AHRS500CA-[ ] User's Manual

AHRS500CA-210
AHRS500CA-212
AHRS500CA-214
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About this Manual

The following annotations have been used to provide additional information.

◀ NOTE

Note provides additional information about the topic.

☑ EXAMPLE

Examples are given throughout the manual to help the reader understand the terminology.

☞ IMPORTANT

This symbol defines items that have significant meaning to the user

◉ WARNING

The user should pay particular attention to this symbol. It means there is a chance that physical harm could happen to either the person or the equipment.

The following paragraph heading formatting is used in this manual:

1 Heading 1

1.1 Heading 2

1.1.1 Heading 3

Normal

1   Introduction

1.1   The AHRS500CA-[ ] Motion and Attitude Sensing Units

This manual explains the use of the AHRS500CA-[ ] product, nine-axis measurement system designed to measure stabilized pitch, roll and yaw angles in a dynamic environment.

The AHRS500CA-[ ] is a nine-axis measurement system that combines linear accelerometers, rotational rate sensors, and magnetometers. The AHRS500CA-[ ] uses the 3-axis accelerometer and 3-axis rate sensor to make a complete measurement of the dynamics of your system. The addition of a 3-axis magnetometer also allows the AHRS500CA-[ ] to make a true measurement of magnetic heading.

The AHRS500CA-[ ] is the solid-state equivalent of a vertical gyro/artificial horizon display combined with a directional gyro.

The AHRS500CA-[ ] units are low power, fast turn on, reliable and accurate solutions for a wide variety of stabilization and measurement applications.

See Table 3 for the serial interface for each AHRS500CA-[] model. Data is streamed continuously.

Crossbow Technology AHRS500CA-[ ] units employ onboard digital processing to compensate for deterministic error sources within the unit and to compute attitude information. The AHRS500CA-[ ] units accomplish these tasks with an analog to digital converter and high performance Digital Signal Processors.

The AHRS500CA-[ ] uses angular rate sensors and linear acceleration sensors that are micro-machined devices. The three angular rate sensors consist of vibrating ceramic plates that utilize the Coriolis force to output angular rate independently of acceleration. The three MEMS accelerometers are surface micro-machined silicon devices that use differential capacitance to sense acceleration. Solid-state MEMS sensors make the AHRS500CA-[ ] both responsive and reliable. The magnetic sensors are state-of-the-art miniature fluxgate sensors. Fluxgate sensors make the AHRS500CA-[ ] sensitive and responsive, with better temperature performance than other technologies such as magneto-resistive sensors.

The AHRS500CA-[ ] product utilizes a sophisticated Kalman filter algorithm to allow the unit to track orientation accurately through dynamic maneuvers. The Kalman filter will automatically adjust for changing dynamic conditions without any external user input. No user intervention or configuration is required at power-up.

1.2   Package Contents

In addition to your AHRS500CA-[ ] sensor product you should have:

- **1 CD with GyroView Software, Rev 2.3 or later**

  GyroView will allow you to immediately view the outputs of the AHRS500CA-[ ] on a PC running Microsoft® Windows™. You can also download this software from Crossbow's web site at http://www.xbow.com.

- **1 Digital Signal Calibration/Maintenance Cable.**

  This links the AHRS500CA-[ ] directly to a serial port. Only the transmit, receive, power, and ground channels are used. The magnetometer calibration switch will be visible on the connector.

- **1 AHRS500CA-[ ] User's Manual**

  This contains the installation and calibration information for the AHRS500CA-[ ].

- **1 CD with AHRS500 Installation MagAlign Software** (part number 8160-0060-04)

  AHRS500 Installation MagAlign software will allow you to align the magnetometers on the AHRS500CA-[] on a PC running Microsoft® Windows™. You can also download this software from Crossbow's web site at http://www.xbow.com.

2   Quick Start

2.1   GyroView Software

Crossbow includes GyroView software to allow you to use the AHRS500CA-[ ] right out of the box and the evaluation is straightforward. Install the GyroView software, connect the AHRS500CA-[ ] to your serial port, apply power to your unit and start taking measurements.

2.1.1   GyroView Computer Requirements

The following are minimum capabilities that your computer should have to run GyroView successfully:

- CPU: Pentium-class
- RAM Memory: 32MB minimum, 64MB recommended
- Hard Drive Free Memory: 15MB
- Operating System: Windows 95, 98, NT4, 2000

2.1.2   Install GyroView

To install GyroView in your computer:

1. Insert the CD "Support Tools" in the CD-ROM drive.
2. Find the GyroView folder. Double click on the setup file.
3. Follow the setup wizard instructions. You will install GyroView and a LabVIEW Runtime Engine. You will need both these applications.

If you have any problems or questions, you may contact Crossbow directly.

2.2   Connections

The AHRS500CA-[ ] is shipped with a calibration/maintenance cable to connect the AHRS500CA-[ ] to a PC communications port.

1. Connect the 15-pin female end of the digital signal calibration/maintenance cable to the port on the AHRS500CA-[ ] .
2. Connect the 15-pin male end of the digital signal calibration/maintenance cable to the cable harness connector that supplies power to the DMU.
3. Connect the 9-pin end of the calibration/maintenance cable to the serial port of your computer.
4. Bolt the base of the unit to a grounded surface. A good ground is required for EMI and lightning over-voltage protection.

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☀ WARNING

Do not reverse the power leads! Applying the wrong power to the AHRS500CA-[ ] can damage the unit; although there is reverse power protection, Crossbow Technology is not responsible for resulting damage to the unit should the reverse voltage protection electronics fail.

2.3   Setup GyroView

With the AHRS500CA-[ ] connected to your PC serial port and powered, open the GyroView software.

1. GyroView should automatically detect the AHRS500CA-[ ] and display the serial number and firmware version if it is connected.

2. If GyroView does not connect, check that you have the correct COM port selected. You find this under the "DMU" menu.

3. Select the type of display you want under the menu item "Windows". Graph displays a real time graph of all the AHRS500CA-[ ] data; FFT displays a Fast-Fourier transform of the data; Navigation shows an artificial horizon display.

4. You can log data to a file by entering a data file name. You can select the rate at which data is saved to disk.

5. If the status indicator says, "Connected", you're ready to go. If the status indicator doesn't say connected, check the connections between the AHRS500CA-[ ] and the computer; check the power; check the serial COM port assignment on your computer.

2.4   Take Measurements

Once you have configured GyroView to work with your AHRS500CA-[ ], pick what kind of measurement you wish to see. "Graph" will show you the output you choose as a strip-chart type graph of value vs. time. "FFT" will show you a real-time Fast-Fourier transform of the output you choose. "Navigation" will show an artificial horizon and the stabilized pitch and roll output of the AHRS500CA-[ ] .

Let the AHRS500CA-[ ] warm up for 90 seconds when first turned on. This allows the Kalman filter to estimate the rate sensor biases. Now you're ready to use the AHRS500CA-[ ]!

3 AHRS500CA-[ ] Details

3.1 AHRS500CA-[ ] Coordinate System

The AHRS500CA-[ ] will have a label on one face illustrating the AHRS500CA-[ ] coordinate system. With the connector facing you, and the mounting plate down, the axes are defined as:

> **X-axis** – from face with connector through the AHRS500CA-[ ]
>
> **Y-axis** – along the face with connector from left to right
>
> **Z-axis** – along the face with the connector from top to bottom

This is the default configuration for the generic AHRS500CA-[ ] model. Other coordinate frame orientations are supported given the model type purchased, and these will be reflected in the label as well as through the model configuration number. The axes form an orthogonal right-handed coordinate system. An acceleration is positive when it is oriented towards the negative side of the coordinate axis. For example, with the AHRS500CA-[ ] sitting on a level table, it will measure zero g along the x- and y-axes and +1 g along the z-axis. Gravitational acceleration is directed downward, and thus will be defined as positive for the AHRS500CA-[ ] z- axis.

The angular rate sensors are aligned with these same axes. The rate sensors measure angular rotation rate around a given axis. The rate measurements are labeled by the appropriate axis. The direction of a positive rotation is defined by the right-hand rule. With the thumb of your right hand pointing along the axis in a positive direction, your fingers curl around in the positive rotation direction. For example, if the AHRS500CA-[ ] is sitting on a level surface and you rotate it clockwise on that surface, this will be a positive rotation around the z-axis. The x- and y-axis rate sensors would measure zero angular rates, and the z-axis sensor would measure a positive angular rate.

The magnetic sensors are aligned with the same axes definitions and sign as the linear accelerometers.

Pitch is defined positive for a positive rotation around the y-axis (pitch up). Roll is defined as positive for a positive rotation around the x-axis (roll right). Yaw is defined as positive for a positive rotation around the z-axis (turn right).

The angles are defined as standard Euler angles using a 3-2-1 system. To rotate from the body frame to an earth-level frame, roll first, then pitch, and then yaw.

3.2   Connections

The AHRS500CA-[ ] has a male DB-15 connector. The signals are as shown in Table 1.

15 Pin "D" Connector Male Pinout
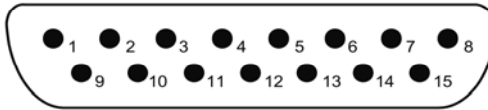
Table 1 Connector Pin Assignments

Pin	Signal	Electrical Specifications
1	RS-232 Transmit	+/- 4.5 VDC min wrt power ground.
2	RS-232 Receive	+/- 25 VDC max wrt power ground.
3	VDC Power Input	10-40 VDC normal, 9VDC emergency
4	Power Input Ground	
5	No connection	Do not connect
6	No connection	Do not connect
7	RS-422 Transmit + A	2.0 VDC differential output (min) into 100 ohms. Common mode output voltage, 3VDC max.
8	RS-422 Transmit – A	
9	Signal Ground	Capacitive coupling to internal system ground. Should be connected to user's system ground to reduce RS232 and RS422 signal noise.
10	Factory mode pin	Factory reserved; do not connect
11	Factory mode pin	Factory reserved; do not connect
12	Magnetometer calibration input (hard and soft iron cal)	Active: Short to power ground. Inactive: Open circuit. (Internally pulled to +3.3VDC through 10Kohm resistor)
13	Hardware BIT Status	Open collector, requires user pull-up resistor. Max pull-up voltage: +15VDC Max current sink: 10ma.
14	RS-422 Receive + A	Common mode input voltage range: 3VDC wrt power ground.
15	RS-422 Receive – A	
N/A	Case Ground	Electrically connected to I/O connector shell

3.2.1   I/O Cable

The user must provide a shielded cable with the shield connected to the I/O connector shell in order to provide the required EMI protection. The cable sent with the unit is intended to provide the user with the ability to perform a magnetometer calibration, and provide routine magnetometer calibration maintenance of the system, and will not provide adequate shielding.

3.2.2   Power Input and Power Input Ground

The AHRS500CA-[ ] power requirements are described in the table below. It is designed to operate with either a nominal 14VDC or 28VDC aircraft power system.

Table 2 Electrical Power Input Requirements

Item	Requirement	AHRS500CA-[ ] specification
1	Input Supply voltage	10-40 VDC
2	Input Supply Current	1 Amp (max)

3.2.3   Case Ground

The case is electrically connected to the I/O connector shell. The shell should be electrically connected to the user's cable shield. The case is isolated from the Power Input Ground, and should be bolted to a good conducting surface that is grounded.

3.2.4   Serial Data Interface

The unit has both an RS-232 and RS422 serial interface. During factory configuration, one port is configured as the user data port while the other is a factory diagnostic port to monitor BIT data. The unit can be configured to allow either port to be the user data port, defaulting the other for BIT diagnostics.
Data output is continuous at a fixed frequency dependant on the baud rate (see table 3 below).

Table 3 DB-9 COM Port Connections

Model Number	User Interface	BAUD Rate	Output Rate	Connector Facing
AHRS500CA-210	RS-232	38400	100	AFT
AHRS500CA-212	RS-232	9600	25	AFT
AHRS500CA-214	RS-232	9600	25	AFT
AHRS500CA-216	RS-422	38400	100	AFT
AHRS500CA-220	RS-232	38400	100	AFT
AHRS500CA-222	RS-232	9600	25	AFT
AHRS500CA-224	RS-232	9600	25	AFT
AHRS500CA-226	RS-422	38400	100	AFT

3.2.5   BIT Status Output Pin

The BIT status output pin will become active high if the system is experiencing a failure. The BIT is an open collector signal and requires a pull-up resistor for proper operation.

3.2.6   Magnetometer calibration Input Pin

The AHRS500CA-[ ] has an input pin to control the magnetometer hard-iron calibration function. When this pin is active (low) the unit will collect the data necessary for magnetometer calibration. When it becomes inactive, the calibration data shall be used to compute the hard and soft iron compensation values. During normal operation, no connection should be made to this pin; this pin shall be tied high internally with a pull-up resistor. This feature has been added as a means to perform a Hardiron/Softiron calibration without sending the calibration commands to the unit. Please see Appendix C, for a complete explanation of the Hardiron/Softiron calibration process, and how this pin can be used as a means of implementing the calibration.

3.2.7   No Connection

During normal operation of the AHRS500CA-[ ], no connection is made to the factory test pin. This pin has an internal pull-up mechanism and must have no connection for the AHRS500CA-[ ] to operate properly.

3.3   Measurements

The AHRS500CA-[ ] is designed to operate as a complete attitude and heading reference system. See the "Data Packet Format" section for the actual structure of the data packet.

3.3.1   Attitude and Heading

In angle mode, the AHRS500CA-[ ] acts as a complete attitude and heading reference system and outputs the stabilized pitch, roll, and yaw angles along with the angular rate, acceleration, and magnetic field information. The angular rate, acceleration, and magnetic field values are calculated as described in the sensor section.

The Kalman filter operates in angle mode to track the rate sensor bias and calculate the stabilized roll, pitch, and yaw angles.

The AHRS500CA-[ ] uses the angular rate sensors to integrate over your rotational motion and find the actual pitch, roll, and yaw angles. The AHRS500CA-[ ] uses the accelerometers to correct for rate sensor drift in the vertical angles (pitch and roll); the AHRS500CA-[ ] uses the magnetometers to correct for rate sensor drift in the yaw angle. This is the modern equivalent of an analog vertical gyro that used a plumb bob in a feedback loop to keep the gyro axis stabilized to vertical. The AHRS500CA-[ ] takes advantage of the rate gyros' sensitivity to quick motions to maintain an accurate orientation when accelerations would otherwise throw off the accelerometers measurement of the AHRS500CA-[ ] orientation relative to gravity; the AHRS500CA-[ ] then uses the accelerometers to provide long term stability to keep the rate gyro drift in check.

The AHRS500CA-[ ] uses a sophisticated Kalman filter algorithm to track the bias in the rate sensors. This allows the AHRS500CA-[ ] to use a very low effective weighting on the accelerometers when the AHRS500CA-[ ] is moved. This makes the AHRS500CA-[ ] very accurate in dynamic maneuvers.

The AHRS500CA-[ ] outputs the stabilized pitch, roll and yaw angles in the digital data packet in angle mode. To convert the digital data to angle, use the following relation:

$$\textbf{angle} = \textbf{data}*(\textbf{SCALE})/2^{15}$$

where **angle** is the actual angle in degrees (pitch, roll or yaw), **data** is the signed integer data output in the data packet, and **SCALE** is a constant. **SCALE** = 180° for roll, pitch and yaw.

3.3.2   Sensor Measurements

The analog accelerometer and gyro sensors are sampled, converted to digital data, temperature compensated, corrected for misalignment, and scaled to engineering units. The digital data represents the actual value of the quantities measured. A calibration table for each sensor is stored in the AHRS500CA-[ ] non-volatile memory. The data is sent as signed 16-bit 2's complement integers. To convert the acceleration data into G's, use the following conversion:

$$\textbf{accel} = \textbf{data}*(\textbf{10} * 1.5)/2^{15}$$

where **accel** is the actual measured acceleration in G's, **data** is the digital data sent by the AHRS500CA-[ ] , and **10** is the G Range for your AHRS500CA-[ ] . (The data is scaled so that $1\ G = 9.80\ m\ s^{-2}$.) This maximum G range is a default value.

To convert the angular rate data into degrees per second, use the following conversion:

$$\textbf{rate} = \textbf{data}*(\textbf{800}*1.5)/2^{15}$$

where **rate** is the actual measured angular rate in °/sec, **data** is the digital data sent by the AHRS500CA-[ ] , and **800** is the Angular rate Range of the AHRS500CA-[ ] . This maximum angular rate is a default value.

3.3.3   BIT Processing

The BIT message in each packet provides comprehensive information into system health. The following information is supplied in the BIT byte fields of the data packet. The table 4 contains the actual bit definition present in the two-byte output BIT field in the angle mode data packet (see section 3.5 below).

Table 4 BIT Message Definition

Bit	BIT Data	Description
0	Hard Failure	0: No hard failure
		1: An unrecoverable failure has been detected
1	Soft Failure	0: No soft failure
		1: A soft failure has been detected. If the soft failure lasts for more than 4500 data packets the Hard Failure bit is turned on and the Soft Failure bit is permanently on.
2	Reserved	
3	Power Failure	0: No power failure
		1: A power loss has been detected and the system is running on back-up power. Power loss will occur within 200 msec.
4	Comm Error	0: No serial port communication failure has been detected.
		1: A serial port communications failure has been detected such as overrun, parity.
5	Reboot Detect	0: No warm reboot of the processor has been detected.
		1: A warm processor reboot was detected possibly due to a watchdog timeout or low-power setting.
6	Calibration Failure	0: Calibration table in flash memory is correct.
		1: A bad calibration table in flash memory has been detected.
7*	External Aiding Comm Status	0: Receiving and processing valid external aiding data packets
		1: External aiding data not present or bad external aiding data
8	Coordinated Turn Detect	Unit is executing a coordinated turn
9	Reserved	
10	Algorithm Status	0: Full accuracy data
		1: Not ready, waiting for power-up, post gyro saturation, or initialization

11	Magnetometer Align Status	0: No magnetometer alignment being performed
		1: Magnetometer alignment in progress
12	Reserved	
13	Hardiron/Softiron Valid	0: Magnetometer hardiron/softiron alignment valid
		1: Magnetometer hardiron/softiron alignment invalid
14	Reserved	
15**	Remote Magnetometer Comm Status	0: Communication with Remote Magnetometer valid (processing data packets)
		1: Communication with Remote Magnetometer invalid (no data packets being processed)

*External aiding applies only to models -22x

**Remote magnetometer reserved for future implementation

3.4   Commands

The AHRS500CA-[ ] does not have a command structure. The default serial interface is provided in table 3 with serial port settings of 8 data bits, 1 start bit, 1 stop bit, no parity, and no flow control.

3.5   Data Packet Format

In general, the digital data representing each measurement is sent as a 16-bit number (two bytes). The data is sent MSB first then LSB.

Table 6 AHRS500CA-[ ] Series Data Packet Format

Byte	Data
0	Header (0xAA)
1	Header (0x55)
2	Roll Angle (MSB)
3	Roll Angle (LSB)
4	Pitch Angle (MSB)
5	Pitch Angle (LSB)
6	Heading Angle (MSB)
7	Heading Angle (LSB)
8	Roll Angular Rate (MSB)
9	Roll Angular Rate (LSB)
10	Pitch Angular Rate (MSB)
11	Pitch Angular Rate (LSB)
12	Yaw Angular Rate (MSB)
13	Yaw Angular Rate (LSB)
14	X-Axis Acceleration (MSB)
15	X-Axis Acceleration (LSB)
16	Y-Axis Acceleration (MSB)
17	Y-Axis Acceleration (LSB)
18	Z-Axis Acceleration (MSB)
19	Z-Axis Acceleration (LSB)
20	Model Number (MSB)
21	Model Number (LSB)
22	BIT (MSB)
23	BIT (LSB)
24	Checksum (MSB)
25	Checksum (LSB)

These numbers are sent as a 16-bit signed integer in 2's complement format. The data is sent as two bytes, MSB first then LSB.

Each data packet will begin with a two-byte header (hex AA 55) and end with a two-byte checksum. The checksum is calculated in the following manner:

1. Sum all packet contents *except* header and checksum.
2. Divide the sum by hex FFFF.
3. The remainder should equal the checksum.

The packet also contains the model type configuration number, and the BIT word output. Please refer to section 3.3.3 for details about the BIT word processing.

3.6   Timing

The AHRS500CA-[] data output rate is set based on the model configuration chosen. See table 3 for currently supported output rates. Depending on the configuration chosen, the system output sample rate can be set to a different constant value.

In some applications, using the AHRS500CA-[]'s digital output requires a precise understanding of the internal timing of the device. The processor internal to the AHRS500CA-[] runs in a loop - collecting data from the sensors, processing the data, and then collecting more data. The data is reported to the user through a parallel process.

The unit goes through three processes in one data cycle. First, the sensors are sampled. Second, the unit processes the data for output. After processing the data, the AHRS500CA-[] will make another measurement while presenting the current measurement for output. Third, the unit actually transfers the data out over the RS-232 port.

3.7   Magnetic Heading

Magnetic north is the direction toward the magnetic north pole; true north is the direction towards the true North Pole.

The AHRS500CA-[ ] yaw angle output is referenced to magnetic north. The direction of true north will vary from magnetic north depending on your position on the earth. The difference between true and magnetic north is called declination or magnetic variance. You will need to know your declination to translate the AHRS500CA-[ ] magnetic heading into a heading referenced to true north.

3.8   External Velocity Input (For models -22x only)

An external velocity input is provided to improve performance on high performance aircraft capable of sustained acceleration and deceleration. For this reason the AHRS500CA-22X models are designed to have a communications interface designed to listen for external Velocity Sensor

information. The interface is required to interpret when proper velocity information is available on the input port (RS232 UART), parse the velocity information, and make the airspeed calculations available for use in the attitude algorithm. In the event that the Airdata sensor is not present, or the Airdata sensor system fails after correct operation, the algorithm shall revert back to the standard algorithm defined above. The input velocity packet format to be provided over RS232 port is provided in Appendix C.

4   AHRS500CA-[ ] Installation Tips

This section describes the procedures to be used before final installation of the AHRS500CA-[]. These procedures describe the installation location selection for the AHRS500CA-[].

4.1   Pre-Mod Avionics Test

Perform a pre-modification avionics systems test to verify that the systems that will be connected to the AHRS500CA-[] are working properly in accordance with their appropriate maintenance manuals.

4.2   Mating Connector Crimp Tools

A crimp tool recommended by the mating tool manufacturer should be used to ensure consistent and reliable crimp contact connections for the mating connector.

4.3   Pre-Mod Load Review

Complete an electrical load analysis on the aircraft prior to installing the AHRS500CA-[] to ensure the aircraft has the electrical load capacity to carry the new load.

4.4   Installation Location Selection

4.4.1   Introduction

Selecting the location for the AHRS500CA-[] is a two-step process.

- The first step is to find a "proposed" location based on the criteria in this section.
- The second step is using the AHRS500CA-[] and the MagAlign software to survey the proposed location for magnetic interference from other aircraft systems.

4.4.2   Location and proximity to IDU (Integrated Display Unit)

The AHRS500CA-[] can be mounted inside or outside of the pressure vessel. Most aircraft can accommodate the AHRS500CA-[] behind the aft cabin bulkhead. Whether you want to place the AHRS500CA-[] there, or elsewhere, the location for the AHRS500CA-[] must comply with the environmental specifications called out in section 3. Dual installations may be mounted in the same area.

4.4.3   Mounting Structure

The AHRS500CA-[] must be installed in a location that is rigid to alleviate potential vibration errors induced from normal airframe vibration sources.

The mounting plate must be stiff enough to rigidly follow the aircraft motions without inducing low frequency motions relative to the aircraft. If you have any doubt concerning the AHRS500CA-[] location suitability, please contact your Crossbow technical representative by phone at (408) 965-3300, or visit our website at http://www.xbow.com

4.4.4   Magnetic Environment Considerations

4.4.4.1   Materials

The AHRS500CA-[] uses a set of sensitive magnetometers inside its housing to measure Earth's weak magnetic field to determine heading. The AHRS500CA-[] should be isolated from magnetic material as much as possible. Magnetic material will distort the magnetic field near the AHRS500CA-[], which can affect its accuracy as a heading sensor. As a result, small amounts of moving magnetic material near the AHRS500CA-[] can have large effects on the heading measurement.

Stationary ferrous objects will be compensated for by the alignment procedure. Moving ferrous objects within 24 inches cannot be fully compensated by the alignment. The AHRS500CA-[] must not be located within 24 inches of any large moving ferrous metal objects such as landing gear components, electric motors, control linkages, etc. Ferrous metal objects that may change position during flight operations, such as landing gear, flap actuators, and control linkages must not be within 24 inches of the AHRS500CA-[].

Materials to avoid include anything that will stick to a magnet: iron, carbon steel, some stainless steels, nickel and cobalt. Materials that will not affect the magnetic heading performance include aluminum, brass, plastic, titanium, wood, and some stainless steels. Use a magnet to test materials that will be near the AHRS500CA-[]. If the magnet doesn't stick, you are working with a material that will not affect the heading.

DO NOT stick a magnet to the AHRS500CA-[].

4.4.4.2   Distance from moving ferrous (iron and steel) metallic objects

The AHRS500CA-[] must not be located within 24 inches of any large, moving, ferrous metal objects such as landing gear components, motors, steel control cables or linkage. Avoid any metallic objects that may change

position between ground operations and flight operations, such as landing gear, flap actuators, and control linkages.

4.4.4.3 Distance from electrical wires

The AHRS500CA-[] should not be located close to high current DC power cables or 400 cycle AC power cables and their associated magnetic fields. Wires carrying high currents, alternate currents, or intermittent currents can cause magnetic variations that will affect the AHRS. Keep wires with these characteristics at least 24 inches away from the AHRS500CA-[]. These wires can include:

> Battery wires
>
> Strobe wires
>
> Autopilot control wires
>
> Position light wires
>
> De-ice boot wires
>
> Air conditioning power wires
>
> HF control wires

4.4.5 AHRS500CA-[] Alignment with the aircraft

The AHRS500CA-[] will measure rotations around the axes of its sensors. The AHRS500CA-[] sensors are aligned with the baseplate. The baseplate references are noted in the installation drawing and are used as reference surfaces for aligning the AHRS500CA-[] sensor axes with the aircraft. The AHRS500CA-[] should be aligned as closely as possible with the axes you define in your system. Errors in alignment will contribute directly to errors in measured acceleration and rotation relative to your system axes. The ideal location of the AHRS500CA-[] is as close to the pitch and roll axes as possible. When faced with a decision between the two, it is better for the AHRS500CA-[] to be near or on the roll axis.

4.4.5.1 CG Alignment

The AHRS500CA-[] should be mounted as close to the center of gravity (CG) of your system as possible. This will minimize any "lever effect." If it is not mounted at the center of gravity, then rotations about the center of gravity will cause the AHRS500CA-[] accelerometers to measure acceleration proportional to the product of the angular rate squared and the distance between the AHRS500CA-[] and the aircraft CG.

4.4.5.2   Attitude Leveling

The AHRS500CA-[] must be level on the yaw and roll planes of rotation when the aircraft is in straight and level flight. The pitch axis must be level to the aircraft when aircraft is leveled for weight and balance measurements.

4.4.5.3   Longitudinal Alignment

The AHRS500CA-202 connector must face aft of the aircraft. For other AHRS500CA models, refer to Table 1.

It is important that the AHRS500CA-[] is properly aligned with the longitudinal axis of the aircraft and NOT with the fuselage skin. The alignment of the AHRS500CA-[] baseplate and the longitudinal axis must be within 0.5 degree for proper operation.

5   Limitations

5.1   Installation

The AHRS500CA-[] must be mounted in accordance with the procedures outlined in the AHRS500CA-[] Installation Manual. The AHRS500CA-[] must be mounted in a location with limited magnetic material near the unit. Refer to the installation manual for detailed instructions.

5.2   Alignment

The AHRS500CA-[] must successfully complete a hard iron alignment to reach full accuracy. Refer to the AHRS500cA-[] installation manual for detailed instructions.

5.3   Operation in Magnetic Environment

Introduction of large ferrous or magnetic material objects close to the AHRS500CA-[], after alignment, will affect the heading performance. Maintain at least 24 inches of distance between moving ferrous metal or magnetic material and the AHRS500CA-[].

5.4   Range Limitations

The internal sensors in the AHRS500CA-[] are limited to maneuvers of less than 200 deg/sec and less than 10 Gs acceleration in bank, pitch, and heading. Over range of a sensor is indicated in the data packet message to the display system. Over range will start a new initialization cycle of the AHRS500CA-[] and will require 90 seconds of straight and level flight to reinitialize the AHRS500CA-[].

The AHRS500CA-[], like all magnetometer and magnetic compass-based systems, will not perform properly at the magnetic North and South Poles.

The AHR500CA-[] will not operate properly in low gravitational fields and magnetic fields encountered during space flight.

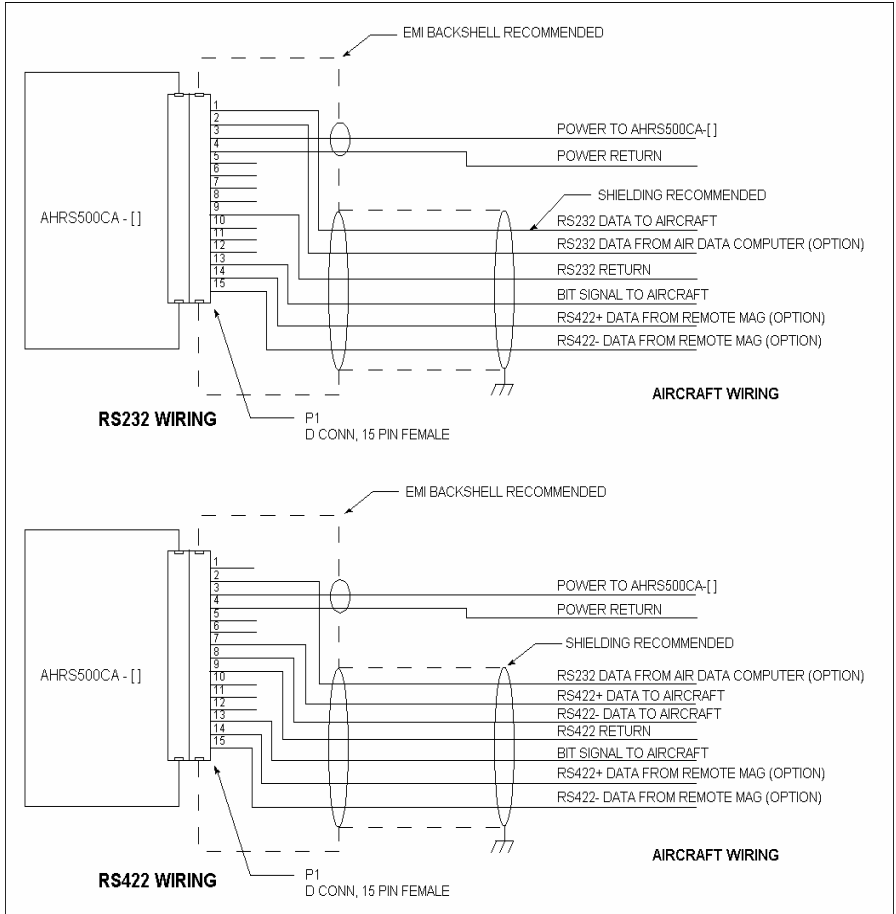# 6 Appendix A. Mechanical Specifications

6.1 AHRS500CA-[ ] Outline Drawing
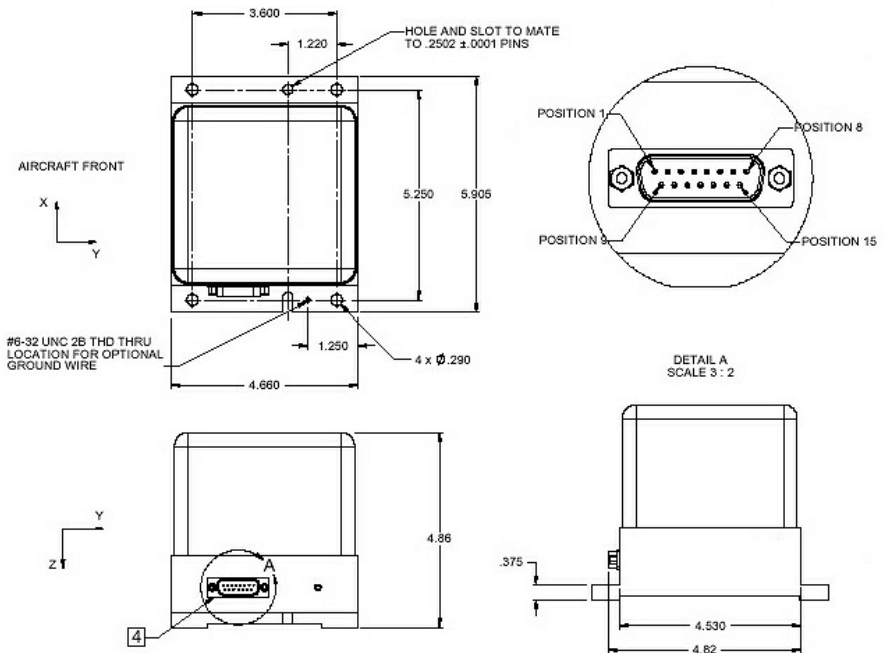
6.2   Installation Wiring Diagram

Model : AHRS500CA	Interface
-210	RS-232
-212	RS-232
-214	RS-232
-216	RS-422
-220*	RS-232

-222[*]	RS-232
-224[*]	RS-232
-226[*]	RS-422

[*]Velocity input interface is always in RS-232 format. Refer to Appendix C for details.

7   Appendix B. AHRS500CA-[ ] Output Quick Reference

10 is the G-range of the accelerometers. This is the default maximum range of the accelerometers.

800 is the rate range of the rate sensors. This is the default maximum range of the gyros.

Digital Output Conversion

Data is sent as 16-bit signed integer.

Acceleration

Accel (G) = **data * 10 * 1.5/2^{15}**

Conversion

Angle (°) = **data * 180/2^{15}**

Rate

Rate (°/s) = **data * 800 * 1.5/2^{15}**

Magnetic Field

Mag (Gauss) = **data * 1.25 * 1.5/2^{15}**

8 Appendix C. Velocity Input Packet Format

(For Models -22x only)

The following table describes the external aiding data packet format that will be supported by the AHRS500CA-22x via serial communication over the RS-232 port. This is sent over RS-232 port at 9600 baud, 8 data bits, no parity and 1 stop bit at the rate of 1 Hz.

Each data packet will begin with a two-byte header (hex AA 55) and end with a two-byte checksum. The checksum is calculated in the following manner:

1. Sum all packet contents *except* header and checksum.
2. Divide the sum by hex FFFF.
3. The remainder should equal the checksum.

Table 6 AHRS Input Velocity Data Packet Format

Bytes	Parameter	Description
0-1	Header	Packet Header (byte 0 = 0xAA, byte 1 = 0x55)
2-5	GNSS Latitude	GNSS Latitude in the range of ±180°. Negative values represent South. Resolution is 31 bits. Invalid indicated by a value of 0xFFFFFFFF. Multiply this integer by $(180 / 2^{31})$ to get degrees of GNSS latitude.
6-9	GNSS Longitude	GNSS Longitude in the range of ±180°. Negative values represent West. Resolution is 31 bits. Invalid indicated by a value of 0xFFFFFFFF (note that a longitude value of W180° is encoded as +180). Multiply this integer by $(180/2^{31})$ to get degrees of GNSS longitude.
10-13	GNSS Altitude	GNSS Altitude in the range of ±131072ft. Resolution is 20 bits. Invalid indicated by a value of 0xFFFFFFFF. Multiply this integer by $(131072/2^{20})$ to get feet of GNSS altitude.
14-15	GNSS Ground Speed	GNSS Ground Speed in the range of 0 - 4096 knots. Resolution is 15 bits. Invalid indicated by a value of 0xFFFF.

		Multiply this integer by (4096/ 2^{15}) to get knots GNSS ground speed.
16-17	GNSS Track	GNSS Track in the range of ±180°. Resolution is 15 bits. Invalid indicated by a value of 0xFFFF (note that a track of 180° is encoded as +180). Multiply this integer by (180/ 2^{15}) to get GNSS track in ° True.
18-19	GNSS Vertical Velocity	GNSS Vertical Velocity in the range of ±32768 feet / min. Resolution is 15 bits. Invalid indicated by a value of 0xFFFF. Multiply this integer by (32768/ 2^{15}) to get GNSS vertical velocity in feet / min.
20-21	True Airspeed	True Airspeed in the range of 0 - 2048 knots. Resolution is 15 bits. Invalid indicated by a value of 0xFFFF. Multiply this integer by (2048/ 2^{15}) to get knots true airspeed.
22-25	Pressure Altitude	Pressure Altitude in the range of ±131072ft. Resolution is 17 bits. Invalid indicated by a value of 0xFFFFFFFF. Multiply this integer by (131072/ 2^{17}) to get feet of pressure altitude.
26-27	Barometric Vertical Velocity	Instantaneous (G-Force quickened) Barometric Vertical Velocity in the range of ±32768 feet / min. Resolution is 11 bits. Invalid indicated by a value of 0xFFFF. Multiply this integer by (32768/ 2^{11}) to get instantaneous barometric vertical velocity in feet / min.
28-29	Magnetic Variation	Magnetic Variation in the range of ±180°. Negative values represent Westerly variation. Resolution is 12 bits. Invalid indicated by a value of 0xFFFF. Multiply this integer by (180/ 2^{12}) to get degrees of magnetic variation.
30-31	Checksum	Two-byte sum of characters 2 through 29

9   Appendix D. Hard and Soft Iron Calibration

9.1   Hard/Soft Iron Alignment Introduction

The AHRS500CA-[] will need to be aligned for hard and soft iron compensation before use with the aircraft. The AHRS500CA-[] series use magnetic sensors to compute heading. Ideally, the magnetic sensors would be measuring only earth's magnetic field to compute the heading angle. In the real world, however, residual magnetism in the AHRS500CA-[] itself and in your system will add to the magnetic field measured by the AHRS500CA-[].

The extra magnetic field can create errors in the heading measurement if they are not compensated. These extra magnetic fields are called hard iron magnetic fields. In addition, magnetic material can change the direction of the magnetic field as a function of the input magnetic field. This dependence of the local magnetic field on input direction is called the soft iron effect. The AHRS500CA-[] measures any extra constant magnetic field that is associated with the AHRS500CA-[] or your aircraft and corrects for it during the alignment procedure. The AHRS500CA-[] can also make a correction for some soft iron effects. The process of measuring these non-ideal effects and correcting for them is called hard iron and soft iron alignment. Alignment will help correct for magnetic fields that are fixed with respect to the AHRS500CA-[]. It cannot compensate for time varying fields, or fields created by parts that move with respect to the AHRS500CA-[].

The AHRS500CA-[] accounts for the extra magnetic field by making a series of measurements. The AHRS500CA-[] uses these measurements to model the hard iron and soft iron environment in your aircraft.

9.2   AHRS500CA-[] Hard and Soft Iron Alignment Procedure

The hard and soft iron alignment procedure is performed in place on the aircraft using the alignment/maintenance cable, a portable PC running Windows, and AHRS500 Installation MagAlign software provided by Crossbow Technology, Inc. A switch on the cable provides a signal input to the AHRS500CA-[] commanding it to enter the hard iron alignment process. The aircraft will then need to be rotated through a complete circle(s) while using the AHRS500 Installation MagAlign software. The alignment software will determine when an adequate set of alignment data has been acquired and notify the user through the Message Box. The entire procedure may take several rotations of the aircraft to collect sufficient data.

It is required that you do the alignment process with the AHRS500CA-[] installed in your system. If you do the alignment process with the

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AHRS500CA-[] by itself, you will only correct for the magnetism internal to the AHRS500CA-[]. If you then install the AHRS500CA-[] in an aircraft and the magnetic environment is different, you will still see errors arising from the magnetism of the aircraft environment.

9.2.1 Equipment Needed

The following equipment and software is needed to perform the hard and soft iron alignment:

- **1 CD with AHRS500 Installation MagAlign Software** (part number 8160-0060-04)

  AHRS500 Installation MagAlign graphically displays the AHRS500CA-[] output and provides step-by-step alignment instructions on a PC running Microsoft® Windows™. You can also download this software from Crossbow's web site at http://www.xbow.com.

- **1 Digital Signal Alignment/Maintenance Cable.**

  This links the AHRS500CA-[] directly to a serial port on a PC running Microsoft Windows for installation and maintenance functions. The cable provides aircraft power to the AHRS500CA-[] and redirects the serial data to the maintenance PC.

- **1 Portable computer**

  The computer should be a portable "laptop" style if possible with a serial port and Windows 95/98/NT4/2000/XP type operating system. The following are minimum capabilities that your computer should have to run AHRS500 Installation MagAlign successfully:

    CPU: Pentium-class

    RAM Memory: 32MB minimum, 64MB recommended

    Hard Drive Free Memory: 15MB

    Operating System: Windows 95, 98, NT4, 2000, XP

    Freely available RS-232 compatible Serial Port

    National Instruments Driver: LabVIEW RunTime Engine 6.1, which comes with AHRS500 Installation MagAlign software.

After finishing the steps aforementioned in Section 4.4.6, the program is ready to perform the alignment.

9.2.2 Alignment Process Overview

There are several steps to the alignment process that are repeated until the AHRS500CA-[] has collected enough data to compute a hard and soft iron

compensation that meets the performance requirements. The alignment steps are:

1. Apply power to the AHRS500CA
2. Wait 90 seconds for initialization to complete
3. Turn the MagAlign switch on
4. Slowly rotate the aircraft through a full 360 degree turn until the software requests to stop the turn
5. Stop the turn
6. Wait 60 seconds for the AHRS500CA-[] to re-initialize
7. Repeat steps 4, 5 and 6 turning the aircraft through 360 degree circles with a wait between each turn, until the MagAlign Message Box indicates the alignment meets the performance requirements
8. Turn off the MagAlign switch to load the mag alignment data in the AHRS500CA-[].

9.2.3 Detailed Alignment Procedure

9.2.3.1   Step 1: Mount the AHRS500CA-[] in the proposed location.

9.2.3.2   Step 2: Install the AHRS500 MagAlign Software on a portable computer

The computer should be a portable "laptop" style if possible with a serial port and Windows 95/98/NT4/2000/XP type operating system. The following are minimum capabilities that your computer should have to run the AHRS500 Installation MagAlign successfully:

> CPU: Pentium-class
>
> RAM Memory: 32MB minimum, 64MB recommended
>
> Hard Drive Free Memory: 15MB
>
> Operating System: Windows 95, 98, NT4, 2000, XP
>
> Freely available RS-232 compatible Serial Port
>
> National Instruments Driver: LabVIEW RunTime Engine 6.1, which comes with AHRS500 Installation MagAlign software.

To install AHRS500 Installation MagAlign Software in your computer:

1. Insert the CD "AHRS500 Installation MagAlign (part number 8160-0060-04)" in the CD-ROM drive.
2. Find the Installer folder. Double click on the setup.exe file.

3. Follow the setup wizard instructions. You will install AHRS500 Installation MagAlign and a LabVIEW Runtime Engine. You will need both these applications.

9.2.3.3   Step 3: Alignment Cable Connections

The AHRS500CA is shipped with an installation and alignment cable to connect the unit to a PC communications port.

1. Connect the 15-pin female end of the alignment cable to the port on the AHRS500CA-[].

2. Connect the 15-pin male end of the alignment cable to the aircraft cable connector which supplies power.

3. Start the computer before connecting the 9-pin end of the cable to the serial port of the computer. Later versions of Windows, especially Windows 2000 and Windows XP, interpret a connection to the serial port at boot time as a serial mouse. The operating system will load the mouse driver and interpret the data from the AHRS500CA-[] as mouse commands if the AHRS500CA-[] is connected before the computer is started and booted.

4. Connect the 9-pin end of the cable to the serial port of your computer.

5. The alignment switch on the cable should be set to OFF. Powering up the unit with the switch in the ON position will erase the magnetometer alignment.

6. Apply power and let the AHRS500CA-[] align for 90 seconds.

7. With the AHRS500CA-[] connected to your PC serial port and powered, open the AHRS500 Installation MagAlign software.

9.2.3.4   Step 4: MagAlign Initialization

Upon starting the AHRS500 MagAlign software, the following disclaimer screen appears. Please read the disclaimer, and click on "I acknowledge" to Continue further.

Once you acknowledge the disclaimer and click on "CONTINUE", the "Connection Instructions" dialog window pops up, reminding users of basic steps before using the software. The screen is shown as follows:
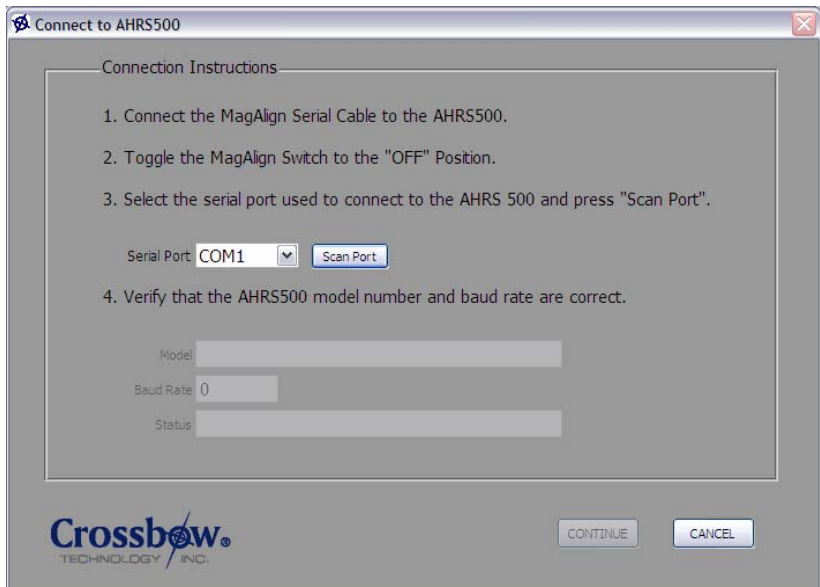

The dialogue leads the user to an important step of connecting AHRS500CA-[] to the computer's serial port. Double-check the serial port

so that it matches with what you select on the screen. Incorrect serial port setting will result in non-response from the program. With proper COM port selected, click on "SCAN PORT".

This should automatically detect the model number of the AHRS500CA-[] connected, display Baud Rate and the status of Remote Magnetometer Connection. If no Remote Magnetometer is connected, you should see "Remote Mag Not Connected" as shown below.

☞ IMPORTANT

If the Status reads "Remote Mag Connected", please refer to the CRM500GA-[] Installation Manual before proceeding further.
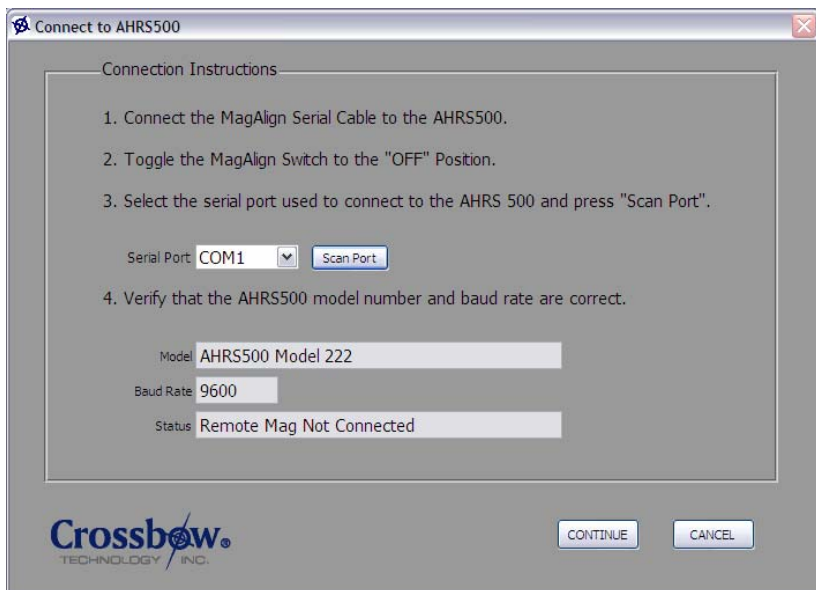
After hitting the "CONTINUE" button, the MagAlign brings up the Window showing Alignment Status, DMU Status, Instructions and Navigation Display Box as shown below. If the MagAlign software was started right after powering up the AHRS500CA-[], the Instructions will read "The AHRS500 is initializing. Wait for further instructions".
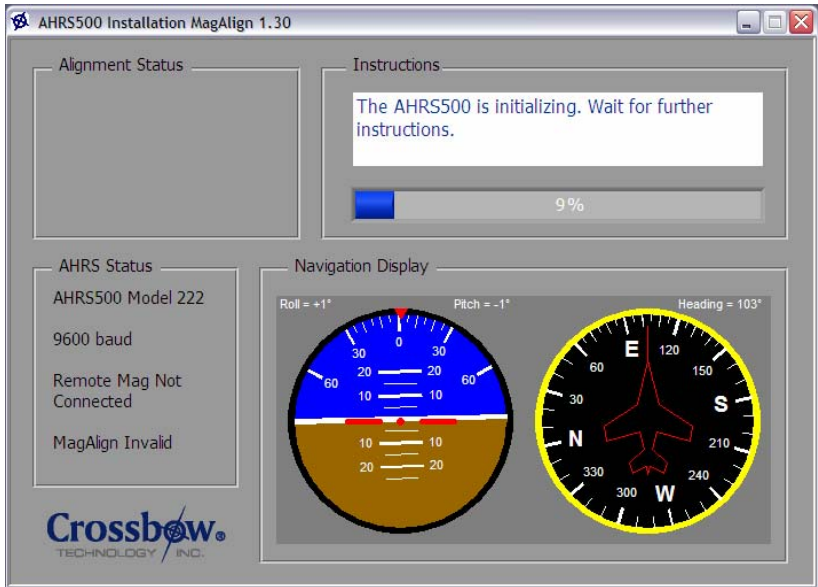
☞ **IMPORTANT**

Please carefully read and follow the instructions in the MagAlign window. Failure to do so may result in unsuccessful alignment.

### 9.2.3.5   Step 5: Turn the MagAlign Switch 'ON'

After finishing the steps aforementioned in Section 4.4.6, the instructions will read "Alignment is required. Flip the toggle switch to the ON position to begin".

The first step is to change the position of the MagAlign switch on the MagAlign cable from "OFF" to "ON." The AHRS500CA-[] may take several seconds to recognize the change in the switch status.

#### 9.2.3.6   Step 6: Rotate the Aircraft

To begin the alignment routine, the program will display instructions "MagAlign needs refinement. Turn slowly in a circle until instructed to stop." You would also see the "Hard/Soft Alignment" highlighted in the Alignment Status box as shown below.
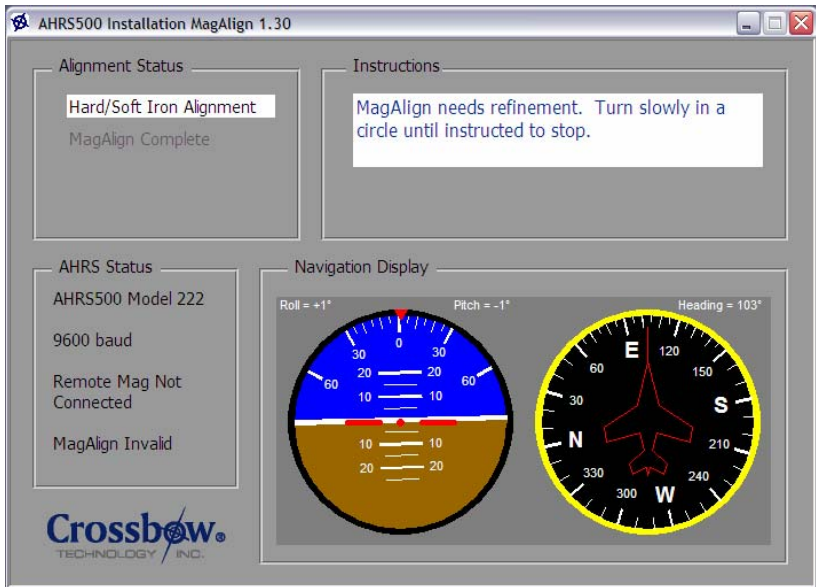
Upon seeing this message, the person performing the magnetometer alignment should turn the aircraft slowly in a circle. Although it does not matter if the aircraft turns in a clockwise or counter-clockwise direction in any of the turns, it is preferable to turn in only one direction. The turn will continue through 360 degrees. At the end of the turn, the display will request the operator to stop.

It is important that the aircraft turns slowly and that the internal calculations done inside the AHRS500CA-[] do not get saturated by a high rate of turning. When saturation occurs, the user will be informed to make subsequent turns until AHRS500CA-[] is satisfied with all the data collected.

Once the aircraft begins to turn, another message appears to inform the user "Performing hard/soft iron alignment. Continue turning in a circle until instructed to stop." The AHRS500CA-[] will monitor the turn and indicate when the turn should stop.
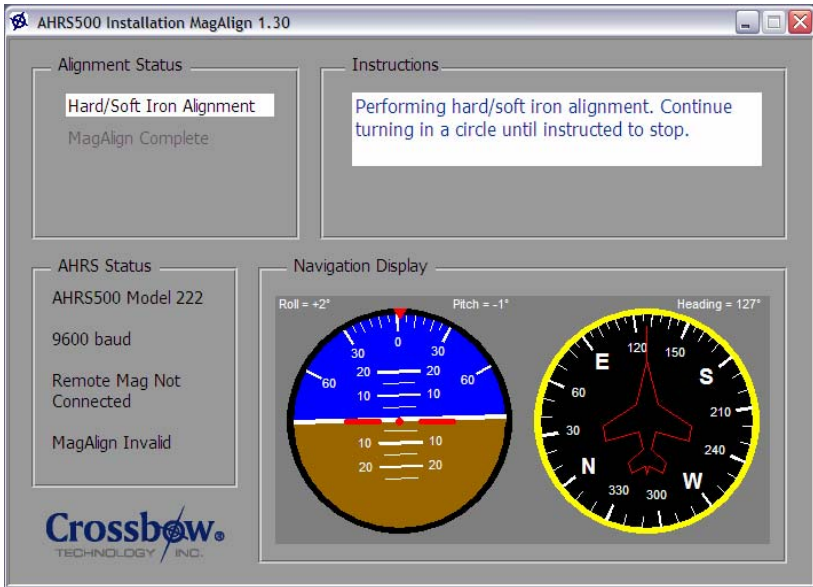
The MagAlign Software Display includes roll and pitch as well as heading of the aircraft. As the aircraft rotates and moves, the display changes to reflect the changes.

9.2.3.7   Turn 360 Degree Complete and Wait for Re-Initialization

When the aircraft completes a full 360 degree circle, the instructions will indicate "Stop Turning. The AHRS500 is now re-initializing. Wait for further instructions." The Progress bar will indicate the percentage of initialization that has been completed.
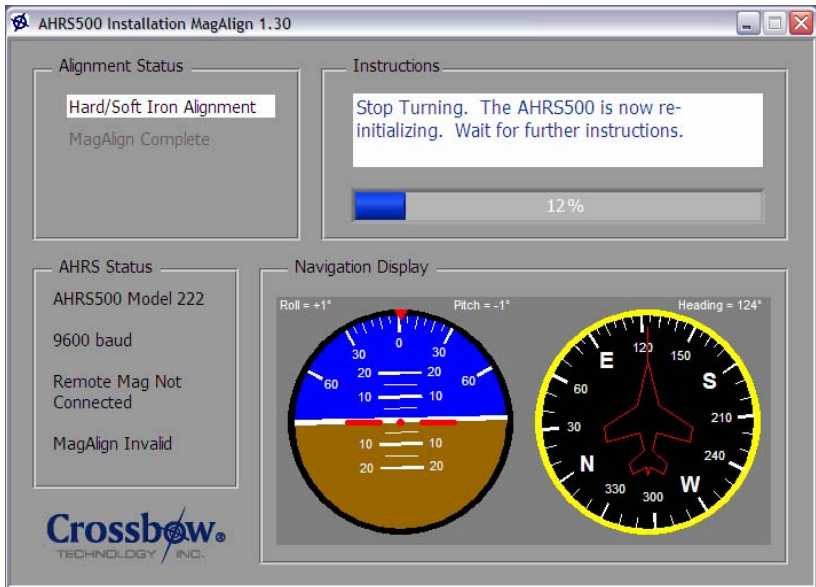
9.2.3.8   Repeat the Previous Steps as Required

In general, a successful magnetometer alignment may require several turns in a circle before the program declares the alignment successful. The message in the MagAlign Message Box will tell the user if additional turns in a circle are required. The same process of turning through 360 degrees (full circle) and a wait of 60 seconds for initialization will be required for each turn.

9.2.3.9   Turn off the MagAlign Switch and Store the Alignment

When the AHRS500CA-[] collects enough data and determines that the magnetometer alignment is successfully done, the following screen appears, declaring "Hard/Soft iron alignment is successful. Flip the toggle switch to OFF position". You should also notice Check mark on "Hard/Iron Alignment" in the "Alignment Status" box indicating the success. Turning the MagAlign switch to the off position will permanently store the MagAlign alignment data in the AHRS500CA-[]. The alignment data will only be erased if the MagAlign switch is turned on again. The MagAlign switch must be in the OFF position before operating the aircraft; failure to do so means that the aircraft will lose MagAlign alignment data.
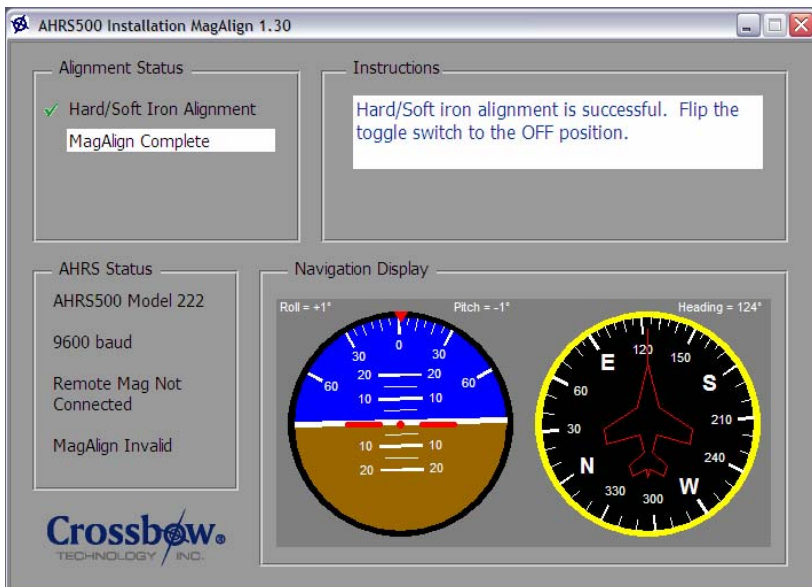
Upon toggling the switch to OFF position, the program declares "MagAlign is successful. Stop the Program. Unit is Ready for Use." A Check mark will also appear on "MagAlign Complete" in the "Alignment Status" box. To stop the program, exit the application.

9.3 Testing the AHRS500CA-[] Alignment

9.3.1 Heading Alignment

The heading alignment can be tested by comparing the heading output of the AHRS500CA-[] on the primary flight display against a known reference such as a compass, compass rose, or runway with known heading.

Align the aircraft along an ordinal heading of North, South, East or West. Make sure the AHRS500CA-[] has completed the 90 second initialization period. Observe the heading reading on the MagAlign software. Make sure heading reading agrees within 4^0 of the reference. Rotate the aircraft along an ordinal heading of North, South, East or West that is 90 degrees from the previous position. Observe the heading reading on the MagAlign software and make sure that this agrees within 4^0 from the reference. A good alignment will not display more than a 4^0 heading change once the turning is stopped. Repeat this test for all the four ordinal heading directions.

Significant errors in the AHRS500CA-[] heading alignment indicate improper alignment or improper operation of the AHRS500CA-[]. If the heading errors are greater than 4^0, go back to section 6.2.3 and repeat the MagAlign procedure until a satisfactory heading performance is obtained.

9.3.2 Attitude Alignment

After installation is complete and while flight testing the aircraft, note the displayed attitude from the PFD while in level flight. If the display horizon line is shown too high, the AHRS500CA-[] must be tilted "nose up" a corresponding amount to bring the horizon line to the center of the screen. If the display horizon line is shown too low, the AHRS500CA-[] must be tilted "nose down" a corresponding amount to bring the horizon line to the center of the screen.

Likewise, if the PFD page shows a slight bank when the aircraft is in level flight, shimming may be required. Typically, the horizon line of the PFD should be near the center of the display when the aircraft is loaded with its typical payload. Once set, a discernible difference in aircraft attitude will be noticed throughout the range of airspeed, weight, and angle of attack combinations.

Carefully shim the AHRS500CA-[] with non-ferrous washers as needed.

10 Appendix E. Warranty and Support Information

10.1 Customer Service

As a Crossbow Technology customer you have access to product support services, which include:

- Single-point return service
- Web-based support service
- Same day troubleshooting assistance
- Worldwide Crossbow representation
- Onsite and factory training available
- Preventative maintenance and repair programs
- Installation assistance available

10.2 Contact Directory

United States:　　Phone:　1-408-965-3300 (8 AM to 5 PM PST)

　　　　　　　　　　Fax:1-408-324-4840 (24 hours)

　　　　　　　　　　Email:　techsupport@xbow.com

Non-U.S.:　　Refer to website　www.xbow.com

10.3 Return Procedure

10.3.1 Authorization

Before returning any equipment, please contact Crossbow to obtain a Returned Material Authorization number (RMA).

Be ready to provide the following information when requesting a RMA:

- Name
- Address
- Telephone, Fax, Email
- Equipment Model Number
- Equipment Serial Number
- Installation Date
- Failure Date
- Fault Description
- Will it connect to GyroView?

10.3.2 Identification and Protection

If the equipment is to be shipped to Crossbow for service or repair, please attach a tag TO THE EQUIPMENT, as well as the shipping container(s), identifying the owner. Also indicate the service or repair required, the problems encountered, and other information considered valuable to the service facility such as the list of information provided to request the RMA number.

Place the equipment in the original shipping container(s), making sure there is adequate packing around all sides of the equipment. If the original shipping containers were discarded, use heavy boxes with adequate padding and protection.

10.3.3 Sealing the Container

Seal the shipping container(s) with heavy tape or metal bands strong enough to handle the weight of the equipment and the container.

10.3.4 Marking

Please write the words, "*FRAGILE, DELICATE INSTRUMENT*" in several places on the outside of the shipping container(s). In all correspondence, please refer to the equipment by the model number, the serial number, and the RMA number.

10.3.5 Return Shipping Address

Use the following address for all returned products:

Crossbow Technology, Inc.
   4145 N. First Street
   San Jose, CA 95134
   Attn: RMA Number (XXXXXX)

10.4   Warranty

The Crossbow product warranty is one year from date of shipment.

Crossbow Technology, Inc.
4145 N. First Street
San Jose, CA 95134
Phone: 408.965.3300
Fax: 408.324.4840
Email: info@xbow.com
Website: www.xbow.com