^S * (2^{e-127}) * (01.f) \text{ If } 0 < e < 255$$

In special cases:

(-1) $S$  \* 0.0                      If  $e = 0$  and  $f = 0$   
 (-1) $S$  \* ( $2^{**(-126)}$ ) \* (0.f) If  $e = 0$  and  $f \neq 0$  (denormalized)  
 (-1) $S$  \* infinity                If  $e = 255$  and  $f = 0$  (infinity)  
 NaN (not a number)            If  $e = 255$  and  $f \neq 0$

Note that the actual I/O byte sequence is system specific. For the greatest compatibility, Polhemus has adopted for output, the following Intel 80X86 byte ordering:

The lowest physical address for a byte is  $a_0$ ,  $a_1$  has address  $a_0+1$ , etc. The least significant byte of data is  $b_0$ , with  $b_3$  the most significant byte. For IEEE FP output from the Tracker/Digitizer, the byte output sequence is  $b_0$ ,  $b_1$ ,  $b_2$ , &  $b_3$ .

<u><math>a_0</math></u>	<u><math>a_1</math></u>	<u><math>a_2</math></u>	<u><math>a_3</math></u>	
$b_0$	$b_1$	$b_2$	$b_3$	80X86
$b_2$	$b_3$	$b_0$	$b_1$	DEC PDP-11
$b_3$	$b_2$	$b_1$	$b_0$	Z8000 / M680XX

## HEMISPHERE OF OPERATION H

---

**Syntax:** Hstation,[p1],[p2],[p3]<

or

Hstation< to read back the current hemisphere selection

**Description:** Because of the symmetry of the magnetic fields generated by the transmitter, there are two mathematical solutions to each set of receiver data processed. Therefore, only half of the total spatial sphere surrounding the transmitter 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 (line-of-sight) vector from the transmitter through a point at the zenith of the hemisphere, and is specified by the LOS direction cosines.

**Purpose:** Since the receiver(s) can only operate in one hemisphere at a time relative to the transmitter, it is necessary to tell the FASTRAK system which side of the transmitter they will be on, for each station. A "hemisphere tracking" option is available, but important criteria must be met in order for it to work properly (see pages that follow for more information). Identification of command parameters is as follows.

station	the number of the station whose operational hemisphere is to be modified.
p1	the x-component of a vector pointing in the direction of the operational hemisphere. (Set to 0 to enable hemisphere tracking.)
p2	the y-component of a vector pointing in the direction of the operational hemisphere. (Set to 0 to enable hemisphere tracking.)
p3	the z-component of a vector pointing in the direction of the operational hemisphere. (Set to 0 to enable hemisphere tracking.)

If all of the optional parameters are set to 0, then hemisphere tracking will be enabled for the specified station.

## IMPORTANT NOTES ABOUT HEMISPHERE TRACKING:

“Hemisphere tracking” is a feature whereby the tracker can continuously modify its operating hemisphere, given that it is started in a known, valid hemisphere.

1. When this command (H1,0,0,0<>) is sent to the FASTRAK system, the receiver of the specified station must be located in the currently set hemisphere.
2. If the Ctrl K command is sent to the FASTRAK system while hemisphere tracking is enabled, the **currently computed hemisphere** will be saved (not the hemisphere tracking feature) to the EEPROM. Therefore, sending Ctrl K during hemisphere tracking is not advised.

**Relatives:** None

**Default:** The default hemisphere value is: 1,0,0 which is positive X or “forward” hemisphere. In addition, the hemisphere tracking feature is disabled in the default condition.

**Example 1:** The user may decide to mount the transmitter above the test area in order to be able to move the receiver 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 receiver to the negative X side of the transmitter, because the signs will flip and it will appear as if the X measurement never goes negative.) If the transmitter 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 one of the FASTRAK 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<>

**Example 2:** The user may decide to take advantage of the hemisphere tracking feature. Assuming the system is in the default hemisphere (forward), the following procedure should be used to enable hemisphere tracking on station 1:

1. Position the receiver on the positive X side of the transmitter and turn the

system on. (The side opposite from where the cable comes out of the transmitter shell.)

2. While the receiver is located in the forward hemisphere, send the hemisphere tracking command to the FASTRAK. The command should be: H1,0,0,0<>
3. The receiver can now be moved to any side of the transmitter, without worrying about hemisphere selection.
4. Do not save this configuration to the system EEPROM (using the Ctrl K command) because it will save whatever the current computed hemisphere selection happens to be for that position of the receiver relative to the transmitter.
5. If necessary, the user can disable the hemisphere tracking feature by sending a “normal” hemisphere selection, e.g. H1,1,0,0<> to go back to the “forward” hemisphere selection.

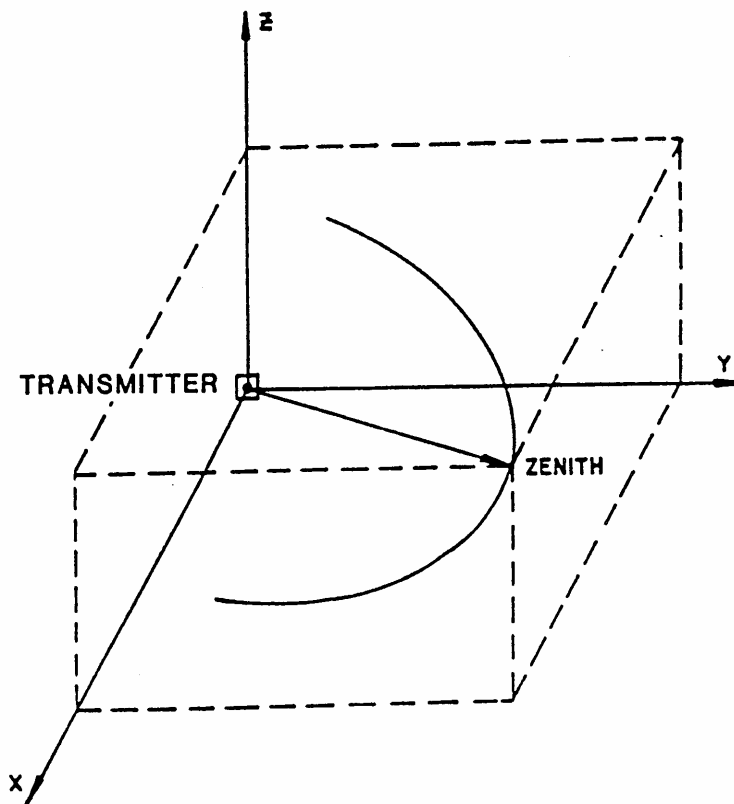


Figure 6.3B Hemisphere Vector  
(Zenith represents the hemisphere vector)

## HEMISPHERE OF OPERATION

RECORD IDENTIFIER ..... H  
INITIATING COMMAND ..... H

---

byte(s)	Identification	Format
1 ....	Record type, "2"	A1
2 ....	Station number	A1
3 ....	Sub-record type "H"	A1
4-10 ....	Vector x-component	Sxx.xxx
11-17 ....	Vector y-component	Sxx.xxx
18-24 ....	Vector z-component	Sxx.xxx
25-26 ....	Carriage return, line feed	

## DEFINE INCREMENT     I

---

**Syntax:**        Istation,[distance]<>

or

Istation<> to read back the current increment selection.

**Purpose:**        This command allows the user to control when data records will be sent to the host, based on receiver movement. The “distance” selection allows the user to specify exactly how much movement will be required before data is produced. If the user enters ‘Istation<>’, the system outputs the current distance value selection. **Note:** The system should be in continuous output mode in order for this command to work properly. Definitions of the command parameters are listed below:

station            the number of the station whose increment is to be changed.

distance           the minimum distance a receiver must move before a data record is output to the host computer. The units of measure (inches or centimeters) for the distance value, must be consistent with the current selection of system units.

**Relatives:**       none

**Default:**        The default value is 0.0 inches, which disables the increment feature.

**Example:**        If the user wants the system to output data each time the receiver on station one moves 2 inches in any axis, the following command should be entered:

I1,2<>

C

The system will now output a data record each time station one receiver moves two inches in any axis.

## INCREMENT DEFINITION

---

RECORD IDENTIFIER ..... I  
INITIATING COMMAND ..... I

---

byte(s)	Identification	Format
1 ....	Record type, "2"	A1
2 ....	Station number	A1
3 ....	Sub-record type "I"	A1
4-10 ....	Distance required to move	Sxxx.xx
11-12 ....	Carriage return, line feed	



## ACTIVE STATION STATE 1

---

**Syntax:**        lstation,[state]<>

or

lstation<> to read back the current station state

**Description:** A station is defined as a transmitter-receiver pair. The four receivers paired with the one transmitter are assigned station numbers one through four (1-4). Although stations are enabled simply by plugging the receivers into the ports on the FASTRAK SEU, the stations can then be disabled (or enabled again) by using a software command. When a station is enabled, data records for that receiver will be transmitted from that station. If the station is disabled, no data records from that station will be transmitted.

**Purpose:** The purpose of this command is to allow the host to turn a station “on” or “off” in software. The command parameters are identified as follows:

Station	1 to 4
state	0 = off 1 = on

**Relatives:** none

**Default:** The default condition depends on the number of receivers that are currently connected to the FASTRAK SEU. The default condition of a station that has a receiver connected to it is a “1” or station “on”. The default condition of a station that does not have a receiver connected to it is a “0” or station “off”.

**Example:** A user could connect four receivers to a FASTRAK and then collect a data point from two receivers at a time, after disabling the other two. To do so, the following commands would be sent:

1. Send the command l3,0<> to turn station 3 off.
2. Send the command l4,0<> to turn station 4 off.
3. Press P to collect a data point from stations 1 and 2.
4. Send the command l3,1<> to turn station 3 on.
5. Send the command l4,1<> to turn station 4 on.

6. Send the command 11,0< to turn station 1 off.
7. Send the command 12,0< to turn station 2 off.
8. Press P to collect a data point from stations 3 and 4.
9. Repeat steps 1 through 8 as necessary.

## ACTIVE STATION STATE

---

RECORD IDENTIFIER ..... I  
INITIATING COMMAND ..... I

---

byte(s)	Identification	Format
1 .....	Record type, "2"	A1
2 .....	Station number	A1
3 .....	Sub-record type "I"	A1
4 .....	Station 1 = 1 if active, else 0	A1
5 .....	Station 2 = 1 if active, else 0	A1
6 .....	Station 3 = 1 if active, else 0	A1
7 .....	Station 4 = 1 if active, else 0	A1
8-9 .....	Carriage return, line feed	

## **\*DEFINE TIP OFFSETS                      N**

---

**Syntax:**            Nstation,[xoff,yoff,zoff]<>

or

Nstation<> to read back the current tip offsets

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

**Purpose:** 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. The command parameters are listed below:

station	1-4
xoff	x-direction tip offset
yoff	y-direction tip offset
zoff	z-direction tip offset

**Relatives:**        None

**Default:** 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.

**Example:** 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 the FASTRAK system is in “inches” units by sending the “u” command.
2. 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.)
3. To add one inch to the factory calibration, type N1,3.523,0.004,0.03<>
4. To verify that the tip offset was entered correctly, type N1<> to read it back.

## OUTPUT DATA LIST      O

---

**Syntax:**      Ostation,[p1],[p2],...,[pn]<>

**Description:**      The output list refers to the subset of data items to be included in a data record. Any combination of up to 32 data items that total less than or equal to 254 bytes is permissible.

**Purpose:**      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 32 data items that total less than or equal 254 bytes is permissible. The allowable values of the parameters are:

- 0      ASCII space character
- 1      ASCII carriage return, line feed pair
- 2      x,y,z Cartesian coordinates of position
- 3      relative movement, x,y,z Cartesian coordinates of position; i.e., the difference in position from the last output. This item should only be selected if the specified station's Increment is = 0.0. See the "I" command.
- 4      azimuth, elevation, roll Euler orientation angles
- 5      x direction cosines of the receiver's x,y,z axes - See Note 1.
- 6      y direction cosines of the receiver's x,y,z axes - See Note 1.
- 7      z direction cosines of the receiver's x,y,z axes - See Note 1.
- 8      x-receiver data (factory use only)
- 9      y-receiver data (factory use only)
- 10      z-receiver data (factory use only)
- 11      orientation quaternion
- 12      self calibration data (factory use only)
- 13      adjusted x-receiver data (factory use only)
- 14      adjusted y-receiver data (factory use only)
- 15      adjusted z-receiver data (factory use only)
- 16      stylus switch status
- 17      not used
- 18      16-BIT binary x,y,z Cartesian coordinates of position (see 16BIT notation)
- 19      16-BIT binary az,el,roll Euler orientation angles (see 16BIT notation)
- 20      16-BIT binary orientation quaternion (see 16BIT notation)
- 21-49      not used (reserved for future use)

Extended precision (50-66)

- 50 ASCII space character (same as 0)
- 51 ASCII carriage return, line feed pair (same as 1)
- 52 x,y,z Cartesian coordinates of position
- 53 relative movement - x,y,z Cartesian coordinates of position; i.e., the difference in position from the last output. This item should only be selected if the specified station's Increment is = 0.0. See the "I" command.
- 54 az,el,roll Euler orientation angles
- 55 x direction cosines of the receiver's x, y, z axes - See Note 1.
- 56 y direction cosines of the receiver's x, y, z axes - See Note 1.
- 57 z direction cosines of the receiver's x, y, z axes - See Note 1.
- 58 x-receiver data (reserved for factory use)
- 59 y-receiver data (reserved for factory use)
- 60 z-receiver data (reserved for factory use)
- 61 orientation quaternion
- 62 self calibration data (reserved for factory use)
- 63 adjusted x-receiver data (reserved for factory use)
- 64 adjusted y-receiver data (reserved for factory use)
- 65 adjusted z-receiver data (reserved for factory use)
- 66 stylus switch status
- 67 not used (reserved for factory use)
- 68-98 not used (reserved for factory use)
- 99 not used (reserved for factory use)

**Relatives:** none

**Default:** 0s,2,4,1<>; i.e., the three Cartesian coordinates, the three Euler orientation angles, carriage return, and line feed for stations 1 through 4.

**Example:** 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 will now be displayed as X, Y, Z direction cosines.

## OUTPUT ITEM LIST

---

RECORD IDENTIFIER ..... O  
INITIATING COMMAND ..... O

---

byte(s)	Identification	Format
1 ....	Record type, "2"	A1
2 ....	Station number	A1
3 ....	Sub-record type "O"	A1
4-5 ....	Data item 01 identification	I2
6-7 ....	Data item 02 identification	I2
8-9 ....	Data item 03 identification	I2
. ....		
. ....		
2*n+2 -		
2*n+3 ....	Data item n identification	I2
2*n+4 -		
2*n+5 ....	Carriage return, line feed	

## SYSTEM DATA RECORD, ASCII FORMAT

---

RECORD IDENTIFIER ..... none  
INITIATING COMMANDS ..... P or in continuous mode

Item	byte(s)	Identification	Format
	1 ..	Record type, "0"	A1
	2 ..	Station Number	A1
	3 ..	System Error Code (See note 2)	A1

### Original Precision:

0 or 50	?* ..	ASCII space character	A1
1 or 51	?* ..	Carriage return, line feed	
2	?* ..	x,y,z position Cartesian Coordinates	3(Sxxx.xx)
4	?* ..	az,el,roll Euler orientation angles	3(Sxxx.xx)
5	?* ..	X-direction cosines of the receiver's x,y,z axis (See Note 3.)	3(Sx.xxxx)
6	?* ..	Y-direction cosines of the receiver's x,y,z axis (See Note 3.)	3(Sx.xxxx)
7	?* ..	Z-direction cosine of the receiver's x,y,z axis (See Note 3.)	3(Sx.xxxx)
11	?* ..	Orientation Quaternion (Q0-Q3)	4(Sx.xxxx)
16	?* ..	Stylus Switch x where: x = 0 or 1	

### Extended precision:

52	?* ..	x,y,z position Cartesian coordinates	3(Sx.xxxxxESxxb)
54	?* ..	az,el,roll Euler orientation angles	3(Sx.xxxxxESxxb)
55	?* ..	X-direction cosines of the receiver's x,y,z axis (See Note 3.)	3(Sx.xxxxxESxxb)
56	?* ..	Y-direction cosines of the receiver's x,y,z axis (See Note 3.)	3(Sx.xxxxxESxxb)
57	?* ..	Z-direction cosines of the receiver's x,y,z axis (See Note 3.)	3(Sx.xxxxxESxxb)
61	?* ..	Orientation Quaternion (Q0-Q3)	4(Sx.xxxxxESxxb)
66	?* ..	Stylus Switch x where: x = 0 or 1	



Factory use only:

8-10  
12-15  
17-49  
58-60  
62-65  
67-69

\* 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 1.** 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.

**Note 2.** This code will in general output the last error that the system BIT (Built In Test) routines found prior to the output of this system data record. If any BIT clearing has been commanded (see the "T" command), the system will search for an error that is currently set, starting at the largest numeric error code value, and then output the first error code found in the search that is set. See the "T" command for specified definitions of each error code.

**Note 3.** Items 5, 6, and 7 or 55, 56, and 57 may be obtained to construct the line-of-sight, line-of-hear, and line-of-plumb vectors as follows:

Three (3) values are obtained from each item above.

Item 5 or 55 =	5a	5b	5c		55a	55b	55c	
Item 6 or 56 =	6a	6b	6c		56a	56b	56c	
Item 7 or 57 =	7a	7b	7c		57a	57b	57c	

Then the a-column above is the line-of-sight vector, the b-column above is the line-of-hear vector, and the c-column above is the line-of-plumb vector.

## SYSTEM DATA RECORD, IEEE FLOATING-POINT FORMAT

---

RECORD IDENTIFIER ..... none  
INITIATING COMMANDS ..... P or in continuous mode

---

byte(s)	Identification	Format
1 .....	Record type, "0"	A1
2 .....	Station Number	A1
3 .....	System error code (See Note 2 on previous page.)	A1
?* .....	ASCII space character	A1
?* .....	Carriage return, line feed	
?* .....	x,y,z position Cartesian coordinates	3(SingleFP)
?* .....	az,el,roll Euler orientation angles	3(SingleFP)
?* .....	X-direction cosines of the receiver's x,y,z axes. See Note 1.	3(SingleFP)
?* .....	Y-direction cosines of the receiver's x,y,z axes. See Note 1.	3(SingleFP)
?* .....	Z-direction cosines of the receiver's x,y,z axes. See Note 1.	3(SingleFP)
?*	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.	

## SYSTEM DATA RECORD, 16-BIT BINARY FORMAT

---

RECORD IDENTIFIER ..... none  
INITIATING COMMANDS ..... P or in continuous mode

---

byte(s)	Identification	Format
1 .....	Record type, "0"	A1
2 .....	Station Number	A1
3 .....	Error code	A1
?* .....	x,y,z position Cartesian coordinates	3(16BIT)
?* .....	az,el,roll Euler orientation angles	3(16BIT)
?* .....	Orientation Quaternion	4(16BIT)
?* .....	Any format from an ASCII or binary format may also be included in this record. (See these formats on previous pages.) Care should be taken not to delete the usefulness of the sync bit discussed below.	

\*\*\*\*\*

?\* 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 16BIT is a special binary output format reserved for those users that need less accurate, but faster I/O. It contains only 14 bits of accuracy and is output in the following format without respect to the "F" (ASCII) or "I" (binary) command setting:

This format is limited to X,Y,Z position (item 18 in the "O" command) and AZ, EL, Roll Euler orientation angles (item 19 in the "O" command), and the unit-less four (4) values of the Orientation Quaternion (item 20 in the "O" command). Data format is 2's-complement. Each 8-bit byte of the 16 bit data will have its high-order bit set to zero, except for the leading data byte, which is set to 1, as a "sync" bit, in the data that is output in this format.

Two things must be noted here: First, the "sync" bit is in the fourth byte of the data record and not a part of the three byte record header. Secondly, this "sync" bit is only valid if the output is limited (by specifying in the "O" command) to only those items that are guaranteed not to contain a high order bit set to 1. The data is output low-order byte first.

For positive values, position (X,Y,Z) full scale is +299.963 cm, which equates to +118.096 inches. For orientation angles, full scale is +179.978 degrees and the quaternion values of 0.999.

Lo byte	Hi byte
X   1   1   1   1   1   1   1	0   0   1   1   1   1   1   1
^	^
--- 0 or 1 for sync	-- sign bit (1 = negative)

This equates to xx011111 11111111 or full-scale positive number of +299.963 cm, which equates to +118.096 inches. For orientation angles, full scale is +179.978 degrees.

For negative values, position (X,Y,Z) full scale is -300 cm, which equates to -118.110 inches. For negative orientation angles, full scale is -180 degrees. For the quaternion values, full scale is -1.

Lo Byte	Hi Byte
X   0   0   0   0   0   0   0	0   1   0   0   0   0   0   0
^	^
- 0 or 1 for sync	- sign bit

This equates to xx100000 00000000 or full scale negative number of -300.000 cm, -118.110 inches, or - 180.000 degrees, or a -1.000 quaternion value.

## SET OUTPUT PORT      o

---

**Syntax:**      orate,parity,bits,HHS<◇

**Description:**    The system output port settings including RS-232 BAUD rate, parity, and number of bits per character may be established to specified values.

**Purpose:**      Sets the output BAUD rate for RS-232 port to a specified rate. The parameters are:

rate is specified as follows:

24	=	2,400
48	=	4,800
96	=	9,600
192	=	19,200
384	=	38,400
576	=	57,600
1152	=	115,200
2304	=	230,400
4608	=	460,800

parity      N = none, O = Odd, E = even

bits      7 or 8

HHS      Set to 1, enables use of hardware handshake (RTS, CTS)

Set to 0, disables use of hardware handshake

**Note 1.** The number of stop bits is always one (1).

**Note 2.** For seven (7) bits, parity may be NONE, ODD, or EVEN. For eight (8) bits there is never a parity bit; i.e., NONE.

**Note 3.** 8 data bits are required when using either the standard binary format or the 16 BIT format.

**Relatives:**    None

**Default:**      Based on I/O switch settings.

**Example:**      Suppose there is a requirement to change the baud rate (in software) to 19,200 baud, while the rate set by the I/O select switches is 9600 baud. It can be accomplished with the following command, without turning off and restarting the

system.

o192,N,8,0<>

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

## SINGLE DATA RECORD OUTPUT

**P**

---

**Syntax:** P

**Description:** Output transmit mode refers to whether the system automatically transmits data records to the host (continuous output mode), or the host must request data records by sending a command to the system each time (non-continuous output mode).

**Purpose:** In non-continuous output mode, this command requests a single data record to be transmitted to the host. If more than one station is enabled, then data from each active station will be displayed in numerical order (station 1 first, station 2 second, etc. That is, a complete cycle of active stations will be output.)

**Relatives:** C, c

**Default:** Continuous output mode is disabled

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

P

One data record from the FASTRAK system will be sent across the serial port to the host computer.

## ANGULAR OPERATIONAL ENVELOPE      Q

---

**Syntax:**      Qs,[azmax],[elmax],[rlmax],[azmin],[elmin],[rlmin]<>

or

Qs<> to read back the current orientation limits

**Purpose:**      This command allows the user to set maximum and minimum limits for the azimuth, elevation, and roll outputs. If the orientation outputs are outside of the limits defined by this command, the system will output an error “y”.

The specific parameters are:

s      the number of the station whose angular limits are to be established.

azmax   the maximum azimuth value for the angular operational envelope.

elmax   the maximum elevation value for the angular operational envelope.

rlmax   the maximum roll value for the angular operational envelope.

azmin   the minimum azimuth value for the angular operational envelope.

elmin   the minimum elevation value for the angular operational envelope.

rlmin   the minimum roll value for the angular operational envelope.

**Relatives:**      V

**Default:**      180, 90, 180, -180, -90, -180

**Example:**      If the FASTRAK system outputs were to be used to drive a gimbaled system that had physical orientation limits, then it would be a good idea to set the FASTRAK angular operational envelope to those limits. Suppose the gimbaled system had azimuth and elevation limits of +/-45 degrees. The following command should be sent:

Q1,45,45,180,-45,-45,-180<>

The FASTRAK data will now contain an error “y” each time the azimuth or elevation limit is exceeded. In addition, the application software should be programmed to ignore any data record containing the “y” error to avoid causing the gimbaled system to slam into a limit.



## ANGULAR OPERATIONAL ENVELOPE

---

RECORD IDENTIFIER ..... Q  
INITIATING COMMAND ..... Q

---

byte(s)	Identification	Format
1 ....	Record type, "2"	A1
2 ....	Station number	A1
3 ....	Sub-record type "Q"	A1
4-12 ....	Maximum azimuth value	Sxxx.xxxb
13-21 ....	Maximum elevation value	Sxxx.xxxb
22-30 ....	Maximum roll value	Sxxx.xxxb
31-39 ....	Minimum azimuth value	Sxxx.xxxb
40-48 ....	Minimum elevation value	Sxxx.xxxb
49-57 ....	Minimum roll value	Sxxx.xxxb
58-59 ....	Carriage return, line feed	

## TRANSMITTER MOUNTING FRAME    r

---

**Syntax:**        rstation,[A],[E],[R]<>

or

rstation<> to read back the current transmitter mounting frame

**Purpose:**        This command allows the user to modify the mounting frame coordinates of the transmitter relative to a particular receiver. It is basically a non-physical rotation of the transmitter and becomes the new orientation reference for the specified receiver's measurements. The command parameters are as follows:

station    the station to be defined

A        azimuth mounting frame angle

E        elevation mounting frame angle

R        roll mounting frame angle

**Relatives:**    none

**Default:**     0,0,0

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

r1,0,0,180<>

The orientation measurements for station 1 will now look as if the transmitter had not been mounted upside down.

## TRANSMITTER MOUNTING FRAME

---

RECORD IDENTIFIER ..... r  
INITIATING COMMAND ..... r

byte(s)	Identification	Format
1 ...	Record type, "2"	A1
2 ...	Station Number	A1
3 ...	Sub-record type "r"	A1
4-11 ...	Azimuth mounting frame angle	Sxxx.xxx
12-19 ...	Elevation mounting frame angle	Sxxx.xxx
20-27 ...	Roll mounting frame angle	Sxxx.xxx
28-29 ...	Carriage return, line feed	

**SYSTEM STATUS RECORD****S****Syntax:** S

**Description:** Status refers to the capability to determine information about the system that is not available from other commands. This command allows the operator to verify communication, determine system configuration, check for BIT errors, determine the firmware version number and read system identification information.

**Purpose:** This command allows the operator to request a status record from the FASTRAK system.

**Relatives:** T

**Default:** N/A

**Example:** Sending the “S” command to the system will yield an output similar to the following:

```
21S3F0 0 103.00OutputCompensat CPG2030-003-10
```

- The fact that the status record was received verifies communication
- **2** is the record type
- **1** is the station number
- **3F0** is the hex code for system configuration (see following pages for explanation)
- **0** is the BIT error code (it would be a number other than 0 if there was a system error to report)
- **103.00** is the firmware version number
- The remainder is system identification information that can be programmed by the operator, using the “X” command

**Note:** The station listed is chosen by the FASTRAK, depending on when the “S” command is sent during the cycle. The user may have to issue this command several times in order to get the status data for a particular station.

## SYSTEM STATUS

---

RECORD IDENTIFIER ..... S

INITIATING COMMAND ..... S

---

byte(s)	Identification	Format
1	Record type, "2"	A1
2	Station number	A1
3	Sub-record type "S"	A1
4-6	System flags	H3
LSBit		
0	Output Format	(0=ASCII,1=Binary)
1	Units	(0=Inches, 1=Centimeters)
2	Compensation	(0=Off, 1=On)
3	Transmit Mode	(0=Non-Continuous, 1=Continuous)
4	Configuration	(1=Tracker)
5	Always 1	(Reserved for future use)
6-9	Reserved	
10-23	Reserved for future use	
MSBit		
7-9	BIT error	I3
10-15	Blank (Reserved for future use)	A6
16-21	Software Version ID	A6
22-53	System Identification (See "X")	A32
54-55	Carriage return, line feed	

# SYSTEM CONFIGURATION STATUS - "S" Command

The system's configuration status is contained as a hexadecimal number in the fourth, fifth, and sixth columns of the "S" command output. For convenience, the following table lists the hexadecimal number and corresponding system configuration.

<u>HEX Code</u>	<u>Continuous Mode</u>	<u>Compensation</u>	<u>Units</u>	<u>Output</u>
3FF	ON	ON	CM	Binary
3FE	ON	ON	CM	ASCII
3FD	ON	ON	IN	Binary
3FC	ON	ON	IN	ASCII
3FB	ON	OFF	CM	Binary
3FA	ON	OFF	CM	ASCII
3F9	ON	OFF	IN	Binary
3F8	ON	OFF	IN	ASCII
3F7	OFF	ON	CM	Binary
3F6	OFF	ON	CM	ASCII
3F5	OFF	ON	IN	Binary
3F4	OFF	ON	IN	ASCII
3F3	OFF	OFF	CM	Binary
3F2	OFF	OFF	CM	ASCII
3F1	OFF	OFF	IN	Binary
3F0	OFF	OFF	IN	ASCII

## BUILT-IN-TEST INFORMATION T

---

**Syntax:** TBITnumber[,0]<>

**Purpose:** This command allows the user to obtain additional information about a particular BIT and clear a BIT error. The additional information is meaningful only to factory personnel. The "T" command is useful to attempt to clear a problem; however, if an error re-occurs, and after you have verified your setup configuration, consultation with the factory is recommended. The parameters are:

BITnumber      The BIT number for which added information is requested (see below).

0                This parameter, if used, is specified as a 0 (zero). If present the BITnumber specified is reset/cleared.

**Relatives:** S

**Default:** N/A

**Example:**

<u>BIT number</u>	<u>Code</u>	<u>Transmitter &amp; Receiver Error Codes</u>
65	A	X Driver Linearity
66	B	Y Driver Linearity
67	C	Z Driver Linearity
68	D	x Gain Linearity
69	E	y Gain Linearity
70	F	z Gain Linearity
71	G	X Slope of Driver X Linearity Line
72	H	Y Slope of Driver Y Linearity Line
73	I	Z Slope of Driver Z Linearity Line
74	J	X Slope of Coil / Receiver X Linearity
75	K	Y Slope of Coil / Receiver Y Linearity
76	L	Z Slope of Coil / Receiver Z Linearity
77-83		Not Used (Reserved for future use)
84	T	Receiver PROM Error
85	U	Transmitter PROM Error
86	V	Receiver PROM Circuit Error
87	W	Transmitter PROM Circuit Error
88	X	Driver Characterization Validity
89	Y	Receiver Characterization Validity
90	Z	Receiver Coil Validity

BIT number      Code      Self Calibration Error Codes

97	a	X Driver Limits Self-Calibration
98	b	Y Driver Limits Self-Calibration
99	c	Z Driver Limits Self-Calibration
100	d	x Gain Limits Self-Calibration
101	e	y Gain Limits Self-Calibration
102	f	z Gain Limits Self-Calibration
103	g	Coil Limits Self-Calibration
104	h	Not Used in FASTRAK

BIT number      Code      Signal Matrix Error Codes

105	i	Not Used in FASTRAK
106	j	A Signal Saturation
107	k	A Low Signal
108	l	A Maximum Signal Element Zero

BIT number      Code      EEPROM Error Codes

109	m	EEPROM Validity Checksum Error or Data Validity Discrepancy
110	n	Reserved for Future Use
111	o	Reserved for Future Use
112	p	Reserved for Future Use
113	q	Reserved for Future Use
114	r	Reserved for Future Use

BIT number      Code      Soft Error Codes

115	s	Unit Normal Position Vector Reset (P/R-Norm)
-----	---	--

BIT number      Code      Miscellaneous Error Codes

116	t	Compensation Structure Errors (Array Size Not In Specification Limits)
117	u	Compensation Point Not Within Mapped Bounds
118	v	No CRT Sync Signal Available
119	w	Write Error on Configuration EEPROM
120	x	Receiver Out of Motion Box
121	y	Euler Angles Outside Allowed Angular Envelope
122	z	Reserved



## BIT INFORMATION

---

RECORD IDENTIFIER ..... T  
INITIATING COMMAND ..... T

---

byte(s)	Identification	Format
1 ...	Record type, "2"	A1
2 ...	Blank	A1
3 ...	Sub-record type "T"	A1
4-6 ...	BIT number	I3
7-?? ...	BIT information (Factory meaningful only)	A??
??-?? ...	Carriage return, line feed	

## ENGLISH CONVERSION UNITS                      U

---

**Syntax:**            U

**Description:**    Input/output units is a reference to the distance unit assumed by the system when interpreting input and generating output data.

**Purpose:**            This command sets the distance unit to English (or inches.) Subsequent input and output lengths will be interpreted as inches.

**Relatives:**        u

**Default:**           The system default units is inches.

**Example:**           Assuming the system units had already been changed to centimeters (with the “u” command), the following command could be sent to change back to inches:

U

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

## METRIC CONVERSION UNITS                      u

---

**Syntax:**                      u

**Purpose:**                      This command sets the distance unit to metric (or centimeters.) Subsequent input and output lengths will be interpreted as centimeters.

**Relatives:**                      U

**Default:**                      The system default units is centimeters.

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

u

The system will now output data in centimeters.

## POSITION OPERATIONAL ENVELOPE V

---

**Syntax:** Vs,[xmax],[ymax],[zmax],[xmin],[ymin],[zmin]<>

or

Vs<> to read back the current limits

**Description:** The position operational envelope is an area defined by X, Y, Z minimum and maximum limits. It provides the user with a means of specifying the location of the limits and notifies the user when the limits have been exceeded.

**Purpose:** This command establishes the position operational envelope limits. If the X, Y, Z output measurements are outside the limits defined by this command, the system will produce a BIT error "x". The specific parameters are:

s        the number of the station whose position limits is to be returned or established.

xmax    the maximum x-coordinate for the position operational envelope.

ymax    the maximum y-coordinate for the position operational envelope.

zmax    the maximum z-coordinate for the position operational envelope.

xmin    the minimum x-coordinate for the position operational envelope.

ymin    the minimum y-coordinate for the position operational envelope.

zmin    the minimum z-coordinate for the position operational envelope.

**Relatives:** Q

**Default:** 78.74,78.74,78.74,-78.74,-78.74,-78.74

200,200,200,-200,-200,-200 (in centimeters)

**Example:** If the user wanted to reduce the position operation envelope to a 30" cube, the following command should be sent:

V1,30,30,30,-30,-30,-30<>

The system will now output an error "x" any time the 30-inch limit is exceeded in any of the axis for station 1.

## POSITION OPERATIONAL ENVELOPE

---

RECORD IDENTIFIER ..... V  
INITIATING COMMAND ..... V

---

byte(s)	Identification	Format
1 ....	Record type, "2"	A1
2 ....	Station number	A1
3 ....	Sub-record type "V"	A1
4-11 ....	Maximum x-coordinate value	Sxxx.xxx
12-19 ....	Maximum y-coordinate value	Sxxx.xxx
20-27 ....	Maximum z-coordinate value	Sxxx.xxx
28-35 ....	Minimum x-coordinate value	Sxxx.xxx
36-43 ....	Minimum y-coordinate value	Sxxx.xxx
44-51 ....	Minimum z-coordinate value	Sxxx.xxx
52-53 ....	Carriage return, line feed	

## ATTITUDE FILTER PARAMETERS      v

---

**Syntax:**      v[F],[FLOW],[FHIGH],[FACTOR]<>

or

v[n]<> Macro filter command

or

v<> to return the current filter values selected

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

**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:  $0 < \text{FLOW} < \text{FHIGH}$  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:  $\text{FLOW} < \text{FHIGH} < 1$

**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:  $0 < \text{FACTOR} < 1$

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

n	Macro filter is enabled when $n \geq 2$ as defined below: (Note this also sets the macro filter setting for position. See x command.)
n=2	No Filter (This macro has the same effect as v,1<> above)
n=3	Low Filter
n=4	Medium Filter
n=5	Heavy Filter

**Example:** To select medium filtering, type v4<>

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 "v".

**Relatives:** none

**Default:** The default mode for all filter parameters is "medium." These settings may be used as a starting point for determining optimum filtering in your particular environment.

F 0.2

FLOW 0.2

FHIGH 0.8

FACTOR 0.95

**Example:** Although they are already stored in the system EEPROM, medium filtering can be selected by sending the following command to the system:

v.2,.2,.8,.95<>

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

## ATTITUDE FILTER PARAMETERS

---

RECORD IDENTIFIER ..... v  
INITIATING COMMAND ..... v

---

byte(s)	Identification	Format
1 ....	Record type, "2"	A1
2 ....	Blank	A1
3 ....	Sub-record type "v"	A1
4-10 ....	Filter sensitivity	bSx.xxx
11-17 ....	Floating filter low value	bSx.xxx
18-24 ....	Floating filter high value	bSx.xxx
25-31 ....	Transition rate maximum	bSx.xxx
32-33 ....	Carriage return, line feed	



## POSITION FILTER PARAMETERS

x

**Syntax:** x[F],[FLOW],[FHIGH],[FACTOR]<>

or

x[n]<> Macro filter command

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

**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:  $0 < \text{FLOW} < \text{FHIGH}$  or 1.0 to disable

**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:  $\text{FLOW} < \text{FHIGH} < 1$

**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:  $0 < \text{FACTOR} < 1$

When the form of the command is x,1<> the position filter is disabled. This is the system default configuration.

n	Macro filter is enabled when $n \geq 2$ as defined below: (Note this also sets the macro filter setting for attitude. See v command.)
n=2	No Filter (This macro has the same effect as x,1<> above)
n=3	Low Filter
n=4	Medium Filter
n=5	Heavy Filter

**Example:** To select medium filtering, type x4<>

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 translational 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 minimize 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 caller as an output record of type "x".

**Relatives:** none

**Default:** The default mode for all filter parameters is "medium." These settings may be used as a starting point for determining optimum filtering in your particular environment.

F 0.2

FLOW 0.2

FHIGH 0.8

FACTOR 0.95

**Example:** Although they are already stored in the system EEPROM, medium filtering can be selected by sending the following command to the system:

x.2,.2,.8,.95<>

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

## POSITION FILTER PARAMETERS

---

RECORD IDENTIFIER ..... x

INITIATING COMMAND ..... x

---

byte(s)	Identification	Format
1 ...	Record type, "2"	A1
2 ...	Blank	A1
3 ...	Sub-record type "x"	A1
4-10 ...	Filter sensitivity	bSx.xxx
11-17 ...	Floating filter low value	bSx.xxx
18-24 ...	Floating filter high value	bSx.xxx
25-31 ...	Transition rate maximum	bSx.xxx
32-33 ...	Carriage return, line feed	

## RESET SYSTEM TO DEFAULTS

W

---

**Syntax:** W

**Purpose:** This command resets all of the system EEPROM variables to their factory default values. When using this command, the Ctrl K command could be used afterwards to save the factory default values to the EEPROM if that is desired. Then the Ctrl Y command can be used to reinitialize the system and verify that the factory defaults are now stored in the system EEPROM.

**Relatives:** Ctrl K, Ctrl Y, X

**Default:** N/A

**Example:** If the FASTRAK EEPROM had been altered (by sending various other commands and saving the result to the EEPROM) and the user wanted to return the system to its original factory default settings, then the following commands should be sent:

W  
Ctrl K  
Ctrl Y

The green light on the front panel of the FASTRAK will now blink several times while the system is initializing. After initialization, the system EEPROM 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** custom settings will be lost as a result of the reset. **Note: This command should only be used after consultation with the factory.**

## CONFIGURATION CONTROL DATA    X

---

**Syntax:**        X[string]<>

or

X<> to retrieve the current configuration control data.

**Definition:**    Configuration control data is user-specified information that is stored in the status record. (The status record is retrieved with the “S” command.) This gives the user the ability to identify a particular FASTRAK system in the status record.

**Purpose:**        A maximum of 32 ASCII characters may be entered as configuration control data in EEPROM with this command. The Ctrl K command must be used to save the new configuration control data in the FASTRAK EEPROM. The specific parameters are:

string        a maximum of 32 ASCII characters can be used to identify the configuration control data.

**Relatives:**    Ctrl K, Ctrl Y, W

**Default:**       The default configuration control data retrieved with the “X” command is as follows:

OutputCompensat CPG2030-003-10 (This is a Polhemus configuration code.)

**Example:**       A user could enter project specific information with the “X” command as follows:

XF18 Simulator05 Saint Louis<>

Sending the “S” command to the system would yield the following result:

21S3F0 0    103.00F18 Simulator05 Saint Louis

**Note:** Resetting the EEPROM with the "W" command alters the contents of this data area to:

OutputCompensat CPG2030-003-10.

## CONFIGURATION IDENTIFICATION

---

RECORD IDENTIFIER ..... X  
INITIATING COMMAND ..... X

---

byte(s)	Identification	Format
1 ....	Record type, "2"	A1
2 ....	Blank	A1
3 ....	Sub-record type "X"	A1
4-35 ....	Configuration identification	A32
36-37 ....	Carriage return, line feed	

## SET SYNCHRONIZATION MODE      y

---

**Syntax:**      y[smode]<>

or

y<> to read back the current synchronization mode

**Description:** Synchronization allows for any one of four conditions:

1. The FASTRAK system can operate in its default condition with the data cycle time set to 8.3 milliseconds. This can be achieved by setting the system to Internal Sync Mode.
2. One to four FASTRAK systems can operate in relatively close proximity without interfering with each other. (The interference is generally seen as noise, where measurements change with out physically moving receiver position or orientation.) This can be achieved by setting the system to External Sync Mode and linking the systems together with a sync cable.
3. The FASTRAK cycle time can be set externally with a sync pulse generator. This can be achieved by setting the system to External Sync Mode and connecting to the external pulse.
4. The FASTRAK receivers can operate in relatively close proximity to a CRT video monitor without picking up interference. This can be achieved by setting the system to Video Sync Mode and connecting the video sync detector between the FASTRAK and the CRT monitor.

**Purpose:** This command allows the host to set the system synchronization mode. The specific parameters are:

<u>smode</u>	<u>Description</u>
0	<b>Internal Sync Mode.</b> Signifies that the system is synced internally (8.3 milliseconds/cycle time).
1	<b>External Sync Mode.</b> Signifies that the system is externally synced to another FASTRAK system or an external sync source. (Note: This setting can not be saved to EEPROM with the Ctrl K command.)
2	<b>Video Sync Mode.</b> Signifies that the system is synced via a video frequency pickup coil.

**Relatives:** none.

**Default:** 0 Internal Sync Mode

**Example:** If the user had a requirement to operate two FASTRAK systems in relatively close proximity, the following steps should be taken:

1. Designate one FASTRAK system as the master and the other as the slave.  
**Note:** Make sure that the two FASTRAKs have different colored dots on them so you will know that they are operating at different frequencies.
2. Connect one end of the sync cable to the “sync out” receptacle of the master FASTRAK.
3. Connect the other end of the sync cable to the “sync in” receptacle of the slave FASTRAK.
4. Send the command y0<> to the master FASTRAK.
5. Send the command y1<> to the slave FASTRAK.

The two systems will now be synced together. **Note:** Although synchronization allows two FASTRAKs to operate in relatively close proximity, make sure the receiver of one system does not get closer to the transmitter of the other system than it is to the transmitter of its own system.

See Section 5.8 for multiple systems synchronization.



## SYNCHRONIZATION MODE

---

RECORD IDENTIFIER ..... y  
INITIATING COMMAND ..... y

---

byte(s)	Identification	Format
1 .....	Record type, "2"	A1
2 .....	Blank	A1
3 .....	Sub-record type "y"	A1
4 .....	Synchronization mode	I1
	0 - none - free run	
	1 = External	
	2 = CRT	
5-6 .....	Carriage return, line feed	

**\* SAVE OPERATIONAL CONFIGURATION      Ctrl K**

---

**Syntax:**            Ctrl K

**Definition:**        EEPROM (Electrically Erasable Programmable Read Only Memory) is memory that can be altered by the system, but is not lost when the power is turned off. System variables are stored in the EEPROM. All of these variables are assigned default values. The values are assigned to these variables at the factory and are therefor called the factory defaults. The default values are applied to the variables at initial power-up and system reset.

**Purpose:**            This command allows the user to save the current state of the system configuration parameters to the system EEPROM. This state is henceforth the power up state until another Ctrl K command is issued. **Note:** There may be a short pause of several seconds while the system executes this command.

**Relatives:**        Ctrl Y, W, X

**Default:**           N/A

**Example:**        If the system were used in an application where only position measurements on station 1 were required and they had to be in metric units, the following commands should be sent:

1. O1,2,1<>
2. u
3. Ctrl K

The system will now be configured to output metric, position measurements only on station one, each time it is powered on.

**\* REINITIALIZE SYSTEM                      Ctrl Y**

---

**Syntax:**                      Ctrl Y

**Purpose:**                      Reinitializes the entire system to the power up state. The user should allow sufficient time for the system to run through its self test and initialization (wait for the green light to stop flashing) before attempting to send the system additional commands.

**Relatives:**                      Ctrl K, W, X

**Default:**                      N/A

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

1.    W
2.    Ctrl K
3.    Ctrl 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 to allow user to verify the Ctrl K save command worked properly.

**\* SUSPEND DATA TRANSMISSION      Ctrl S**

---

**Syntax:**      Ctrl S

**Purpose:**      This command suspends data transmission to the host device until a subsequent Ctrl Q is received. If a previous Ctrl S command has been issued, without an intervening Ctrl Q, this command will have no effect.

**Relatives:**      Ctrl Q

**Default:**      N/A

**Example:**      If the FASTRAK system had been issued the “C” command to output data continuously the following command could be used to suspend or temporarily stop the data transmission:

Ctrl S

The data stream will stop scrolling and will not begin again until a Ctrl Q is issued.

**\* RESUME DATA TRANSMISSION**

**Ctrl Q**

---

**Syntax:** Ctrl Q

**Purpose:** Resumes data transmission to the host device following suspension of transmission by a Ctrl S command. If a previous Ctrl Q command has been issued, without an intervening Ctrl S, this command will have no effect.

**Relatives:** Ctrl S

**Default:** N/A

**Example:** If the FASTRAK system had been issued the “C” command to output data continuously and then the Ctrl S command had been used to suspend or temporarily stop the data transmission, the following command could be used to start the data again:

Ctrl Q

The continuous data stream will now resume.

## 6.4 Command Error

Command errors are defined as follows:

### COMMAND ERROR

\*\*\*\*\*

RECORD IDENTIFIER ..... \*

INITIATING COMMAND ..... all invalid commands

---

byte(s)	Identification	Format
1 ...	Record Type, "2"	A1
2 ...	Blank	A1
3 ...	Sub-record type "E"	A1
4-10 ...	"*ERROR*"	
11-?? ...	Erroneous command as it was input	
??-+11...	"*ERROR* EC "	
??-?? ...	Error code from following list:	
	-1 Required field missing	
	-2 Required numeric is non-numeric	
	-3 Value is outside required range	
	-4 Specified frequency not hardware configured	
	-5 Internal buffer limits exceeded	
	-99 Undefined input - cannot identify command	
??-+3 ...	"*PS" (position)	
??-?? ...	Character position in the input record - note numbering starts 0,1,2...	
??-+3 ...	"*FL" (field)	
??-?? ...	Field number causing the error - note numbering of the field is 0,1,2... and starts at '0' following the command identifier.	
??-+3 ...	"*ST" (station)	
??-?? ...	Number of the affected system station less 1; i.e., this value ranges from 0-3, stations are numbered in commands as 1-4.	

\*\*\*\*\*

## 6.5 Default Operation with a Stylus or 3BALL

Operation of the switch on either the Stylus or 3BALL will cause the following actions as a function of the various FASTRAK commands and modes. No other actions are possible.

In NON-continuous output mode pressing the switch defines to the FASTRAK system a 'P' command. When a 'C' command is entered via RS-232 or USB to enable continuous mode, the system immediately responds with output as defined in the manual; however, when the Stylus/3BALL switch is pressed, output is interrupted (but this cycle is completed; i.e., all currently configured stations complete output for this cycle). The Stylus/3BALL switch then serves as a toggle for system output from then on until an RS-232 or USB 'c' command is issued. Each toggle will initiate or terminate a continuous stream of output that begins with station one (1) and terminates (by a subsequent switch pressing) with output for the last station in the cycle list.

Note that all output begins with the FIRST station (in the sequence 1, 2, 3, 4) that is configured ON and ends with the LAST station in the sequence list that is configured ON. Configured ON requires both a proper selection switch at power-on, or enabling the station via the "I" command.

Increment functions are as previously defined in this document. That is, if any receiver does NOT move, since its last cycle, by an amount equal to or greater than its defined increment, output is skipped for the receiver when the above actions cause an output.

A switch cycle takes 40 system cycles. At 8.33 msec per cycle, the switch is responsive at a speed of 333 msec or about 1/3 second. In other words, if the switch is held down while the system is in NON-continuous mode, an output cycle is generated as if a "P" command is entered at the rate of 3/second. If the switch is pressed twice within the 333 msec window, the second pressing is ignored.

See the Define Stylus Button function ("e" Command) for other options and operational information.

## **7.0 LIMITED WARRANTY AND LIMITATION OF LIABILITY**

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

**7.2** In the event any System or portion thereof is defective, Buyer shall, within the warranty period, notify PI in writing of the nature of the defect, remove the defective parts and, at the direction of PI, ship such parts to PI. Upon determination by PI that the parts or Systems are defective and covered by the warranty set forth above, PI, at its option shall repair or replace the same without cost to Buyer. Buyer shall pay all charges for transportation and delivery costs to PI's factory for defective parts where directed to be sent to PI, and PI 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 PI.

**7.3** In the event that allegedly defective parts are found not to be defective, or not covered by warranty, Buyer agrees that PI 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 therefor. Buyer shall bear the risk of loss or damage during transit in all cases.

**7.4** 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.

**7.5** Warranties shall not apply to any Systems which have been:

- (a) repaired or altered other than by PI, except when so authorized in writing by PI.
- (b) used in an unauthorized or improper manner, or without following normal operating procedures; or
- (c) improperly maintained and where such activities in PI's 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.

**7.6** PI DOES NOT WARRANT AND SPECIFICALLY DISCLAIMS THE WARRANTY OF MERCHANTABILITY OF THE PRODUCTS OR THE WARRANTY OF FITNESS OF THE PRODUCTS FOR ANY PARTICULAR PURPOSE. PI MAKES NO WARRANTIES, EXPRESS OR IMPLIED, EXCEPT OF TITLE AND AGAINST PATENT INFRINGEMENT, OTHER THAN THOSE SPECIFICALLY SET FORTH HEREIN.

**7.7** IN NO EVENT SHALL PI BE LIABLE UNDER ANY CIRCUMSTANCES FOR SPECIAL INCIDENTAL OR CONSEQUENTIAL DAMAGES, INCLUDING, BUT NOT LIMITED TO LOSS OF PROFITS OR REVENUE. WITHOUT LIMITING THE FOREGOING PI'S 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 BUYER'S ACTUAL DIRECT DAMAGES, NOT TO EXCEED THE PRICE OF THE GOODS UPON WHICH SUCH LIABILITY IS BASED.

## **8.0 INDEMNITY AGAINST PATENT INFRINGEMENT**

Polhemus Incorporated (PI) shall have the right at its own expense, to defend or at its option to settle, any claim, suit or proceeding brought against Buyer on the issue of infringement of any United States patent by any product, or any part thereof, supplied by PI to Buyer under this Agreement. PI shall pay, subject to the limitations hereinafter set forth in this paragraph, any final judgment entered against Buyer on such issue in any such suit or proceeding defended by PI. PI at its sole option shall be relieved of the foregoing obligations unless Buyer notified PI promptly in writing of any such claim, suit or proceedings, and at PI's expense, gave PI proper and full information and assistance to settle and/or defend any such claim, suit or proceeding. If the product, or any part thereof, furnished by PI to Buyer becomes, or in the opinion of PI may become, the subject of any claim, suit or proceeding for infringement of any United States patent, or in the event of an adjudication that such product or part infringes any United States patent, or if the use, lease or sale of such product or part is enjoined, PI may, at its option and its expense: (a) procure for Buyer the right under such patent to use, lease or sell, as appropriate, such product or part, or (b) replace such product or part, or (c) modify such product, or part, or (d) remove such product or part and refund the aggregate payments and transportation costs paid therefore by the Buyer less a reasonable sum for use, damage and obsolescence. PI shall have no liability for any infringement arising from: (i) the combination of such product or part with any other product or part whether or not furnished to Buyer by PI, or (ii) the modification of such product or part unless such modification was made by PI, or (iii) the use of such product or part in practicing any process, or (iv) the furnishing to Buyer of any information, data, service or application assistance. Buyer shall hold PI harmless against any expense, judgment or loss for infringement of any United States patents or trademarks which results from PI's compliance with Buyer's designs, specifications or instructions. PI shall not be liable for any costs or expense incurred without PI's written authorization and in no event shall PI's total liability to Buyer under, or as a result of compliance with, the provisions of this paragraph exceed the aggregate sum paid to PI by Buyer for the allegedly infringing product or part, exclusive of any refund under option (4) above. The foregoing states the entire liability of PI, and the exclusive remedy of Buyer, with respect to any actual or alleged patent infringement by such product or part.

## 9.0 TROUBLE SHOOTING

Symptom	Possible Solution
FASTRAK Won't Communicate	Check Dipswitch Settings Check RS-232 Cable Check Communication Program Settings Check PC COM Port Return SEU for Repair
Green Light Won't Stop Flashing	Download New Firmware Return SEU for Repair
Solid Light Without Flashing First	Return SEU for Repair
BIT Error A-C, G-I	Return Transmitter for Repair Return SEU for Repair
BIT Error a-c	Change Tuning Module Move Transmitter Away From Metal Replace Power Supply Brick Return SEU for Repair
BIT Error D-F, J-L	Turn Off CRT-Based Displays Separate Receivers Return Receiver for Repair Return SEU for Repair
BIT Error T,V,Y,Z	Return Receiver for Repair Return SEU for Repair
BIT Error U,W,X	Return Transmitter for Repair Return SEU for Repair
BIT Error d-g	Move Receivers Away From CRT-Based Displays Separate Receivers Return Receiver for Repair
BIT Error j,l	Return SEU for Repair
BIT Error k	Reduce Range Return Transmitter and/or Receiver for Repair
BIT Error m,x,y	Perform Following Command Sequence: "W", "Ctrl K", "Ctrl Y" (Resets System Defaults)
BIT Error n,w	Return SEU for Repair

Symptom	Possible Solution
BIT Error s	Reduce Range Return SEU for Repair
BIT Error t,u	Test with Compensation Turned Off (Send "d" Command)

## GLOSSARY

- Alignment** Obtaining congruence between the axes of the tracker and the axes of the application. For active technologies, this is often the same as aligning the active element from which all measurements are referenced. Alignment in an active system is not the same as a boresight operation, which concerns only the receiver. Only in passive systems, alignment and boresight can be identical.
- Alignment Frame** The reference frame in which the position and orientation of the receiver is measured. The default alignment frame is the transmitter frame.
- 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 receiver's x axis in column one, the direction cosines of the receiver's y axis in column two, and the direction cosines of the receiver's z axis in column three. The order of the 3SPACE Euler angle rotation sequence is azimuth, elevation, and roll.

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

where:

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

<b>Azimuth</b>	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.
<b>Baud Rate</b>	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 $9600 \times 8/10 = 7680$ bit rate.
<b>Benign Environment</b>	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 tracker performance shall be regarded as occurring in such a benign environment.
<b>BIT</b>	Built-In Test features monitoring the status and health of the tracking system as well as flagging of certain preset conditions monitored by the tracking system software. Not to be confused with bit, a contraction of binary digit.
<b>Boresight</b>	<p>Any procedure that rotates the receiver frame so as to precisely align the receiver to the designated reference frame.</p> <p>In a 3SPACE system context, the term usually refers to the system software routine that, on command, performs a coordinate rotation, which effectively aligns the receiver frame to a predefined boresight reference orientation.</p> <p>Note that the boresight routine accomplishes the boresight orientation of the receiver regardless of the receiver's physical orientation at the instant of boresight initiation. So, for applications that require the orientation tracking of the body (or body member) to which the receiver is attached, a prerequisite to initiating the boresight function is a physical orientation of the body to be tracked to the boresight reference orientation.</p>
<b>bps</b>	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.)
<b>Compensation Data</b>	A set of invariable data that allows the 3SPACE to compensate for fixed distortions of the magnetic field due to the surrounding environment. The compensation data generally results from an application-specific distortion

mapping procedure.

<b>Direction Cosines</b>	The cosines of the angles between the receiver's x, y, z-axes and the X, Y, Z axes of the measurement reference (alignment) frame.
<b>EEPROM</b>	Electronically Erasable Programmable Read Only Memory. Memory that can be altered by the 3SPACE, but is not lost when the power is OFF. User default data is stored here, as well as the system identification data.
<b>Elevation</b>	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.
<b>Factory Defaults</b>	The values assigned to certain system variables by the factory. Stored in PROM, they are used to reinitialize the variables if EEPROM is lost.
<b>Format</b>	The interchange coding used to present data. The 3SPACE outputs either ASCII or BINARY data, but accepts only ASCII inputs from the host.
<b>Hemisphere</b>	<p>Because of the inversion symmetry of the magnetic fields generated by the transmitter, there are two possible mathematical solutions for the X, Y, Z, position coordinates for each set of receiver data processed, and the 3SPACE is unable to determine which solution is the correct one without additional information. Therefore, only half of the total spatial sphere surrounding the transmitter can be utilized at any one time for unambiguous position measurement.</p> <p>The selected hemisphere is referred to as the "current hemisphere." It is defined by an LOS (line-of-sight) vector from the transmitter through a point at the zenith of the hemisphere, and is specified by the direction cosines of the chosen LOS vector.</p> <p>The orientation coordinates do not have a two-solution spherical ambiguity and are therefore valid throughout the operating sphere centered at the transmitter.</p>
<b>Host</b>	Any device capable of supporting an RS-232C interface or the high speed USB interface when available and capable of bi-directional data transmission. Devices may range from a dumb terminal to a mainframe computer.
<b>Increment</b>	The minimum movement necessary to cause the 3SPACE to transmit a

record to the host.

<b>I/O latency</b>	The interval of time needed by the host computer to transfer tracker data from the tracking system into the host application.
<b>Lag</b>	The total time from motion data sample capture to host inputting where the data are ready for application use.
<b>Line of Sight (LOS)</b>	1) The orientation angle of the tracker receiver. 2) In active tracker systems, the angle between the source of stimulation and the tracker receiver. 3) Not obscured or blocked from view, such as a clear line of sight for optical uses.
<b>LSB</b>	Least significant bit.
<b>LSD</b>	Least significant digit.
<b>MSB</b>	Most significant bit.
<b>Motion Box</b>	The volume in which motion tracking is guaranteed 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 transmitter) 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.
<b>Orientation Angles</b>	<p>The azimuth, elevation, and roll angles that define the current orientation of the receiver coordinate frame with respect to the designated reference frame.</p> <p>The Euler angle coordinates that are output by the 3SPACE as one measure of receiver orientation are graphically defined in Figure A1.</p> <p>In Figure A1, 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 receiver frame in its current orientation state. The X,Y,Z triad represents the reference frame against which the relative orientation of the receiver frame is measured. By definition then, the X,Y,Z frame also represents the zero-orientation reference state of the receiver frame.</p> <p>The 3SPACE Euler angles, azimuth, elevation and roll, are designated <math>\psi</math>, <math>\theta</math>, and <math>\phi</math> in Figure A1. These angles represent an azimuth-primary sequence</p>



of frame rotations that define the current orientation of the receiver 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  $\psi$  is defined in Figure A1 as a rotation of the X and Y reference axes about the Z reference axis. Note that the transition axes labeled X' and Y' represent the orientation of the X and Y axes after the azimuth rotation.

The elevation angle  $\theta$  is defined as a rotation of the Z reference axis and the X' transition axis about the Y' transition axis. Note that the transition axis labeled Z' represents the orientation of the Z reference axis after the elevation rotation. Note also that the current x-axis of the current receiver frame represents the orientation of the X' transition axis after the elevation rotation.

Lastly, the roll angle  $\phi$  is defined as a rotation of the Y' and Z' transition axes about the x-axis of the receiver frame. Note that the y and z-axes of the current receiver frame represent the orientation of the Y' and Z' transition axes after the roll rotation.

Note also that in the example of Figure A1, the azimuth, elevation and roll rotations are positive, negative and positive respectively.

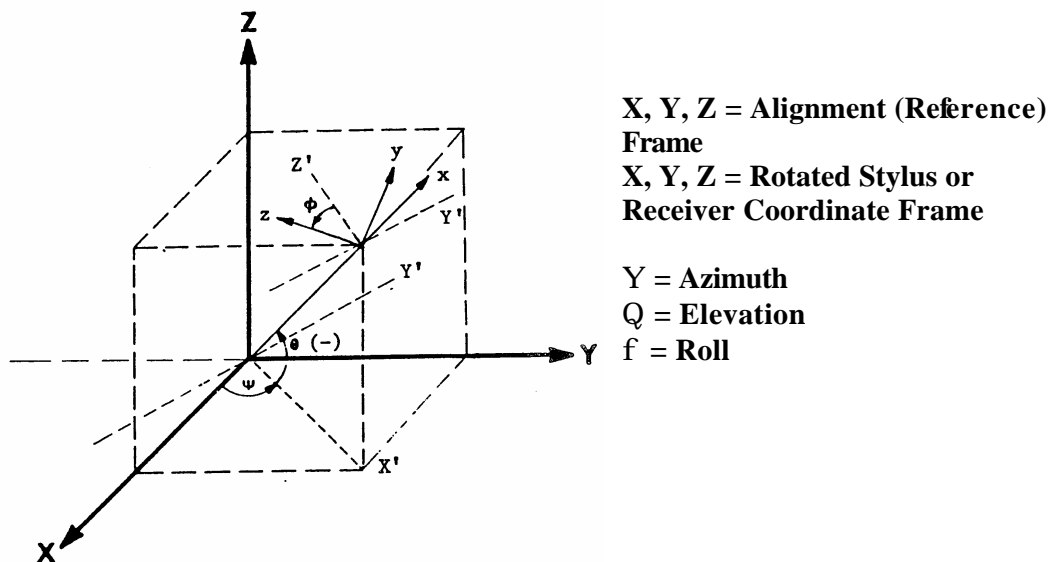


Figure A1. 3Space Euler Angles

#### Output List

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

#### 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 receiver's orientation without the need for trigonometric functions. The attitude matrix output from the 3SPACE can be equivalently represented by the following matrix using quaternions:

X Directional Cosines	Y Directional Cosines	Z Directional Cosines
$q_0^2 + q_1^2 - q_2^2 - q_3^2$	$2(q_1 q_2 - q_0 q_3)$	$2(q_1 q_3 + q_0 q_2)$
$2(q_3 q_0 + q_1 q_2)$	$q_0^2 - q_1^2 + q_2^2 - q_3^2$	$2(q_2 q_3 - q_0 q_1)$
$2(q_1 q_3 - q_0 q_2)$	$2(q_1 q_0 + q_3 q_2)$	$q_0^2 - q_1^2 - q_2^2 + q_3^2$

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

**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.

**Sensor** Same as Receiver.

**Station** The transmitter-receiver pair. Up to four receivers are permitted, yielding a possible four stations.

**Stylus** A pencil-shaped housing for the receiver 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.

<b>System ID Data</b>	Thirty-two characters of ASCII data (hardware serial number, etc.) stored in EEPROM containing information identifying the system. See “X” command.
<b>Tracker Alignment</b>	The process whereby the tracking system coordinate reference is brought into coincidence, either physically or mathematically, with other coordinates of the environment.
<b>Tracker Calibration</b>	The process whereby the tracking system is made to operate accurately in the installed environment to produce tracking data throughout the motion box.
<b>Tracker Latency</b>	The interval of time between when tracker measurement data were collected and when the P&O result is formatted ready for transfer to the host computer. In some systems, namely active trackers, there is a timer interval when the active element is illuminating the environment when the data are collected after which the P&O computation can be done. Hence, this definition is intended to correspond to the center point of data collection time so that tracker latency is straightforward and understandable as stated. Other tracking systems (e.g., inertial) may produce raw data continuously or nearly continuously. Tracker latency in this case reduces to the computation time for producing the answer ready for transfer to the host computer.
<b>Tracker Response</b>	The interval of time between a request to the tracking system to collect a data point and when that data is available for input from the tracker.
<b>Transmitter</b>	The transmitter generates the low-frequency magnetic field measured by the receiver. The transmitter's X, Y, and Z-axes are the default measurement reference frame.
<b>Units</b>	The unit of assumed distance. The 3SPACE allows either inches or centimeters.
<b>Update Rate</b>	The rate at which motion-tracking data can be made available from the tracking system.
<b>Useful Range</b>	The maximum distance at which the resolution and noise performance of the tracking system can be realized.

<b>User Defaults</b>	The values assigned to certain system variables by the user. Stored in EEPROM, the system receives these variable values at power-up.
<b>XYZ or X, Y, Z</b>	The Cartesian coordinates of position tracking where normally +X is in the forward direction; +Y is in the right hand direction and +Z is upward.
<b>XYZAER</b>	The output string of data reporting the position, XYZ, and orientation, AER - azimuth, elevation and roll, of the tracking receiver.
<b>Yaw</b>	Same as azimuth.
<b>&lt;&gt;</b>	Used in text to indicate the “Enter” key.

## **APPENDIX A: STANDARD/OPTIONAL ITEMS**

### **FASTRAK HARDWARE**

The FASTRAK system consists of the following standard and optional items:

#### **Standard Items**

1. System Electronics Unit (SEU) w/ Std. Frequency Select Module (12KHz)	4A0451-01
2. Power Supply Brick	1C0034
3. 110V Power Cord	17500B-BLK
4. Standard Transmitter w/ 10' cable	3A0369-07
5. Standard Receiver w/ 10' cable	4A0314-01
6. FASTRAK User Manual Kit	OPM6762-001

#### **Optional Items**

1. RS-422 SEU in lieu of standard RS-232 SEU	4A0451-02
2. Short Ranger SEU in lieu of standard SEU	4A0451-03
3. Short Ranger Transmitter	4A0350-01
4. Long Ranger Transmitter	4A0345-02
5. Long Ranger Cable	3A0454-02
6. Standard Transmitter w/ 20' cable	3A0369-08
7. Standard Receiver w/ 20' cable	4A0314-02
8. Mini Receiver w/ 20' cable	4A0394-06
9. Stylus w/ 10' or 20' cable	4A0318-01/-02
10. Short Handle Stylus w/ 10' or 20' cable	4A0318-03/-04
11. Round Tip Stylus w/ 10' or 20' cable	4A0318-06/-05
12. 3Ball w/ 10' cable	4A0314-05

13. 220V Power Cord	17850
14. Synchronization cable	1C0218
15. Video Sync Detector	36-010
16. Black Frequency Select Module (8 KHz)	3A0363-01
17. Red Frequency Select Module (10 KHz)	3A0363-02
18. Yellow Frequency Select Module (12 KHz – Std.)	3A0363-03
19. Blue Frequency Select Module (14 KHz)	3A0363-04

**Note:** Because the FASTRAK is a diverse system and is used in many different types of applications, special options are often created for specific applications. Please contact Polhemus for more information.

## APPENDIX B: 'ACCURACY AND RESOLUTION' WHITE PAPER

### ACCURACY AND RESOLUTION IN ELECTROMAGNETIC SIX-DEGREE-OF-FREEDOM MEASUREMENT SYSTEMS APB 8500-001A

#### INTRODUCTION

The classical definitions of resolution and accuracy as articulated by Cook and Rabinowicz in "Physical Measurement and Analysis," Addison-Wesley Publishing Company, 1963, are:

Resolution: the smallest amount of the quantity being measured that the instrument will detect.

Accuracy: the fractional error in making a measurement.

Clearly, confusion over these issues in light of the burgeoning need to measure both the position and orientation of a freely movable object in space with respect to a fixed reference, can lead to inconclusive results and lost effort in application measurements.

From the outset of electromagnetic six degree-of-freedom measurement technology, regardless of the application, the subjects of accuracy and resolution have been confusing in light of claims by competing technologies and product manufacturers. This Application Note attempts to clarify accuracy and resolution and to illustrate their total applicability to the classical definitions.

#### THEORY OF OPERATION

The position of a point in space may be fully described by its relationship to any fixed and convenient three axis (x, y, z) coordinate system. Orientation means direction in relationship to that position and may be fully described by three parameters or angles known as azimuth (yaw), elevation (pitch), and roll.

A typical Polhemus system consists of a fixed magnetic-dipole transmitting antenna called a transmitter; a freely movable magnetic-dipole receiving antenna called a receiver; and associated electronics as shown in Figure B1. Both the transmitter and receiver antennas consist of three mutually orthogonal loops (coils). The loop diameters are kept very small compared to the distance separating the transmitter and receiver so that each loop may be regarded as a point or infinitesimal dipole. Exciting a loop antenna produces a field consisting of a far-field component and a near or induction-field component. The far-field intensity is a function of loop size and excitation frequency and decreases with the inverse of the distance ( $1/r$ ). The induction-field or "quasi-static" field component intensity is not frequency dependent and decreases by the inverse cube of the distance ( $1/r^3$ ). The quasi-static field is not detectable at long distances; in fact, its strength dominates at short distances and the far-field is negligible.

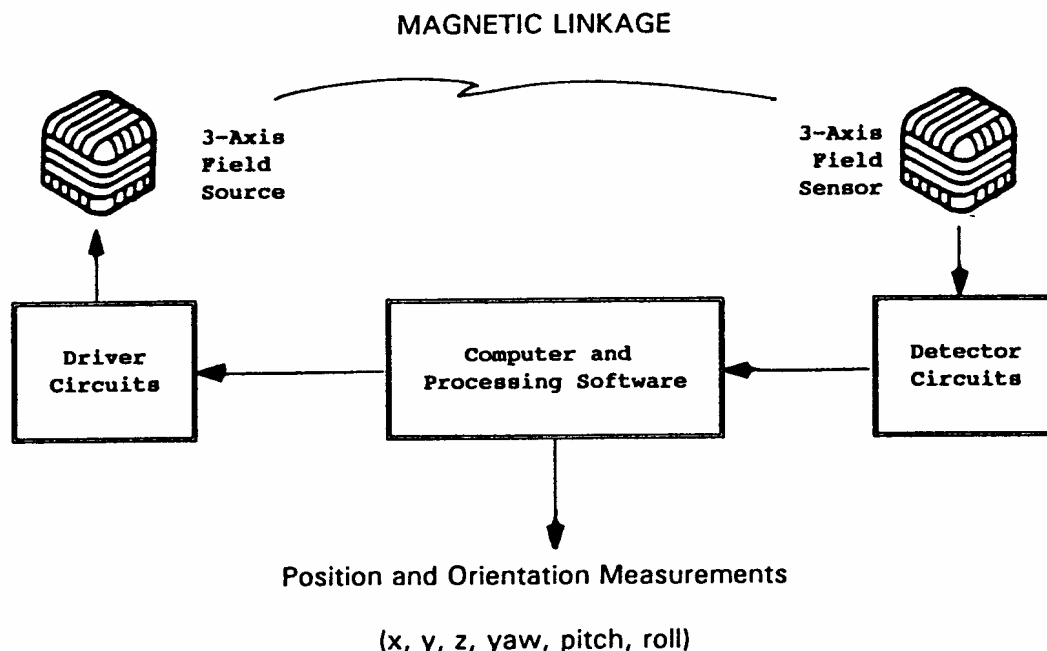


Figure B1. Position and Orientation Measurement System Block Diagram

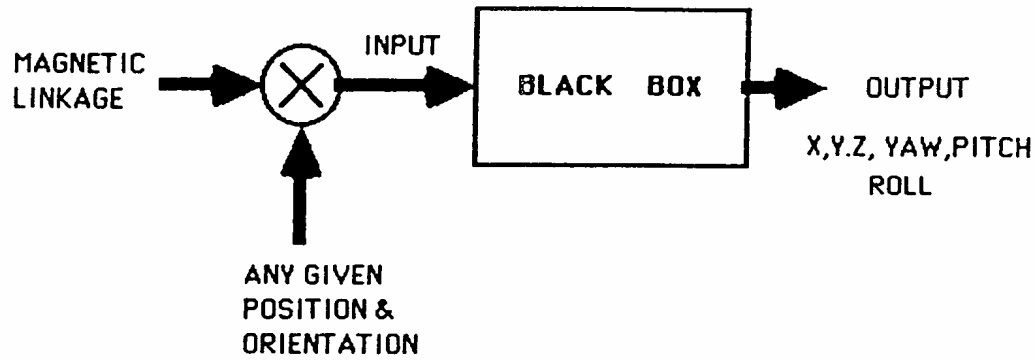
In the system shown in Figure B1, each loop of the transmitter antenna is in turn excited with a driving signal identical in frequency and phase. Each excitation produces a single axis transmitter dipole. The transmitter excitation is a pattern of three states. Exciting the transmitter results in an output at the receiver of a set of three linearly independent vectors. The three output (receiver) vectors contain sufficient information to determine the position and orientation of the receiver relative to the transmitter. Essentially nine measurements are available to solve for the six unknowns of x, y, z for position and azimuth (yaw), elevation (pitch), and roll for orientation.

## DEFINITIONS

For resolution and accuracy considerations, the electromagnetic instruments are treated as "black boxes" thereby focusing on the performance of the instruments and negating the process of solution from the definitions.

A key element for determining resolution and accuracy from a "black box" point of view is the system's signal-to-noise (S/N) ratio. First, consider the black box system shown in Figure B2. The Magnetic Linkage is the magnetic field or B field which is a vector quantity derived from the vector sum of the radial and tangential field components for a magnetic dipole. It contains both the magnetic moment vector **m** and the inverse cube of the range factors given by the quantity  $K/r^3$ .





**MAGNETIC LINKAGE** = Magnetic Moment

**POSITION & ORIENTATION** = Sensor Loop triad receiving antenna for position and orientation

Figure B2. Black Box System

There are three sensing coils and three magnetic moments with the resultant matrix = **M** expressed by **M** = [**m**<sub>1</sub> | **m**<sub>2</sub> | **m**<sub>3</sub>]. Position and orientation are described by the voltages induced in the three receiver loops according to their sensitivity and orientation and given by the matrix quantity **S** = [**s**<sub>1</sub> | **s**<sub>2</sub> | **s**<sub>3</sub>]. Coupling between the Magnetic Linkage and Position and Orientation sensitivity produces nine voltages giving rise to the input voltage matrix expressed as:

$$V = \frac{1}{r^3} S^t K M$$

Coupled through the Magnetic Linkage is a noise quantity **N<sub>i</sub>**, which is composed of incidental link noise plus atmospheric noise. Additionally, system noise, generated as a function of the black box electronics is given by **N<sub>b</sub>**. System noise (**N<sub>b</sub>**) is the sum of quantization, shot and thermal noise and is referred to the input of the black box. These noise quantities are algebraically added to the voltage equation for the input to the black box and expressed as:

$$V = \frac{1}{r^3} S^t K M + N_i + N_b$$

## SIGNAL-TO-NOISE (S/N) RATIO

At the output of the black box, the signal (S) portion of the S/N ratio is the value of any given position and orientation of the receiver. It could be considered as the input equation stated above, minus the noise components, times the transfer function of the "black box." The noise portion (N) is the noise components of the input equation times the "black box" transfer function and is observed as the deviation in the output parameters about the given position and orientation. Therefore, determining the S/N ratio from a "black box" perspective involves the use of a precise mechanical positioning instrument with a precision gimbal. Using surveyed (precisely known) attitude coordinates (azimuth, elevation and roll), a statistically valid number of measurement samples are taken at each attitude. For each attitude the mean vector sum of these samples yields the signal (S) component and the vector sum of the one sigma values of the deviation yields the noise (N) component. The S/N ratio may be expressed as a unitless number or in db, that is,  $20 \log_{10} S/N$ .

## RESOLUTION

Resolution for electromagnetic six degree-of-freedom measurement instruments is generally specified as angular resolution and translational resolution.

### ANGULAR RESOLUTION

Considering that the receiver is an all-attitude (360 degree) device, the angular resolution is calculated by dividing 360 degrees by the S/N ratio thus yielding its value in degrees.

### TRANSLATIONAL RESOLUTION

The translational or positional resolution is a function of the S/N ratio and range. Being a positional function, there are three orthogonal vectors whose vector sum multiplied by any given range number yields the required translational resolution as shown in Figure B3. One vector is defined along the axis of the range and is therefore a function of the inverse cube of the range. The remaining two orthogonal vectors (a & b) are a function of the tangent of the angle derived by dividing 180 degrees by the S/N ratio. Unlike angular resolution which uses 360 degrees divided by the S/N ratio, 180 degrees is used for these translational resolution component vectors because with an electromagnetic system there are two possible solutions to the six degree-of-freedom measurement problem. This two solution possibility constitutes a potential system ambiguity. Obviously for a position measurement, only one solution is permitted and valid. The units for translational resolution are either English (inches) or metric (cm.).

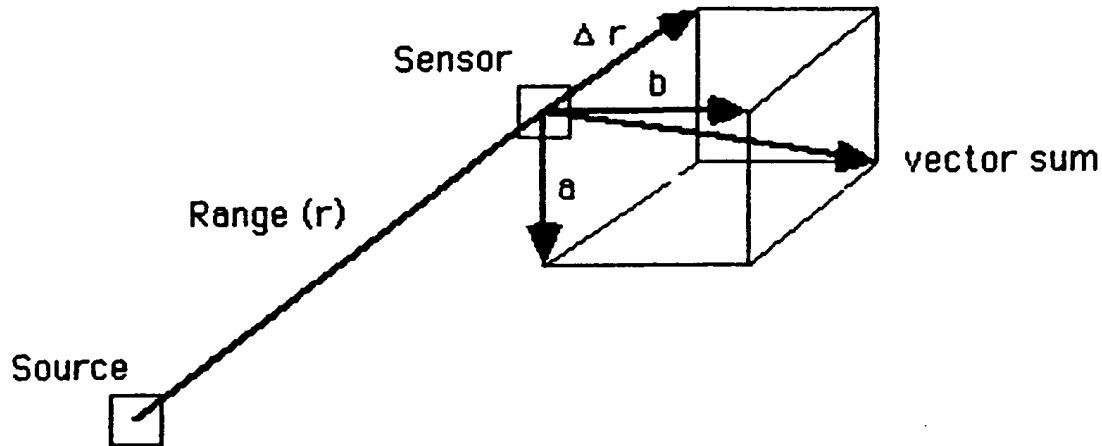


Figure B3. Translational Resolution.

## ACCURACY

The accuracy of electromagnetic six degree-of-freedom measurement instruments is a function of the error involved in making measurements and is therefore expressed in statistical error terminology. It should be noted here that the use of statistical error terminology is the reason the accuracy of such instruments is generally specified in degrees RMS for attitude (orientation) and in inches or centimeters RMS for position. As with resolution, accuracy will be considered here from the point of view of the instruments as "black boxes." When treating the instruments as "black boxes," all classic error terms such as linearity, repeatability, hysteresis and drift are included.

One factor to be considered with any of the electromagnetic instruments is range or field-of-regard. All instruments have a practical operating range for which accuracy is specified. Operation beyond that range will degrade accuracy as a function of the degradation of the system's S/N ratio. Additionally, all electromagnetic six degree-of-freedom systems are affected somewhat by the metallic environment in which they operate. As this is clearly an uncontrollable function of the environment from the manufacturer's viewpoint, accuracy is generally specified and/or should be determined in a metallically clean environment.

The accuracy specified by manufacturers of electromagnetic six degree-of-freedom instruments is called "Static Accuracy" as the measurements are made with both the transmitter and receiver in a fixed and surveyed attitude and position condition within a specified motion box or field-of-regard.

## POSITIONAL STATIC ACCURACY

The positional Static Accuracy may be determined by measuring the vector positions ("X", "Y", "Z") of a receiver positioned in a statistically valid number of fixed and known locations throughout a specified motion box using a precise mechanical positioning instrument with a precision gimbal. The X, Y, and Z error terms are recorded and the RMS values calculated for each term.

These resulting error values (one of "X", one for "Y", and one for "Z") are the system's positional Static Accuracy at each given point within the specified motion box. Obviously, an overall positional Static Accuracy for "X", "Y", and "Z" may be obtained by calculating the RMS value for all positional Static Accuracy points taken within the specified field-of-regard.

## ORIENTATIONAL STATIC ACCURACY

Whereas a similar exercise is required to determine the orientational Static Accuracy, a clear understanding of the orientation parameters is necessary to understand the meaning of the specification and how it is measured. The electromagnetic instruments all measure and output six degree-of-freedom data in different optional formats including Cartesian coordinates of position and Euler angles and/or direction cosines as orientation parameters. The azimuth, elevation, and roll (yaw, pitch, and roll) angles are the more intuitive of the orientation parameters of the receiver and are measured with respect to the alignment (or fixed transmitter) reference frame.

Euler angles are defined as the sequence of angles (azimuth, elevation, and roll) that define the orientation of the receiver with respect to the X, Y, Z alignment reference frame. Azimuth is a rotation of the receiver's **x** axis projection in the X Y reference plane about the Z reference axis. Elevation is a rotation of the receiver's **x** axis about the Y reference axis. Roll is a rotation of the receiver's **y** (or **z**) axis about its **x** axis.

In order to measure the orientation Static Accuracy in the same manner that the positional accuracy was obtained, the aforementioned precise gimbal test fixture is required to allow input of precise and simultaneously different attitudes. As with the positional measurements, azimuth, elevation, and roll measurements of the receiver are taken in a statistically valid number of known attitudes in fixed and known locations throughout the same specified motion box as used for the positional measurements. The azimuth, elevation, and roll error terms are recorded and the RMS values calculated for each term. The resulting error values (one for azimuth, one for elevation, and one for roll) are the instrument's orientational Static Accuracy. As for the positional Static Accuracy, the overall orientational Static Accuracy for azimuth, elevation, and roll may be obtained by calculating the RMS value for all orientational Static Accuracy points taken within the specified field-of-regard.

## CONCLUSION

It can be seen from the above discussions that accuracy and resolution for electromagnetic, six-degree-of-freedom instruments conform to the classical definitions of these terms. Accuracy is indeed the fractional error obtained in making a measurement and Resolution is the granularity of the measurement or the smallest amount of the quantity being measured that the instrument will detect. It can also be seen that numerical values of accuracy and resolution may be obtained from careful and precise measurements of the system's output data with respect to surveyed and known receiver positions and orientations.

## APPENDIX C: 'LATENCY' WHITE PAPER

### TECHNICAL NOTE

#### Latency - 3SPACE® FASTRAK®

H. R. Jones

### INTRODUCTION

ANSI/IEEE Std 100-1977 defines latent period as "The time elapsing between the application of a stimulus and the first indication of a response". The definition excludes the time required to transmit the response. It is in this context that we define the latent periods (1) between the application of a synchronization pulse and a response, and (2) between the application of receiver motion and a response. The "response" for both cases occurs when the receiver coordinate solution is made ready for output, and, as noted above, does not include the time required to transmit the coordinates over the interface in use (e.g. RS-232, MIL-STD-1553, IEEE-488, etc).

Polhemus 3SPACE FASTRAK magnetic six-degree-of-freedom measurement systems emanate low frequency magnetic fields from a stationary transmitting antenna and sense them with a movable receiving antenna. The received magnetic field samples are subjected to analog and digital processes, and are ultimately solved for the receiver's position and orientation coordinates. The solutions are formatted in varied ways according to user selections, then output over various types of interfaces depending on the product.

The FASTRAK system's latent period is due to the time required to sample the magnetic fields, solve for the receiver coordinates, and make the solutions available for output. However, from the user's point of view, the latent period may appear longer than this due to delays in the interface or in the user's computer, or due to (incorrectly) configured FASTRAK filters which can make the response appear to occur later. These topics are discussed in the following paragraphs.

### SYNC-TO-OUTPUT LATENT PERIOD

Application of an external synchronization pulse<sup>1</sup> initiates magnetic field sampling, a period that lasts about 3.5 ms. It goes beyond the scope of this note to explain the sampling process in more detail, so let it suffice that nine magnetic field samples are taken per cycle time. The samples are then solved for receiver coordinates, a period that requires another 2 ms. The solution is then placed in an output buffer and is made ready for transmission over the interface in use. The total "sync-to-output" latent period is the sum of field sampling and coordinate solution periods, or 5.5 ms, and is independent of update rate.

### EFFECTIVE LATENT PERIOD

"Sync-to-output" latency is important for reasons of interface timing; however, it does not

---

<sup>1</sup> If external synchronization and continuous print are not implemented, the environment is being run asynchronously and the latent period cannot be defined precisely.

quantify the effective latent period between receiver motion and output coordinate values. This period is important to helmet display or virtual reality applications since dynamic errors between the actual and computed coordinates can be very noticeable to the eye.

To discuss effective latent period let the beginning of the magnetic field sampling be at  $t=0$ ; let the end of sampling be at  $t=\tau$ ; and let the time that the solution appears in the output buffer be  $t=T$ . The computed solution for a receiver moving at constant velocity will correspond to where the receiver was at  $t=\tau/2$ , the midpoint of the sampling period; hence, the effective latency is  $T - \tau/2$ , or 3.75 ms.

## OTHER FACTORS

Although the time to transmit data is not included in the definition of latent period, a knowledge of how to compute these delays is needed to properly align in time the receipt of tracker solution with the actual event. For example, the factory default ASCII output record x-y-z-az-el-rl is composed of 47 bytes (3 status bytes, 6 data words each 7 bytes long, and a CR LF terminator) and at 115.2 kBaud requires a transmission time of 4 ms (recall that there is one start bit and one stop bit per 8 bit data byte). The tracker's sync-to-output latent period plus transmit time for this example is 9.5 ms, and the effective latent period plus transmit time is 5.8 ms.

It is very important to note that if the transmit time exceeds the tracker cycle time (8.33 ms), which could happen if the baud rate is too slow or if the record length is too long, it becomes necessary for the tracker to periodically discard solutions to prevent output buffer overflow. This would make it appear as though the tracker was not tracking continuously or was dropping data. This interface problem is most noticeable in multiple receiver operation as the tracker is designed to maintain constant order of receiver processing. If the interface just missed a given receiver in the list of multiple receivers, the tracker will output nothing until this receiver is again processed.

Another common problem is the RS232 communications XON/XOFF protocol. If the user's computer cannot assimilate the tracker's output fast enough, the computer can transmit an XOFF signal to the tracker commanding it to stop transmitting. When the user's computer has finally assimilated the data it has accumulated, it transmits an XON command and the tracker once again begins transmitting coordinate data. During the XOFF period the tracker's output buffer is continually discarding solutions to prevent buffer overflow, thus many data sets are never transmitted. Toggling of XON/XOFF in the user's computer could be happening without the user's knowledge and could again make it appear that tracker sync-to-output latent period was varying from 5.5 ms to many times this, and periodically dropping data. The RS232 lines should be monitored if this problem is suspected.

A third problem is asynchronous interfacing, and a particularly annoying example of such an interface is MIL-STD-1553 as this bus is not only asynchronous but often very slow (e.g. 25 Hz). Asynchronous interfaces guarantee that on the average the apparent latent period will be increased by one half the tracker cycle time. For a slow 25 Hz bus rate, the sync-to-output latent period would vary from 5.5 ms to 13.8 ms. Another example is a unsynchronized computer issuing single record print commands at random times in the tracker's cycle.

## FILTER RESPONSE (LAG)

FASTRAK has optional filters that are intended to smooth the receiver's calculated position and orientation in mechanically or magnetically noisy environments. The degree of filtering is user selectable from very heavy to none at all, or the degree of filtering can be automatically selected in real time by the tracker as it adapts to "noise". Filtering can introduce lag in response; the sync-to-output latent period remains unchanged (recall that latent period is defined as "a first indication" and not a final settled response), but the data that is output may not correspond to where the receiver was recently.

To help understand the response of the optional filters, the filter algorithm is described and analyzed in the following paragraphs.

FASTRAK coordinate filters are exponential filters as described by the following equation.

$$\langle x \rangle_k = \alpha x + (1 - \alpha) \langle x \rangle_{k-1} \quad (1)$$

In this equation "x" is the unsmoothed receiver coordinate measured at time "k"; it may be a coordinate of position or orientation. The variable " $\langle x \rangle_k$ " is the filter output at discrete time "k" and " $\langle x \rangle_{k-1}$ " is the smoothed value at time "k-1". The filter parameter " $\alpha$ " controls the degree of filtering and must be within the range  $0 < \alpha < 1$ . Small values of  $\alpha$  produce heavy filtering; large values produce light filtering; in the limit as  $\alpha \rightarrow 0$  the filter output never changes; and in the limit as  $\alpha \rightarrow 1$  the output exactly follows the input. The filter parameter  $\alpha$  can be set to a specific value through system commands, or a range of values can be specified which allows the system to choose its own optimum value automatically adapting to environmental noise.

Equation (2) expresses the steady state filter response for zero acceleration in receiver coordinates and for a constant filter parameter  $\alpha$ . In the derivation of the equation, the coordinate "x" is assumed to be of the general form "x = vt", where "v" represents a constant velocity (in either position or orientation), "t" is time, and " $\Delta t$ " is the tracker's cycle time (the inverse of update rate).

$$\langle x \rangle_k = x - \left( \frac{1 - \alpha}{\alpha} \right) v \Delta t \quad (2)$$

Equation (2) can be reformulated to express the filter time delay for a constant rate of change ("v") in input.

$$\frac{x - \langle x \rangle_k}{v} = \left( \frac{1 - \alpha}{\alpha} \right) \Delta t \quad (3)$$

Equation (3) may be interpreted as the error in degrees per "v" degrees/second in orientation input, or the error in inches per "v" inches/second of translation. Note that in either case the units are in seconds.

As an example, suppose that the update rate of the tracker is 120 Hz, thus  $\Delta t = 1/120$  second. Suppose also that the receiver is slewing in azimuth at 90 degrees per second and that  $\alpha$  is a constant 0.95, a value that can be attained by either fixing both the upper and lower limits of  $\alpha$  to 0.95, or by setting just the upper limit to 0.95 and letting the adaptive filter push  $\alpha$  to this maximum limit which is what would happen for slew rates of this magnitude. The filter lag for this example is

calculated to be 0.44 ms. The correct interpretation of this figure is that the receiver coordinates output at  $t=5.5$  ms correspond to where the receiver was at  $t = \tau/2 - 0.44$  ms = 2.2 ms; this would increase apparent latency to  $T - \tau/2 + 0.43$  ms = 4.2 ms.

The next example demonstrates what can happen when the filter constant is set too low producing extremely heavy filtering. Suppose  $\alpha$  is set to 0.05 and all other conditions are the same as in the above example. In this case the filter lag calculates to 158 ms, and the interpretation is that the coordinates output at  $t=5.5$  ms corresponds to where the receiver was at  $t = \tau/2 - 158$  ms; this yields an apparent latent period of  $T - \tau/2 + 158 = 162$  ms. Obviously, low filter settings must be avoided if any reasonable dynamic response is desired.

## RECAPPING

This technical note has discussed the latency in the application of a PI 3SPACE<sup>®</sup> FASTRAK product. As pointed out, sync-to-output and effective latencies are measures of tracker throughput and cannot be changed, while apparent latency and filter response are controlled to a degree by the interface and application environment. To derive best performance the FASTRAK product should be synchronized and data records should be reduced to the minimum required. Also, use the fastest baud rates available, consider the use of binary formats, and use the continuous print mode.



## APPENDIX D: CABLE DIAGRAMS

### RS-232 Cable Diagram

- IBM (PC) Compatible Computer
- SGI O2, Onyx 2, or Octane

To PC  
D-Type Connector  
9-Pin Female

To FASTRAK  
D-Type Conn.  
9-Pin Female

<u>Pin #</u>	<u>Identification</u>	<u>Pin #</u>
1		
2	--Receive Data -----Transmit Data---	3
3	--Transmit Data -----Receive Data--	2
4		8
5	-----Signal Ground-----	5
6		7
7		
8		
9		

# RS-232 Cable Diagram

- IBM (PC) Compatible Computer

To PC  
D-Type Connector  
25-Pin Female

To FASTRAK  
D-Type Conn.  
9-Pin Female

<u>Pin #</u>	<u>Identification</u>	<u>Pin #</u>
1		
2	--Transmit Data -----Receive Data--	2
3	--Receive Data -----Transmit Data--	3
4		
5		
6		7
7	-----Signal Ground-----	5
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		8
21		
22		
23		
24		
25		

# RS-232 Cable Diagram

- SGI Indigo2, Indigo, Onyx, Iris

To PC  
Circular Connector  
DIN-8

To FASTRAK  
D-Type Conn.  
9-Pin Female

<u>Pin #</u>	<u>Identification</u>	<u>Pin #</u>
1		8
2		
3	--Transmit Data -----	Receive Data-- 2
4	-----	Signal Ground----- 5
5	--Receive Data -----	Transmit Data-- 3
6		
7		7
8		

# RS-232 Cable Diagram

- SGI VTX, Onyx, Personal Iris

To PC  
Circular Connector  
DIN-8

To FASTRAK  
D-Type Conn.  
9-Pin Female

<u>Pin #</u>	<u>Identification</u>	<u>Pin #</u>
2	--Transmit Data-----Receive Data--	2
3	--Receive Data-----Transmit Data-	3
4		
5		
6		
7	-----Ground-----	5
8		7
9		8

## Index

<b>3</b>		25-Pin Female .....	2
3BALL.....	11, 26	9-Pin Female .....	1
3BALL (Photograph).....	26	DIN-8.....	3
3Space Euler Angles .....	127	<b>CABLE DIAGRAMS</b> .....	1
<b>4</b>		Carrier Frequency .....	13
4" Transmitter.....	28	Cartesian coordinates .....	12, 73
<b>A</b>		centimeters .....	94
<u>Accuracy</u> .....	1	character width .....	17
ACCURACY .....	5	Command Error .....	115
ACCURACY AND RESOLUTION WHITE PAPER .....	1	Command Format Notation and Convention .....	43
ACTIVE STATION STATE.....	68	Command Format Notes .....	44
<b>Alignment</b> .....	122	Command/Output Listing.....	45
alignment command.....	46	<b>Compensation Data</b> .....	124
<b>Alignment Frame</b> .....	122	Complete FASTRAK System.....	1
ALIGNMENT REFERENCE FRAME.....	46	Completing the Found New Hardware Wizard ....	36
Angular Coverage.....	12	<b>COMPONENT DESCRIPTION</b> .....	15
ANGULAR OPERATIONAL ENVELOPE.....	83	concentric .....	11
ANGULAR RESOLUTION .....	4	Configuration Changes .....	30
APPENDIX A .....	1	CONFIGURATION CONTROL DATA .....	106
APPENDIX B.....	1	Configuration Identification .....	107
APPENDIX C.....	1	CONTINUOUS OUTPUT MODE.....	54
APPENDIX D.....	1	Cooling Fan.....	22
ASCII .....	12, 122	<b>CUSTOMER SERVICE</b> .....	120
ASCII FORMAT .....	75	<b>D</b>	
ATTITUDE FILTER PARAMETERS.....	98	Default Operation with Stylus or 3BALL.....	116
<b>Attitude Matrix</b> .....	122	defective parts .....	117
<b>Azimuth</b> .....	123	defects in material.....	117
azimuth mounting frame .....	85	DEFINE INCREMENT .....	66
<b>B</b>		DEFINE STYLUS BUTTON FUNCTION.....	58
baud rate.....	17	DEFINE TIP OFFSETS.....	71
<b>Baud Rate</b> .....	123	determine system configuration.....	87
BAUD rate.....	80	determine the firmware version number.....	87
<b>Benign Environment</b> .....	123	Device Driver Installation .....	36
binary .....	12	DIN .....	3
<b>BIT</b> .....	123	DIN-8.....	4
BIT (Built In Test).....	76	Direction cosines.....	12
BIT error.....	90	<b>Direction Cosines</b> .....	124
bits .....	80	DISABLE CONTINUOUS PRINTING.....	55
Black Box System.....	3	DISABLE FIXED METAL COMPENSATION.....	57
<b>Boresight</b> .....	123	distance unit.....	93
BORESIGHT.....	50	Driver Files Search Results .....	34
BORESIGHT REFERENCE ANGLES .....	51	<b>E</b>	
<b>bps</b> .....	123	EEPROM .....	105, 111, 124
BUILT-IN-TEST INFORMATION.....	90	EFFECTIVE LATENT PERIOD.....	2
<b>C</b>		electro-magnetic .....	11
Cable Diagram		<b>Elevation</b> .....	124
		elevation mounting frame.....	85
		ENABLE ASCII OUTPUT FORMAT.....	59
		ENABLE BINARY OUTPUT FORMAT .....	60
		ENABLE FIXED METAL COMPENSATION.....	56

English .....	12, 93
ENGLISH CONVERSION UNITS .....	93
<b>Enhanced Alignment Procedure</b> .....	47
envelope limits .....	95
Euler .....	12
Euler Angles .....	127
External Sync .....	39
External Sync I/O .....	15, 19
<b>External Sync Mode</b> .....	108

## F

F .....	98
FACTOR .....	98
factory defaults .....	105
<b>Factory Defaults</b> .....	124
FASTRAK Commands Index .....	10
FASTRAK Data Record .....	6
FASTRAK GUI icon .....	36
<b>FASTRAK HARDWARE</b> .....	1
FHIGH .....	98
FILTER RESPONSE (LAG) .....	3
FLOW .....	98
<b>Format</b> .....	124
Frequency Select Module .....	20
Frequency Select Modules (FSM) .....	13

## G

GLOSSARY .....	122
----------------	-----

## H

hardware handshaking .....	17
Hardware Handshaking .....	29
Hardware Install .....	35
hemisphere .....	62
<b>Hemisphere</b> .....	124
HEMISPHERE OF OPERATION .....	62
hemisphere tracking .....	62
<b>HEMISPHERE TRACKING</b> .....	63
Hemisphere Vector .....	64
HHS .....	80
<b>Host</b> .....	125

## I

I/O Cables .....	15
I/O Considerations .....	29
<b>I/O latency</b> .....	125
I/O Select Dip Switch Settings .....	5
I/O Select Switch .....	15, 17
IBM (PC) Compatible Computer .....	1, 2
IEEE FLOATING-POINT FORMAT .....	77
inches .....	93
increment .....	66
<b>Increment</b> .....	125
Increment Definition .....	67
infringement .....	119
Initial Power Up Procedure .....	30
Install Hardware Device Drivers .....	33

Installing USB Device Drivers .....	32
Interface RS-232 .....	13
Interface USB .....	13
Internal Sync .....	39
<b>Internal Sync Mode</b> .....	108

## L

<b>Lag</b> .....	125
Latency .....	12
LATENCY WHITE PAPER .....	1
Latest FASTRAK vs. Previous Versions .....	9
LIMITATION OF LIABILITY .....	117
LIMITED WARRANTY .....	117
<b>Line of Sight (LOS)</b> .....	125
Locate Driver Files .....	34
Long Ranger Transmitter .....	27
LOS (line-of-sight) .....	62
<b>LSB</b> .....	125
<b>LSD</b> .....	125

## M

Magnetic Linkage .....	2
metric .....	12, 94
METRIC CONVERSION UNITS .....	94
Mini Receiver .....	28
<b>Motion Box</b> .....	125
mounting frame .....	85
Mounting Transmitter and Receiver .....	3
<b>MSB</b> .....	125
Multiple Systems Synchronization .....	40

## N

New Hardware Wizard .....	32
non-continuous output mode .....	82
<b>NULL MODEM</b> .....	5

## O

Operating Environment .....	14
Operating Temperature .....	14
<b>Optional Items</b> .....	1
Optional RS-422 I/O .....	21
orientation angles .....	73
<b>Orientation Angles</b> .....	125
ORIENTATIONAL STATIC ACCURACY .....	6
Output .....	12
Output Considerations .....	41
OUTPUT DATA LIST .....	72
<b>Output List</b> .....	127

## P

<b>P &amp; O</b> .....	127
parity .....	17, 80
Parity select .....	18
PATENT INFRINGEMENT .....	119
PCB .....	20
Physical Characteristics .....	14
<b>Pitch</b> .....	127

Position and Orientation Measurement.....	2
Position Coverage.....	12
POSITION FILTER PARAMETERS.....	102
POSITION OPERATIONAL ENVELOPE.....	95
POSITIONAL STATIC ACCURACY.....	5
Power Cable Insertion .....	4
Power Connector.....	3
Power Indicator .....	17
Power Input.....	15
Power Input Receptacle .....	22
Power Requirements .....	14
power up.....	18
Powering Up FASTRAK.....	30
Procedure for Synchronizing Multiple Systems ..	41
PROM .....	71

## Q

<b>Quaternion</b> .....	127
quaternions .....	12

## R

receiver .....	11
<b>Receiver</b> .....	127
Receiver Connection .....	2
Receiver Input(s).....	15
Receiver Ports (4).....	17
Receiver(s) .....	24
REINITIALIZE SYSTEM .....	112
RESET ALIGNMENT REFERENCE FRAME.....	49
RESET SYSTEM TO DEFAULTS.....	105
Resolution.....	12, 1
RESOLUTION.....	4
RESUME DATA TRANSMISSION .....	114
<b>Roll</b> .....	127
roll mounting frame .....	85
rotation .....	85
RS-232.....	13, 29
RS-232 Cable Connection .....	5
RS-232 Cable Diagram	
IBM (PC) Compatible Computer.....	1, 2
SGI 02, Onyx 2, or Octane .....	1
SGI Indigo2, Indigo, Onyx, Iris .....	3
SGI VTX, Onyx, Personal Iris .....	4
RS-232 communication.....	31
RS-232 I/O.....	20
RS-232 Interface .....	13
RS-232 mode .....	31
RS-422 Cable Connections .....	30
RS-422 port.....	13

## S

SAVE OPERATIONAL CONFIGURATION .....	111
<b>Sensor</b> .....	128
<b>Separation distance</b> .....	40
SET OUTPUT PORT .....	80
SET SYNCHRONIZATION MODE.....	108
SEU (Front View).....	15

SEU (Rear View).....	16
SGI 02, Onyx 2, or Octane.....	1
SGI Indigo2, Indigo, Onyx, Iris .....	3
SGI VTX, Onyx, Personal Iris .....	4
Short Ranger Transmitter.....	28
SIGNAL-TO-NOISE (S/N) RATIO .....	4
SINGLE DATA RECORD OUTPUT .....	82
SPECIFICATION.....	12
<b>Standard Alignment Procedure</b> .....	47
<b>Standard Items</b> .....	1
STANDARD/OPTIONAL ITEMS.....	1
Static Accuracy .....	12
station .....	68
<b>Station</b> .....	128
stylus.....	11
Stylus .....	25, 128
Stylus (Dimensions).....	25
Stylus (Photograph).....	25
stylus tip .....	71
<b>Sync</b> .....	128
Sync In .....	19
SYNC IN/SYNC OUT.....	40
Sync Out .....	19
Synchronization.....	39, 108
Synchronizing multiple systems .....	41
SYNC-TO-OUTPUT LATENT PERIOD.....	1
System Alignment.....	45
System Block Diagram.....	2
System Commands.....	43
SYSTEM CONFIGURATION STATUS.....	89
System Data Record, 16-Bit Binary Format .....	78
<b>System ID Data</b> .....	128
SYSTEM OPERATION.....	29
system re-initialization .....	18
SYSTEM STATUS RECORD.....	87

## T

THEORY OF OPERATION .....	1
<b>tip</b> .....	71
<b>tip offsets</b> .....	71
<b>Tracker Alignment</b> .....	128
<b>Tracker Calibration</b> .....	128
<b>Tracker Latency</b> .....	128
<b>Tracker Response</b> .....	128
Translational Resolution.....	5
TRANSLATIONAL RESOLUTION.....	4
transmitter.....	11
Transmitter .....	22, 129
Transmitter Connection.....	2
Transmitter Input.....	15
TRANSMITTER MOUNTING FRAME.....	85
Transmitter Port .....	17
TROUBLE SHOOTING.....	120
TTL compatible.....	19

## U

UNBORESIGHT .....	53
-------------------	----

<b>Units</b> .....	129
Update Rate .....	13, 129
USB .....	13
USB communication -- establishing .....	32
USB communication with FASTRAK established .....	37
USB communications with FASTRAK established .....	38
USB I/O.....	21
USB Interface.....	13
USB mode.....	31
USB operation .....	31
<b>Useful Range</b> .....	129
<b>User Defaults</b> .....	129
User's application software .....	36
Using the USB Interface .....	31
<b>V</b>	
verify communication .....	87
Video Sync .....	39
Video Sync Detector.....	26
Video Sync Detector (Photograph).....	27
Video Sync Input .....	15, 21
<b>Video Sync Mode</b> .....	108
<b>W</b>	
Welcome to the Found New Hardware Wizard ...	32
Windows 2000 .....	32
Windows XP.....	32
workmanship.....	117
<b>X</b>	
<b>XYZ or X, Y, Z</b> .....	129
<b>XYZAER</b> .....	129
<b>Y</b>	
<b>Yaw</b> .....	129
<b>Z</b>	
zero orientation.....	50