AS9100C &
ISO9001:2008
Cert# 87834

LandMark^{TM} 10/20/40 AHRS
(Attitude and Heading Reference System)
User's Guide

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1 Revision History

#	Rev.	Date	Approval	Changes Summary
1	L	11-20-12	M. Kane	Updated AS9100 cert number in header
2	K	10-09-12	R. Hulsing	Added grounding note & AS9100 Rev C
3	J	04-27-12	R. Hulsing	Added USB powered SDK
4	I	02-07-12	R. Hulsing	Updated Status Byte, Sync and BW filter
5	H	07-12-11	J. Fritch	Removed reference to “airs” Software
6	G	07-11-11	M. Chamberlain	Combined LMRK10, 20 & 40 AHRS User Guides & updated to standard format for technical support etc. Effectivity is S/N 150.
7	F	04-26-2011	R. Hulsing	Added Airspeed Wheel Diameter Definition Figure 16 and AHRS Coef Load Fig 47
8	E	08-16-2010	A. Ryan	Updated SDK instructions for Glamr SW, Update Rate, SN Effectivity 100
9	D	07-20-2010	A. Ryan	Updated VRW for 2g Accels, Weight, Text Edits, Inserted VRW Graph; SN Effectivity 100
10	C	07-16-2010	A. Ryan	Updated VRW for 10g Accels; SN Effectivity 100
11	B	06-29-2010	A. Ryan	Updated start-up time frequency, text edits, updated bandwidth frequency, SN Effectivity 100
12	A	03-22-2010	R. Hulsing	Updated 1PPS section.
13	New	02-04-2010	M. Chamberlain	Incorporated new sensor performances from standard LandMarkTM 10/20/40 AHRS, added 1pps sync and updated some graphics. Due to product naming effectivity SN:110

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Gladiator Technologies
High Performance Inertial MEMS

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SAFETY AND HANDLING INFORMATION

- **ALWAYS USE CAUTION WHEN HANDLING THE LandMark™ 10/20/40 AHRS!**
- **SUPPLYING TOO HIGH OF INPUT VOLTAGE, COULD PERMANENTLY DAMAGE THE UNIT.** Input Power is specified at +3.1V to +5.5V Maximum with +3.3V Nominal Input for specified performance. The unit can withstand input power up to +5.5V without damaging the unit, but will not perform within specification.
- The LandMark™ 10/20/40 AHRS is a sensitive scientific instrument containing shock and vibration sensitive inertial and other sensors. **Excessive shock and or vibration can damage these sensors** and can adversely affect sensor performance and unit output.
- Avoid exposure to electrostatic discharge (ESD). Observe proper grounding whenever handling the LandMark™ 10/20/40 AHRS.
- Properly attach connector and ensure that it has been wired correctly before applying power to the LandMark™ 10/20/40 AHRS.

4 PATENT AND TRADEMARK INFORMATION

The LandMark™ 10/20/40 AHRS is a newly developed unit containing significant intellectual property and it is expected to be protected by United States of America (USA) and other foreign patents pending. LandMark™ is an official and registered Trademark that identifies Gladiator Technologies brand name for our digital inertial and integrated GPS systems products.

5 APPLICABLE EXPORT CONTROLS

The LandMark™ 10, 20 & 40 AHRS have been classified by Gladiator Technologies under the Export Administration Regulations (EAR), as ECCN7A994 and as such may be exported without a license using symbol NLR (No License Required) to destinations other than those identified in country group E of supplement 1 to Part 740 *(commonly referred to as the T-5 countries)* of the Export Administration Regulations. It is the policy of Gladiator Technologies to self-classify all products and then submit to the U.S. Department of Commerce for formal Export Classification with a CCATS#. Please contact Gladiator for copies of formal classifications. Items otherwise eligible for export under NLR may require a license if the exporter knows or is informed that the items will be used in prohibited chemical, biological or nuclear weapons or missile activities as defined in Part 774 of the EAR. Copies of official U.S. Department of Commerce Commodity Classification of the LandMark™ 10, 20 & 40 AHRS product line are available upon request.

6 USER LICENSE

Gladiator Technologies grants purchasers and/or consignees of Gladiator's LandMark™ 10/20/40 AHRS a no cost, royalty free license for use of the following software code for use with the LandMark™ 10/20/40 AHRS. Companies or persons not meeting the criteria as a purchaser or consignee are strictly prohibited from use of this code. Users in this category wanting to use the code may contact the factory for other user license options. See the Software Interface Document for complete information on this software code.

7 STANDARD LIMITED WARRANTY

Gladiator Technologies offers a standard one year limited warranty with the factory's option to either repair or replace any units found to be defective during the warranty period. Opening the case, mishandling or damaging the unit will void the warranty. Please see Gladiator Technologies Inc.'s Terms & Conditions of sale regarding specific warranty information.

8 QUALITY MANAGEMENT SYSTEM

Gladiator Technologies' Quality Management System (QMS) is certified to AS9100 Rev. C and ISO9001:2008. STR is the company's registrar and our certification number is 87834.


STR-REGISTRAR LLC ISSUES THIS

CERTIFICATE OF CONFORMANCE

TO:

Gladiator Technologies Inc.
8022 Bracken Place SE
Snoqualmie, WA 98065

FOLLOWING ASSESSMENT OF ITS QUALITY MANAGEMENT SYSTEM AND FINDING IT IN CONFORMANCE WITH:

AS9100 Rev. C
ISO 9001:2008 – (Design Included)
IN ACCORDANCE WITH THE REQUIREMENTS OF AS9104A

FOR THE FOLLOWING SCOPE OF REGISTRATION:

Design and Manufacture of inertial sensors, systems and integrated GPS

Registration Number: 87834
Certificate Issue Date: 06/05/2012
Issue Number: 1
Expiration Date: 06/16/2014
Initial Certification Date: 06/24/2008

AUTHORIZED BY:

Bryce E. Carson, Sr. General Manager

STR-Registrar, LLC
639 Main Street
Stroudsburg, Pennsylvania 18360
United States of America
800-903-5660

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Figure 1: STR AS9100 Rev. C & ISO9001:2008 Certification

9 THEORY OF OPERATION

The LandMark™ 10/20/40 AHRS (Attitude & Heading Reference System) is a digital 6 Degree of Freedom MEMS (Micro Electro-Mechanical System) VG (Vertical Gyro) that provides heading (yaw), pitch and roll angles, delta velocity (meters/second and delta theta (degrees), altitude as well as temperature outputs. Utilizing Gladiator's proprietary thermal modeling process, this unit is fully temperature compensated, with corrected bias, scale factor, misalignment and g-sensitivity.

The unit contains:

- Three MEMS gyro signals with active filtering and 10X over sampled (100 Hz data rate) with a 12 bit A/D converter. The gyros are available in standard ranges (see applicable datasheet). Other ranges may be available. Please contact the factory for further information.
- Three MEMS accelerometer signals with analog buffering and 10X over sampled (100 Hz data rate) with a 12 bit A/D converter. The accelerometers are available in standard ranges (see applicable datasheet). Other ranges may be available. Please contact the factory for further information.
- Six internal temperature sensors outputs are 10X over sampled (100 Hz data rate) with a 12 bit converter. These temperature measurements are co-located with each X, Y and Z axis gyro to enable accurate temperature compensation of the gyro and accelerometer outputs.
- A calibrated barometric pressure sensor.
- A triaxial magnetometer calibrated over temperature as well as both a hard iron and soft iron calibration.
- The calibration process measures temperature at a minimum of 5 set points from -40°C to +85°C and a 9 point correction table is generated that identifies temperature based offsets for each of the gyro and accelerometer data sets. Depending upon the variable, up to a 3rd order thermal model is used to create a correction model.
- Though a precision orthogonal mounting block is used in the LandMark™ 10/20/40 AHRS, misalignment error correction is also essential in enabling high performance navigation from a MEMS inertial sensor assembly. The calibration process also corrects and compensates for internal misalignment errors.
- In addition "g-sensitivity" errors associated with the gyros are also modeled and calibrated to correct these performance errors associated with acceleration inputs in all three gyro axes.
- All of the calibration data is then loaded into an internal memory EEPROM enabling a look-up table for thermal modeling correction of the outputs during use.

- The digital interface enables the user to monitor the output during use. Over-sampling is done on the unit output rate (10X at 100Hz data rate) and then averaged to improve the noise of the MEMS sensors. The nominal unit output rate in the LandMark™ 10/20/40 AHRS is 100Hz ±5%. An RS485 serial interface provides serial data outputs. An RS485 to USB converter is available in Gladiator's LandMark™ 10/20/40 AHRS Software Development Kit (SDK) to enable a quick AHRS to PC integration and ease of use.
- **CAUTION: An internal power switching regulator enables clean input power at +3.3 Volts nominal (unit accepts input power from +3.1V to +5.5V MAX – see caution on supplying over voltage in section 4).** The AHRS lower power consumption enables ultra-low power usage as demanded in many applications today. Nominal power consumption is typically about 650mW to 800mW depending upon the product family being used. The standard unit is calibrated at +3.3V ±0.2V input power. A separate part number exists for users that prefer a +5V input power option. This option will draw about 50% more power. Please contact the factory for more details.

The LandMark™ 10/20/40 AHRS SDK software design enables updates to the AHRS interface. As these software enhancements and upgrades become available, Gladiator will make these available to our AHRS customers. For more information see Gladiator's website at www.gladiatortechnologies.com.

10 PRODUCT DESCRIPTION

10.1 *LandMark™ 10/20/40 AHRS (Attitude and Heading Reference System)*

The new LandMark™ 10/20/40 AHRS features low noise gyros and accelerometers with excellent in-run bias as well as over temperature bias performance with ruggedized environmentally sealed packaging enclosure and a MILSPEC connector. The unit is form, fit and function interchangeable with both the LMRK10 & 40 AHRS. The unit is ideal for applications demanding excellent performance coupled with challenging environmental requirements at low cost. Other features include: low power consumption, small size, light weight, long life MTBF and enhanced packaging with environmental sealing and EMI protection. The signature feature of this AHRS is the **low noise gyros and accelerometers,** which enable precision measurement and improved in-run and bias over temperature as well as reduced jitter on an attitude indicator display. This is combined with an accurate magnetometer for heading, that is calibrated over temperature, as well as pitch and roll angle outputs. The AHRS's performance is optimized with **fully temperature compensated bias and scale factor and compensated misalignment and g-sensitivity.**

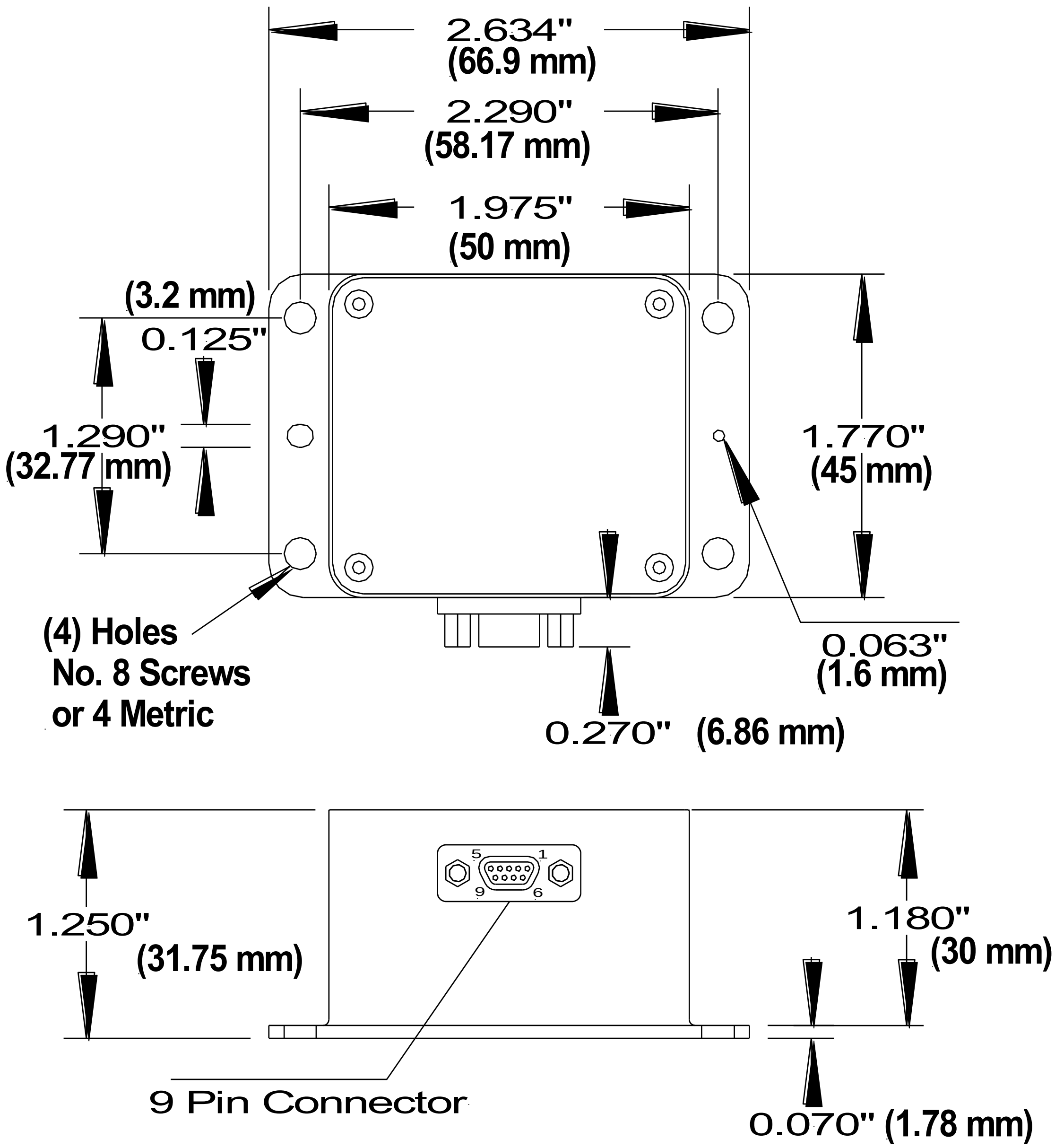
Figure 2: LandMark™ 10/20/40 AHRS with Euro Coin

- ***Rugged* Environmentally Sealed Packaging & MILSPEC Connector**
- ***Low Noise* Silicon MEMS AHRS**
- **Low Gyro Noise** *0.01°/sec/√Hz 1σ*
- **Low Accel Noise** *0.05mg/√Hz (2g) 1σ*
- **In-Run Gyro Bias** *15°/hour 1σ*
- **Heading (Yaw) Angles** *0.5° stationary*
- **Pitch & Roll Angles** *0.25° stationary*
- **Altitude** *±3 meter 1σ*
- **Fully Temperature Compensated Bias and Scale Factor**
- **Compensated Misalignment** *1mrad* **and g-Sensitivity** *<0.02°/sec/g 1σ*
- **External Sync Input** *(1kHz or 1pps)*
- **Low Power** *<3/4 watt typical*
- **Low Voltage** *+3.3V (single sided power)*
- **Light Weight** *114 grams*
- **Small Size** $< 72cm^3/4.4in^3$

- **Bandwidth Filtering Capability**
- **RS485 Data Rate** *100 Hz (user selectable)*
- **Internal Vibration Isolation**
- **6 Temperature Sensors**
- **Export Category ECCN7A944**

The unit is well suited for the harsh environments of commercial automotive and motorcycle testing, motorsports racing, commercial aircraft and sea applications that require both low cost and high performance as well as rugged durability. Custom ranges available (consult factory).

Mechanical Interface and Outline Drawing



Mating Connector: M83513/01-AN

Figure 3: LandMark™ 10/20/40 AHRS Outline Drawing

10.2 LandMark™ 10/20/40 AHRS Axis Orientation

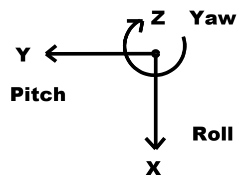


Figure 4: LandMark™ 20 Axes (Top View) Right Hand Rule

It is important to note that the AHRS is designed to indicate magnetic North with its best accuracy when mounted on a flat surface that is parallel with the ground. The unit will not output magnetic North correctly if you stand it on its side (as a user might do when mounting it on a belt and having the connector point up or down), as that it Nadir. It is possible to recalibrate the AHRS for those types of applications so that it does output correctly with respect to the user's mounting and orientation when differing from the factory recommendation. Please contact the factory for more information. The magnetic sensing element is located just below the top of the package, 0.14 inches or 3.5 mm along the y axis. It is best to keep all magnetic effects away from this point. The unit is calibrated with the stainless steel bolts shipped with the unit.

Some applications need to know where the navigation (NAV) point of the accelerometers is located. The NAV point at which all three accelerometers sensing axes pass through is located along the centerline of the package at a distance from the base plate of 0.389 inches (9.87mm). From this point there are three size effect distances from this NAV point as follows:

- X Accel offset = +0.616 inches (along the x-axis direction) (15.6mm)
- Y Accel offset = +0.718 inches (along the y-axis direction) (18.3 mm)
- Z Accel offset = +0.167 inches (along the z-axis direction down from the NAV point) (4.23 mm)

Note that the Z Accel NAV point can also be expressed as 0.222 inches (5.64mm) up from the base plate.

Some applications need to know the CG or center of gravity of the package which is just the mass center. The CG is also along the center line of the package at a point just 0.01 inches (0.23 mm) above the midpoint along the z-axis. This is 0.635 inches or 16.13 mm above the base plate.

LandMark™ 10/20/40 AHRS Block Diagram

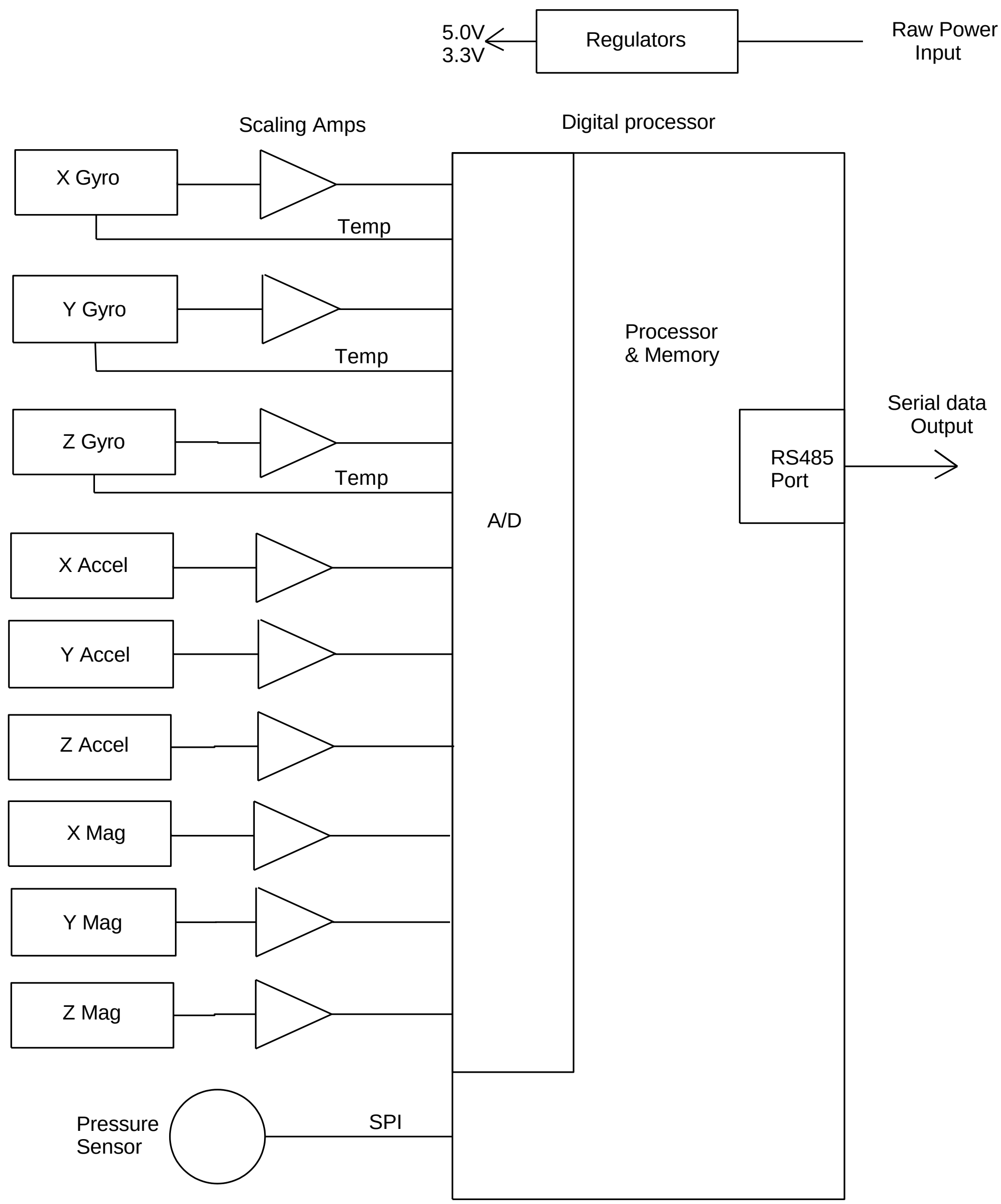


Figure 5: LandMark™ 10/20/40 AHRS Block Diagram

10.3 *LandMark™ 10/20/40 AHRS Part Number Configurations*

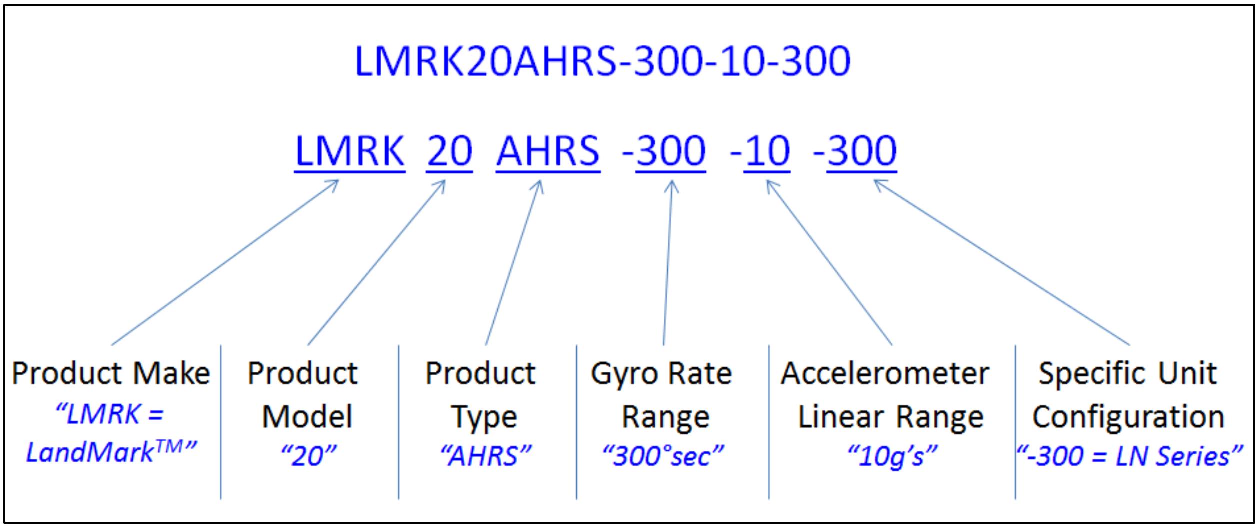


Figure 6: Gladiator Part Number Naming Convention

LandMark™ 20 AHRS "*LN Series*"

LMRK20AHRS-075-**02**-300 or -**10**
LMRK20AHRS-150-**02**-300 or -**10**
LMRK20AHRS-300-**02**-300 or -**10**

Figure 7: LandMark™ 10/20/40 AHRS Part Number Configurations

10.4 *LandMarkTM 20AHRS Pin Assignments*

The LandMark™ 10/20/40 AHRS has a 9 pin connector interface which provides the electrical interface to the host application. The signal pin-out is as follows:

Pin No.	Assignment
1	RS-485 A (+)
2	RS-485 B (-)
3	Power Ground
4	Analog/Digital Input (0V to 5V)
5	**+3.1V to +5.5V Input Power**
6	External Sync Input (1kHz or 1pps)
7	+5V Regulator Out
8	Signal Ground
9	Self Test

Note: Any unused inputs (Pins 4, 6, 9) must be connected to signal ground (Pin 8).

Outputs	Serial Sequence at 100Hz
1, 2, 3	Gyros: Roll (X), Pitch (Y), Yaw (Z)
4, 5, 6	Accelerometers: (X), (Y), (Z)
7	IMU Temperature
8, 9 , 10	Magnetometers: (X), (Y), (Z)
11	Pressure
12, 13, 14	Angles: Roll, Pitch, Yaw
15, 16, 17	AC Velocities: (X), (Y) & Vertical Velocity: (Z)
18, 19, 20	Altitude, Temp, Forward Velocity

User to provide either analog or external velocity for velocity functions to be enabled (pin 4).

Note: If the input pins have long wires with no termination, they can pick up noise in a high EMI environment and upset the proper operation of the IMU. Pin 6 is particularly vulnerable to noise pickup and can cause data drops. For an AHRS, Pin 4 is used for either an analog or digital pulse velocity input. Pin 9 is self-test and is OK if connected to a logic level signal source otherwise it should be grounded.

Figure 8: LandMark™ 10/20/40 AHRS Pin Assignments and Outputs

Specification Subject to Change without Notice.

10.5 *Roll and Pitch Angle Definition & Vibration Environments*

The definition of Roll Angle error is proportional to 1/Cosine *(pitch)*. This means that the Roll Angle is undefined at +/- 90 degrees pitch. Also the accuracy quoted for Roll Angle of 0.25 degrees increases with increasing Pitch Angle. For example at 45 degrees pitch the roll accuracy is 0.35 degrees. The bandwidth of the Roll and Pitch angles is 140Hz. So there is no increase in errors at higher rates, but there may be a delay associated with the delay of a 140Hz low-pass filter.

Note: The roll and pitch angle accuracy can be degraded by excessive vibration. This is less sensitive to high frequency vibration with a bandwidth greater than 140Hz. However, for accelerations exceeding 1g, there will be a slight degradation depending on actual levels and durations longer than 10 milliseconds.

10.6 *LandMark™ 10/20/40 AHRS Message Protocol*

10.6.1 *Serial Communication Settings*

Parameter	Value
Bits/second:	115200
Data bits:	8
Parity:	E
Stop bits:	2

Figure 9: Serial Communication Settings

10.6.2 *AHRS Input Messages*

The AHRS device receives input in the form of 8-byte messages. Input messages are only used to alter AHRS device settings or to initialize a value (such as altitude) at startup. AHRS device output is inhibited while input messages are being transmitted.

10.6.2.1 *AHRS Input Message Format*

Note that most messages have a variable 4-byte parameter value (in little-endian floating point format or little-endian 4-byte integer format). The tables below shows an example value; however the user may send what is appropriate, but must also ensure the checksum byte is updated appropriately.

Description	Number of bytes	Value
Start of message	1	0x2b
Command byte 1	1	depends on command
Command byte 2	1	depends on command
Checksum	1	forces sum of 8 bytes to zero
Parameter value	4	little endian 4-byte value

Figure 10: Generic Format of Command Packets Sent to AHRS

10.6.2.2 *AHRS Input Message Command Summary*

The following table summarizes AHRS input message commands. The single-byte command values and 4-byte integer parameter values are shown in hexadecimal. The parameter values are either floating-point or an integer type depending on the command message. All fields are always transmitted, thus if the field is not applicable, send zero data.

AHRS command	Command byte 1	Command byte 2	Parameter type	Parameter value
Zero Airspeed	0c	N/A	N/A	N/A
Set Altitude, m	08	N/A	floating-point	altitude, meters
Set Mag Deviation, deg	0b	N/A	floating-point	mag deviation, degrees
Set TEST mode	05	13	integer	3
Set SPEC 200 mode	05	13	integer	1
Set SPEC 100 mode	05	13	integer	4
Set FULL mode	05	13	integer	5
Set IMU 200 mode	05	13	integer	10001
Set IMU 100 mode	05	13	integer	10004
Set ASCII mode	05	13	integer	8
Set Filter Coefficient	05	02	floating-point	filter value (see examples)
Load Wheel Diameter, ft	05	03	floating-point	wheel diameter, feet
Load Mag Deviation, deg	05	11	floating-point	magnetic deviation, degrees
Load Initial Altitude, m	05	12	floating-point	initial altitude, meters
Store *n* updates to Flash	06	*n*	N/A	N/A

Figure 11: AHRS Input Command Summary

10.6.2.3 *Startup Commands*

Commands such as these do not require a store to Flash operation. They follow this sequence:

1. Send unlock byte sequence

2. Send the desired message (one of the three shown)

AHRS command	Example Tx byte sequence
Unlock byte sequence	d4 (repeat each 1ms for 10ms)
Zero Airspeed	2b 0c 00 c9 00 00 00 00 (value is N/A)
Set Altitude, m	2b 08 00 0e 00 00 80 3f (value is 1.0)
Set Mag Deviation, deg	2b 0b 00 11 00 00 80 3f (value is 1.0)

Figure 12: Commands That May Typically be Sent After Device Power-up

10.6.2.4 *Operating Mode and Parameter Update Commands*

Single update commands follow this sequence:

1. Send unlock byte sequence
2. Send the parameter to be updated (one of the twenty shown)
3. Send the store to Flash command

AHRS command	Example Tx byte sequence
Unlock byte sequence	d4 (repeat each 1ms for 10ms)
Set TEST mode	2b 05 13 ba 03 00 00 00
Set SPEC 200 mode	2b 05 13 bc 01 00 00 00
Set SPEC 100 mode	2b 05 13 b9 04 00 00 00
Set FULL mode	2b 05 13 b8 05 00 00 00
Set IMU 200 mode	2b 05 13 bb 01 00 01 00
Set IMU 100 mode	2b 05 13 b8 04 00 01 00
Set ASCII mode	2b 05 13 b5 08 00 00 00
Set Filter 75Hz	2b 05 02 0f 00 00 80 3f (value is 1.00)
Set Filter 50Hz	2b 05 02 6f c3 f5 68 3f (value is 0.91)
Set Filter 40Hz	2b 05 02 aa cd cc 4c 3f (value is 0.80)
Set Filter 35Hz	2b 05 02 2c 48 e1 3a 3f (value is 0.73)
Set Filter 30Hz	2b 05 02 af c3 f5 28 3f (value is 0.66)
Set Filter 25Hz	2b 05 02 20 e1 7a 14 3f (value is 0.58)
Set Filter 20Hz	2b 05 02 6d 48 e1 fa 3e (value is 0.49)
Set Filter 10Hz	2b 05 02 58 71 3d 8a 3e (value is 0.27)
Set Filter 1Hz	2b 05 02 ab 49 9d 00 3d (value is 0.0314)
Load Wheel Diameter, ft	2b 05 03 0e 00 00 80 3f (example value of 1.0)
Load Mag Deviation, deg	2b 05 11 00 00 00 80 3f (example value of 1.0)
Load Intial Altitude, m	2b 05 12 ff 00 00 80 3f (example value of 1.0)
Store 1 update to Flash	2b 06 01 ce 00 00 00 00

Figure 13: AHRS Commands Shown with Example Values

A further note on the Store to Flash command is that if the user wishes to update multiple parameters, it is possible to change the command byte 2 field to reflect the number of parameters updated. For example, if the user updates 5 parameters, the sequence would be:

1. Send unlock byte sequence
2. Send the commands to update 5 parameters (10ms spacing between commands)
3. Send the store 5 updates to Flash command: 2b 06 05 ca 00 00 00 00

10.6.3 *AHRS Output Messages*

The following table summarizes the output data stream messages from the AHRS device for each of its various modes. The transmit sequence follows from top to bottom in the table, with the start of message byte transmitted first and the checksum transmitted last in all cases. For each mode, only parameters marked with an X are transmitted. At power-up, the AHRS device reads the operation mode (i.e. Full, IMU, etc.) from its Flash storage and begins to transmit data in that mode.

10.6.3.1 *Summary AHRS Output Message Packet Format*

Description	Full	Norm	#byte	Value	LSB weight
Start of message	X	X	1	0x23(Full) 0x2B(Norm)	N/A
Message counter	X	X	1	Mod 256 counter	N/A
Gyro – X axis	X		2	Signed 16-bit int	0.01 deg/sec note5-7
Gyro – Y axis	X		2	Signed 16-bit int	0.01 deg/sec note 5-7
Gyro – Z axis	X		2	Signed 16-bit int	0.01 deg/sec note 5-7
Accel – X axis	X		2	Signed 16-bit int	See note 5-8
Accel – Y axis	X		2	Signed 16-bit int	See note 5-8
Accel – Z axis	X		2	Signed 16-bit int	See note 5-8
Temp – X axis	X		2	Signed 16-bit int	0.01 deg C
Mag – X axis	X		2	Signed 16-bit int	1 milligauss
Mag – Y axis	X		2	Signed 16-bit int	1 milligauss
Mag – Z axis	X		2	Signed 16-bit int	1 milligauss
Pressure	X		2	Unsigned 16-bit int	2.0 PA
Roll Angle	X	X	2	Signed 16-bit int	0.01 deg
Pitch Angle	X	X	2	Signed 16-bit int	0.01 deg
Yaw Angle	X	X	2	Unsigned 16-bit int	0.01 deg
Vx AC Dynamic Only	X	X	2	Signed 16-bit int	meters/sec
Vy AC Dynamic Only	X	X	2	Signed 16-bit int	meters/sec
Vz Vertical Only	X	X	2	Signed 16-bit int	meters/sec
Altitude	X	X	2	Signed 16-bit int	1.0 meter
Alternate temperature	X	X	2	Signed 16-bit int	0.05 deg C
Analog air speed	note 4	note 4	2	Signed 16-bit int	0.01 meters/sec
Digital wheel velocity	note 4	note 4	2	Signed 16-bit int	0.01 meters/sec
Status Byte	X	X	1	See note 5.	N/A
Checksum	X	X	1	Two's complement sum	See note 1.
Total size (bytes)	**44**	**22**			
Output Rate	**100Hz**	**100Hz or 200Hz**			

Figure 14: AHRS Message Packet Format

10.6.3.2 *Notes:*

1. The checksum byte is the two's complement of the sum of all bytes in the message excluding the checksum byte. Thus, performing a byte-wide sum of all bytes in the entire message (including the checksum byte itself) is always equal to zero.
2. All 16-bit data are transferred in little-endian format. Thus, the least significant byte is received first.
3. Total transport time per message packet:
   Full: (44 bytes * 11 bits/byte) / 115200 bps = 4.2ms
   Norm/Spec: (22 bytes * 11 bits/byte) / 115200 bps = 2.1ms
4. In normal (spec) output mode, only the active air speed value will be transmitted. If there is a wheel counter input to J1-4, then active air speed value is the digital wheel velocity; otherwise it is the analog air speed input from J1-4. Input to the wheel diameter will be decoded as follows:

Case	Wheel Diameter Value	Condition
1	+ Diameter in feet	Uses logic level pulses of 3.3 to 5V rising edge per one turn and computes velocity as π times dia divided by period measured between pulses
2	Zero Diameter	Airspeed 0V to 5V analog input, 1.45 differential pressure sensor from pitot tube input
3	-1 Diameter	Airspeed 0V to 5V analog input, linear velocity from 0 to 500 knots Assumes GPS update rate of 4Hz (same as -4 in case 5 below).
4	-2 Diameter	Airspeed 0V to 5V analog input, linear velocity from 0 to 500 knots
5	-3 Assumes 3Hz Update -4 Assumes 4Hz Update -5 Assumes 5Hz Update -10 Assumes 10Hz Update -20 Assumes 20Hz Update -50 Assumes 50Hz Update -100 Assumes 100Hz Update	Airspeed 0V to 5V analog input, linear velocity from 0 to 500 knots Assumes GPS update rate of 3Hz (-3) up to 100Hz (-100) and all cases shown (-5 is 5Hz update etc.)

Figure 15: External Air/Wheel Speed Input Conditions

5. AHRS status byte format: The status byte contains 4 error bits and 4 status bits, as shown in the tables below. The status will occasionally transmit accel/gyro range information (i.e. when bit 6 is 1).

AHRS status byte decode when message counter set to 2 - 255, bit 6 = 0:

Bit	Name	Value
0	Cal/Test mode indicator	1=Test mode, 0=Cal or Norm
1	Sync	1=external sync, 0=internal sync
2	SCP1000 error	1=SCP1000 pressure sensor fail
3	Flash checksum error	1=Flash coefficient checksum fail
4	Software error	1=internal software fail
5	Software timing error	1=software missed real-time
6	Status byte select	0 (bits 2-5, bit 7 are status)
7	Self-test	1=self-test active

Normal byte is 00000110 after the GPS has acquired at least 4 satellites

Figure 16: Status byte Decode when bit 6 is set to 0

AHRS status byte decode when message counter set to 2 - 255, bit 6 = 1:

Bit	Name	Value
0	Gyro Range indicator	0= Norm, 1=Wide
1	Accel range bit 0	000b=default, 001b=3g, 010b=2g,011b=6g, 100b=10g, 101b=16g, 110=32g, 111b=65g
2	Accel range bit 1	
3	Accel range bit 2	
4	Gyro range LSB	Norm - 00=default, 01b=75°/s, 10b=150°/s, 11b=325°/s
5	Gyro range MSB	Wide - 00=25°/s, 01b=650°/s, 10b=1625°/s, 11b=TBD
6	Status byte select	1 (bits 2-5, bit 7 are settings)
7	Digital board rev 9	1=rev9 (or greater), 0=rev 8

The occasional bit 6 byte is 11110000 for a 300°/sec gyro and a 10g accel

Figure 17: Status byte decode when bit 6 is set to 1(every other message)

AHRS status byte decode when message counter set to 0 or 1

Message Count	Bit	Name	Value LSB = bit 0
0	0-7	IMU SW major revision number	0 to 255
1	0-7	IMU SW minor revision number	0 to 255

Figure 18: Status byte decode when message count set to 0 or 1

6. The Accel LSB scaling depends on the g-range of the Accels in the selected IMU device. Please note that some accelerometers may have inherent over-range versus the range reflected on the datasheet. An example is the 16g part number. This accelerometer is

designed to have over-range up to 20+ g's. As the LSB is set to an equal to or less than Accel Range, the user would want to use the next higher up Accel range LSB in order to use the inherent over-range of the applicable Accel. In this example they would instead use the 30g Accel Range and the associated LSB of 0.0010 g.

7. The Gyro LSB scale factor depends on the rate-range of the Gyros:

Status Bits [5:4:1]	Gyro RangeValue	LSB Scale Factor
000	Default (no value listed)	0.01 °/s
001	25	0.01 °/s
010	75	0.01 °/s
011	650	0.02 °/s
100	150	0.01 °/s
101	1625	0.05 °/s
110	325	0.01 °/s
111	N/A	N/A

Figure 19: Gyro LSB Scale Factor

8. The Accel LSB scaling depends on the g-range of the accels in the selected AHRS device:

Accel Bits [3:2:1]	Accel Range Value	LSB Scale Factor
000	Default (no value listed)	0.0010 g
001	≤ 3g	0.0001 g
010	≤ 2g	0.0001 g
011	≤ 6g	0.0005 g
100	≤ 10g	0.0005 g
101	≤ 16g	0.0005 g
011	≤ 32g	0.0010 g
111	≤ 65g	0.0020 g

Figure 20: Accel LSB scale factor

10.6.3.3 *User Interface Comments*

The **AHRS messaging protocol is quite important** and can be somewhat confusing for the user. Please note that the proper sequence of the output data is:

gyro X, gyro Y, gyro Z, Accel X, Accel Y, Accel Z, IMU Temp, Mag X, Mag Y, Mag Z, Pressure, Roll, Pitch, Yaw, Vx, Vy, Vz, Altitude, Pressure Temp, Analog Air Speed, Digital Wheel Speed

Also the unit should be LSB 0.01 deg/sec for gyros and 0.0005 g for 10g accels or 0.0001g for 2g accels, 0.01 degrees for temperature, 0.01 deg for angles and 0.05 degrees for pressure temperature sensor. So you divide the data by 100 for the gyros, temperature and angles, 2,000 for 10g accels or 10,000 for 2g accels, and 20 for pressure temperature to get the corrected data without using the SDK as the software interface does this correction for the user internally. If you are not using the SDK then you will need to do this divide function to get corrected data. See Figure 14 for LSB scaling values.

Please find below some additional explanation on the protocol info:

1). 0x23 or 0x2B is the start of message depending on Full or Spec mode.

2). 11-bits per byte is the total: (8 data + even parity + 2 stop).

3). GLAMR (Gladiator AHRS Reader) decodes messages like this:

A. Wait until at least 44 bytes are received.
B. Check first byte for valid start of message (0x23 or 0x2B). If not 0x23 or0x2B , move one byte ahead and go to step (A), otherwise continue with next step.
C. Perform checksum of 44 bytes (if beginning with 0x23). If checksum is not 0, move one byte ahead and go to step (A), otherwise continue with next step.
D. Perform checksum of 22 bytes (if beginning with 0x2B). If checksum is not 0, move one byte ahead and go to step (A), otherwise continue with next step.
E Valid message: extract data fields.

10.6.4 *Sample Data Format (Full Mode)*

Please see below a sample AHRS data format output (full mode) in Excel. The actual output includes both the header information and data (see rows with MSGCOUNT) that contain actual output data. Also included is the multiplier information, averages and units of measure for additional clarity for the user as described on page 23 above. The AHRS SDK also includes the actual excel file below, so that the user can quickly identify the formulas to use in their system integration directly from the sample data file.

MSG COUNT	GYRX (°/s)	GYRY (°/s)	GYRZ (°/s)	ACCX (mg)	ACCY (mg)	ACCZ (mg)	TEMPX (C)	MAGX (mG)	MAGY (mG)	MAGZ (mG)	PRESSURE (kPa)	ROLL_ANGLE (deg)	PITCH_ANGLE (deg)	YAW_ANGLE (deg)	VELX (m/s)	VELY (m/s)	VELZ (m/s)	ALTITUDE (m)	SCP_TEMP (C)	A_AIRSPD (m/s)
204	-0.15	0.24	0.08	-34.5	2.4	-997	29.19	241	-26	486	98.9	-0.12	-2.01	6.6	0	0	0	250	29.9	0
205	0.19	0.39	0.04	-35.7	1.9	-994	29.25	239	-27	482	98.9	-0.12	-2.01	6.6	0	0	0	250	29.9	0
206	0.49	0.04	-0.41	-37.1	0.5	-993	29.16	236	-24	481	98.9	-0.12	-2.01	6.59	0	0	0	250	29.9	0
207	0.08	-0.08	0.1	-37.1	-0.6	-997	29.21	239	-29	480	98.9	-0.12	-2.01	6.6	0	0	0	250	29.9	0
208	0.11	-0.17	0.08	-35.2	-4.6	-996	29.16	239	-24	485	98.9	-0.11	-2.01	6.59	0	0	0	250	29.9	0
209	-0.18	0.02	0.03	-35.1	0.5	-997	29.18	239	-29	478	98.9	-0.11	-2.01	6.6	0	0	0	250	29.9	0
210	0.26	0.05	-0.26	-37	0.4	-998	29.18	240	-30	481	98.9	-0.1	-2.01	6.62	0	0	0	250	29.9	0
211	-0.04	0.15	-0.35	-39.9	-0.1	-999	29.16	241	-27	482	98.9	-0.1	-2.01	6.62	0	0	0	250	29.9	0
212	-0.31	0.08	-0.06	-35.8	2.5	-995	29.18	235	-26	478	98.9	-0.1	-2.01	6.62	0	0	0	250	29.9	0
213	0.08	-0.15	-0.12	-34.8	2.7	-996	29.2	239	-28	479	98.9	-0.11	-2.01	6.63	0	0	0	250	29.9	0
214	-0.2	-0.02	0	-35.9	3.1	-998	29.19	239	-30	483	98.9	-0.11	-2.01	6.65	0	0	0	250	29.9	0
215	0.01	0	0.32	-34.1	1.2	-996	29.17	238	-27	478	98.9	-0.11	-2.01	6.65	0	0	0	250	29.9	0
216	0.28	-0.23	-0.18	-32.1	2.4	-997	29.18	238	-25	477	98.9	-0.11	-2.01	6.64	0	0	0	250	29.9	0
217	0	-0.07	0.01	-33.7	2.5	-996	29.21	238	-25	482	98.9	-0.11	-2.01	6.63	0	0	0	250	29.9	0
218	0.01	-0.14	0.32	-35.4	1.8	-997	29.19	236	-33	479	98.9	-0.11	-2.01	6.67	0	0	0	250	29.9	0
219	0.42	-0.06	0.04	-34.7	2.2	-997	29.16	237	-28	480	98.9	-0.11	-2.01	6.68	0	0	0	250	29.9	0
220	-0.05	-0.54	0	-34.5	0.9	-998	29.14	239	-26	481	98.9	-0.11	-2.01	6.68	0	0	0	250	29.9	0
221	-0.64	-0.13	-0.15	-35.8	0.7	-998	29.17	240	-27	479	98.9	-0.11	-2.01	6.68	0	0	0	250	29.9	0
222	-0.28	0.13	0.01	-36.3	-0.6	-997	29.19	239	-27	477	98.9	-0.11	-2.01	6.68	0	0	0	250	29.9	0
223	0.12	-0.14	0.04	-37.7	0.6	-997	29.17	239	-27	487	98.9	-0.11	-2.02	6.69	0	0	0	250	29.9	0
224	0.22	0.04	0.09	-36.8	-1	-998	29.16	238	-31	480	98.9	-0.11	-2.02	6.71	0	0	0	250	29.9	0
225	-0.15	-0.22	-0.2	-36	-4.4	-997	29.19	239	-27	480	98.9	-0.1	-2.02	6.71	0	0	0	250	29.9	0

Figure 21: Screenshot of LandMark™ 10/20/40 AHRS Sample Data

10.7 *Sync Input (1kHz)*

The optional input to the IMU or AHRS is a sync square wave to pin 6. This allows the data stream to be synchronized to an external clock. In a GPS/IMU the GPS generates a 1 kHz square ware and this is sent to the IMU or AHRS when the GPS has acquired at least 4 satellites. However, any external clock of logic level can be used to synchronize the data.

10.7.1 *Specification:*

- Clock- 1 kHz ± 5% square wave (40 - 60 duty cycle not critical)
- Data sample starts on the rising edge only
- 3.3V or 5V logic is acceptable
- Input has diode protection for levels below -0.7V or above 5.5V to 10.5V

10.7.2 *Sync Input (1pps)*

By applying a 1 pps logic level input (either +3.3V or +5V is OK), the output serial message count will be set to zero on the rising edge of the input pulse. The minimum pulse width needs to be >20 µsec. The 1 pps input is applied to pin 6 (Sync In), with respect to Pin 8 (Signal Ground). The software will automatically detect the 1 pps and switch to the **mode using the internal clock** for the data stream with the message count being reset to zero on the rising edge. This means that the message count will nominally be 0 to 99, but could be up to 3 counts short or long, depending on the actual speed of the internal clock which could vary up to ±3% maximum, but is typically 1%. Note that the detection of the 1 pps edge will be transmitted on the next 100Hz packet of data, so the timing can vary from 1.5 msec to 11.5 msec ±0.05msec delay for a 100Hz data transmission rate from the start of the data package. For 200Hz output data rate the delay will vary from 1.5 msec to 6.5 msec ±0.05msec and the message count will roll over from 0 to 199 typically.

10.7.3 *Status Bit*

The IMU or AHRS will operate on an internal 1 kHz clock until an external clock is detect. Then the IMU will automatically switch over and set status bit 1 true. Note, as the internal and external clocks are asynchronous, the first transition may occur on any sample 1 through 5 of that period. The status bit will be set true for that period even if there is only one sample. However, the next 200Hz data package will all be samples on the external clock.

10.7.4 *Timing*

The time between the 5th (last sample) and the start of the 200Hz data transmission is 1.5 ± 0.05 msec. If the start of the external sync is delayed to between 2.5 msec and 3.5 msec from the start of the 200Hz data package transmission, then all 5 of the next 1 kHz samples will be on the external clock. If the delay is close to 3.5 msec, then the internal to external clock shift will have minimum impact on the data as this is the first sample clock. This would allow the data to be processed right through the transition. Note that for the very next transmission, the status bit will not be true as that data package contains internal clock samples. Only the subsequent following data packages will contain all external clock samples. In most cases, this is not a problem. Otherwise without a timed transition, it is best to discard the first data pack with a sync status bit true because this may be a partial external sync and may not have equally spaced samples. The IMU will revert to the internal clock if the external clock is removed and data will continue to be sent. In most cases the timing of the external sync application is not critical and the data can be used as is. Only in special applications where this is critical is this of concern.

Bit	Name	Value
0	Cal/Test mode indicator	1=Test mode, 0=Cal or Norm
1	**Sync**	**1=external sync, 0=internal sync**
2	SCP1000 error	1=SCP1000 pressure sensor fail
3	Flash checksum error	1=Flash coefficient checksum fail
4	Software error	1=internal software fail
5	Software timing error	1=software missed real-time
6	Status byte select	0 (bits 2-5, bit 7 are status)
7	Self-test	1=self-test active

Figure 22: Status byte decode when bit 6 is set to 0

10.8 *Bandwidth vs. Noise*

Note that our standard LandMark™ 10/20/40 AHRS is optimized for high bandwidth, so the gyros are set at 140Hz. True bandwidth which includes the 100Hz sampling effects has the -3dB point is approximately 50Hz. These are the settings for the standard unit when shipped and the noise may not be optimized for an end-user's specific application. The high bandwidth is ideal for dynamic applications where the high bandwidth would be required to close control loops in flight control in a UAV for example. However, in UAV navigation a lower bandwidth would be possible and we would see an improvement in peak-to-peak noise. Laboratory uses, automotive monitoring or stabilization applications would likely prefer improved noise and could tolerate reduced bandwidth.

With the AHRS SDK, Gladiator offers the end-user the capability to set bandwidth filtering in permanent memory that enables the end-user to set lower bandwidth levels than 50Hz and benefit from the reduced noise of the sensors in the AHRS.

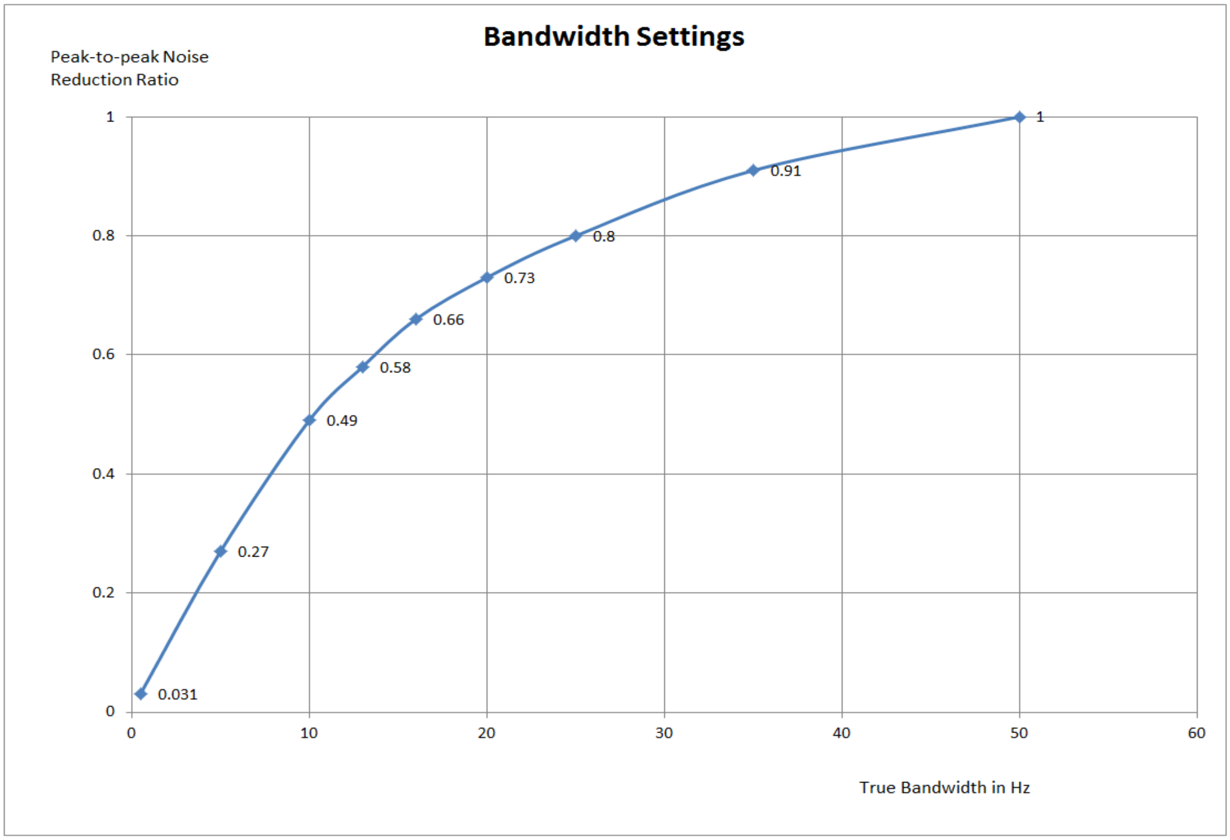


Figure 23: Gyro Noise vs. Bandwidth

11 LandMark™ 10/20/40 AHRS Software Development Kit (SDK)

The LandMark™ 10/20/40 AHRS SDK is an optional product to assist first time users of the LandMark™ 10/20/40 AHRS. This kit provides the user everything they need to facilitate a rapid setup and test of the unit. The SDK (P/N LMRK20AHRS-DEMO-120) and includes display software with user defined options including the following components:

- **Turn-Key Solution for LandMark™ 10/20/40 AHRS on User PC**
- **All Cabling, Interface Connectors and Software Included and Ready for Use**
- **Easy Integration of Direct AHRS RS485 to PC's USB Port**
- **Includes PC Display Software for AHRS** *(GUI Attitude Indicator Display with Heading, Airspeed and Altitude)*
- **Data Record Capability**
- **Multiple User Selected Field Options for Programming and Initializing the Unit**
- **User Defined Bandwidth Settings and Data Output Rate on AHRS**
- **Self-Contained USB Power Supply**
- **Self-Test Switch**

Please contact the factory or your local Gladiator Representative for in-country service and support http://www.gladiatortechnologies.com/INFO/info_salesRepresentatives.htm.

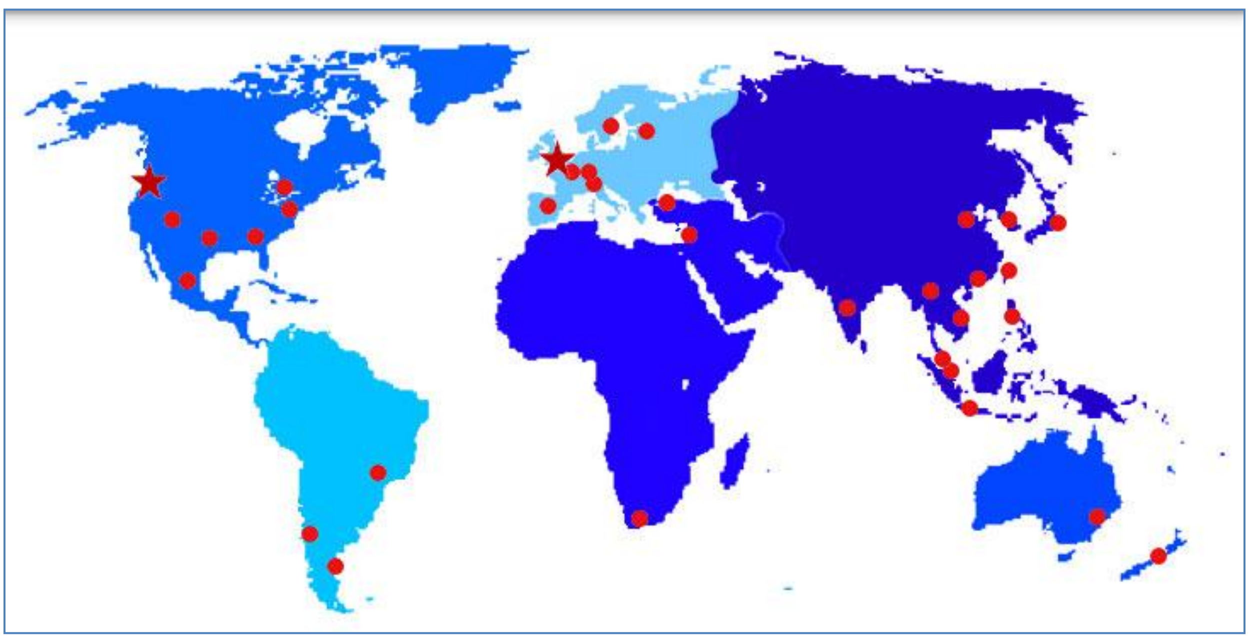


Figure 24: Gladiator Global Sales Network

11.1 *Installation CD-ROM*

If you purchased the SDK then please insert the CD-ROM titled GLAMR– LandMark™ 20 MEMS AHRS SDK User Software and copy the GLAMR software (see GLAMR Icon depicted below) to the hard drive on your computer.

Figure 25: GLAMR Software Icon

Figure 26: SDK Software CD-ROM

11.2 *RS485 to USB Power Supply & Converter Cable*

Contained in the Software Development Kit is a complete RS485 to USB converter cable including self-test switch, below. The power supply uses the USB 5V supply.

An RS485 to USB converter board (it requires additional drivers that are included in the CD-ROM and must be installed to your computer) is also included.

Figure 27: SDK Battery Power Supply, Cabling, RS485 to USB & Self-Test Switch

This power supply converter cable and self test switch enables the user to quickly connect the AHRS to their PC to ease integration and testing. Connect the Connector to Unit Cable, shown above, to the LandMark™ 10/20/40 AHRS unit. Connect the white Connector to the Converter Board Cable, shown above, to the unit. ***Be sure to install with "TOP" on topside of converter cable.*** Finally, connect the square end of the USB cable to the converter board and the rectangular end to the PC. Install the software first before plugging in the unit.

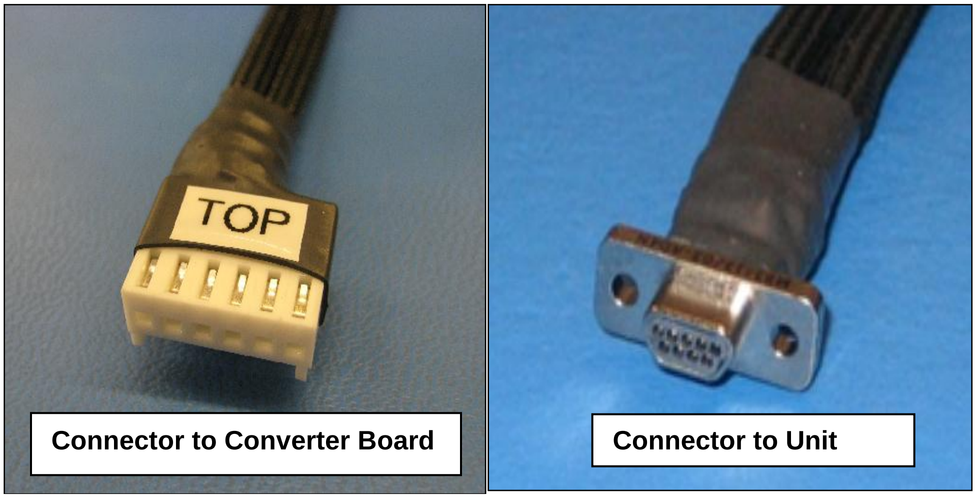


Figure 28: RS485 to USB Converter Connectors

11.3 *AHRS Mating Connector*

The AHRS mating connector and mating pins are contained in a separate package to enable customer-specific wiring options (please see items 4 and 5 in the table in Section 9). If you purchased the SDK then you also have an RS485 Converter board and USB connector mate and mating pins as well. The wiring diagram for the RS485 to USB Converter Schematic is pictured below.

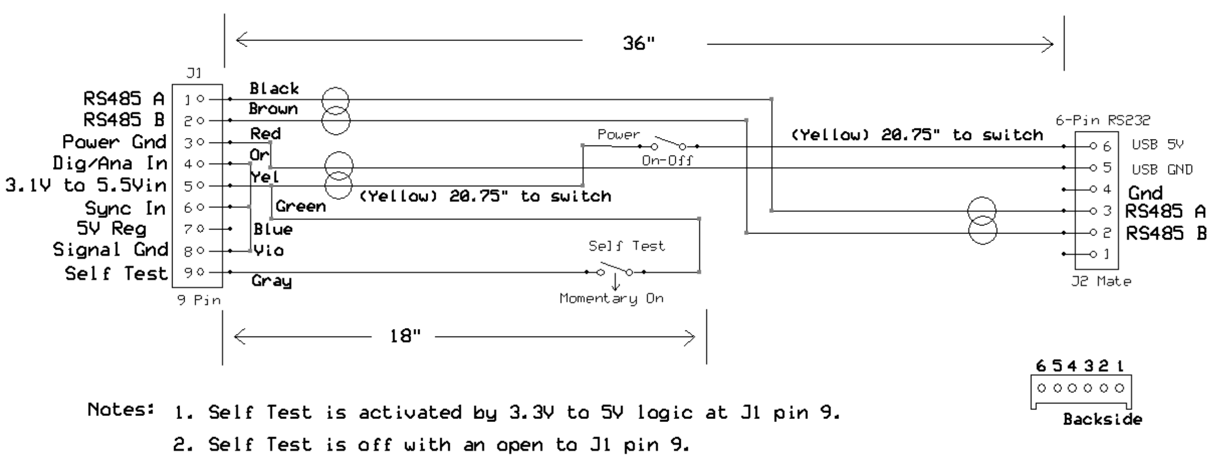


Figure 29: LandMark™ 20 Development Kit – RS485 to USB Converter Schematic

11.4 *STOP! Read This First*

You must first install the USB drivers from the enclosed USB Driver CD ROM before using GLAMR to read the unit. Insert the Software Development Kit CD ROM, look under Linx SW, and perform the instructions in "Read Me First - Installation Guide" (shown below, *now in PDF format*).

Note: This driver is designed for windows programs only.

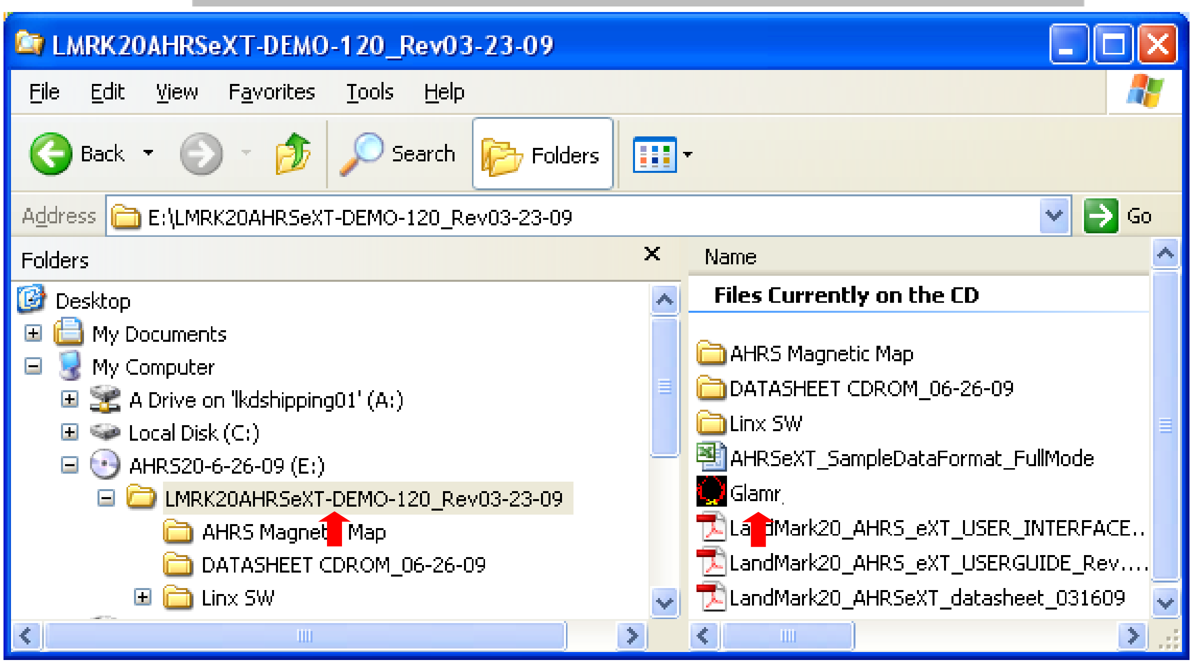


Figure 30: GLAMR Software on CD-ROM

You must first install the USB drivers from the enclosed USB Driver CD ROM before using GLAMR to read the unit. Look on the CD ROM under Linx SW and perform the instructions in "Read Me First - Installation Guide".

11.5 *GLAMR Software Installation*

Now install the GLAMR application off of the Software Development Kit CD-ROM by navigating in Explorer to the file depicted below.

Figure 31: SDK Software CD-ROM

Open the GLAMR file, in the enclosed CD ROM and copy it to your PC's hard drive.

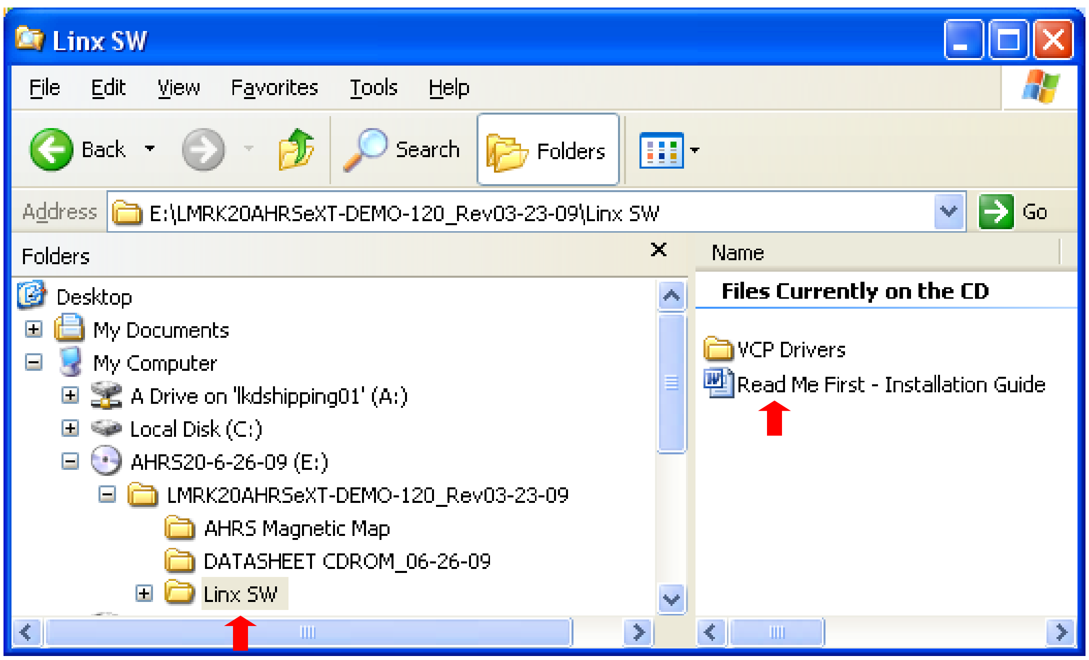


Figure 32: Linx USB SW Location & Read Me First Install Guide

Once you have copied the GLAMR application then you need to create a shortcut on your desktop to the application. Right click on the Glamr Software icon on your hard drive file. Select Create Shortcut. Drag this shortcut file and drop on your desktop.

Figure 33: GLAMR Software Icon

Open the GLAMR software and a window will appear as shown below.

Figure 34: GLAMR Screen before selecting correct COM port settings

Select the drop down menu titled Com Port at the top of the AHRS Reader window, as shown above. The Com Port default is COM1, indicated by the checkmark. By removing the USB plug on the RS485 TO USB converter (after installing the GLAMR software) you will see the Com Port you need be removed from the list. Reconnect the USB plug to the RS485 TO USB converter and select the Com Port your USB cable is plugged into.

Only one copy of Glamr can be open at a time therefore make sure there is not another copy open on the task bar. If there are multiple copies of Glamr open, you will see a message at the bottom of the AHRS Reader window as shown below.

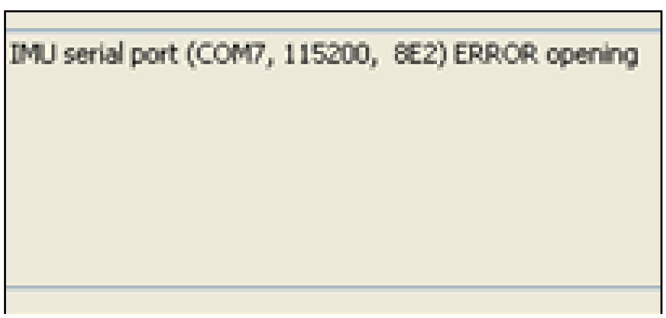


Figure 35: Confirmed COM Port with Message "ERROR opening"

With the correct Com Port selected, the message at the bottom of the AHRS Reader window should read the Com Port selected followed by “success”, as shown below.

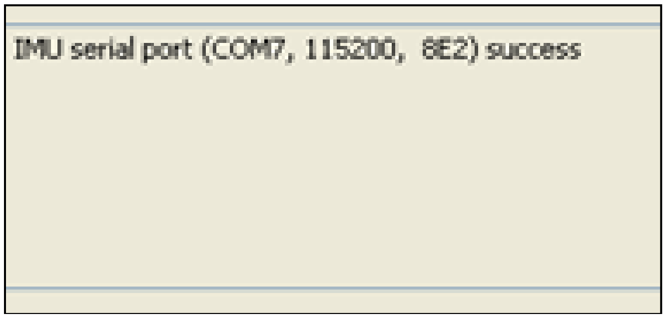


Figure 36: Confirmed Correct COM Port with Message "success"

Turn on the battery switch on the unit power supply and you should see data appear in the window as shown below. You should be able to move the AHRS with your hand and see changes in rate and acceleration for each axis located within the AHRS on the screen. Note that the screen is a one second average and the data may not change instantaneously. To see rapid change the record function will capture real time data without the filter effect on the screen.

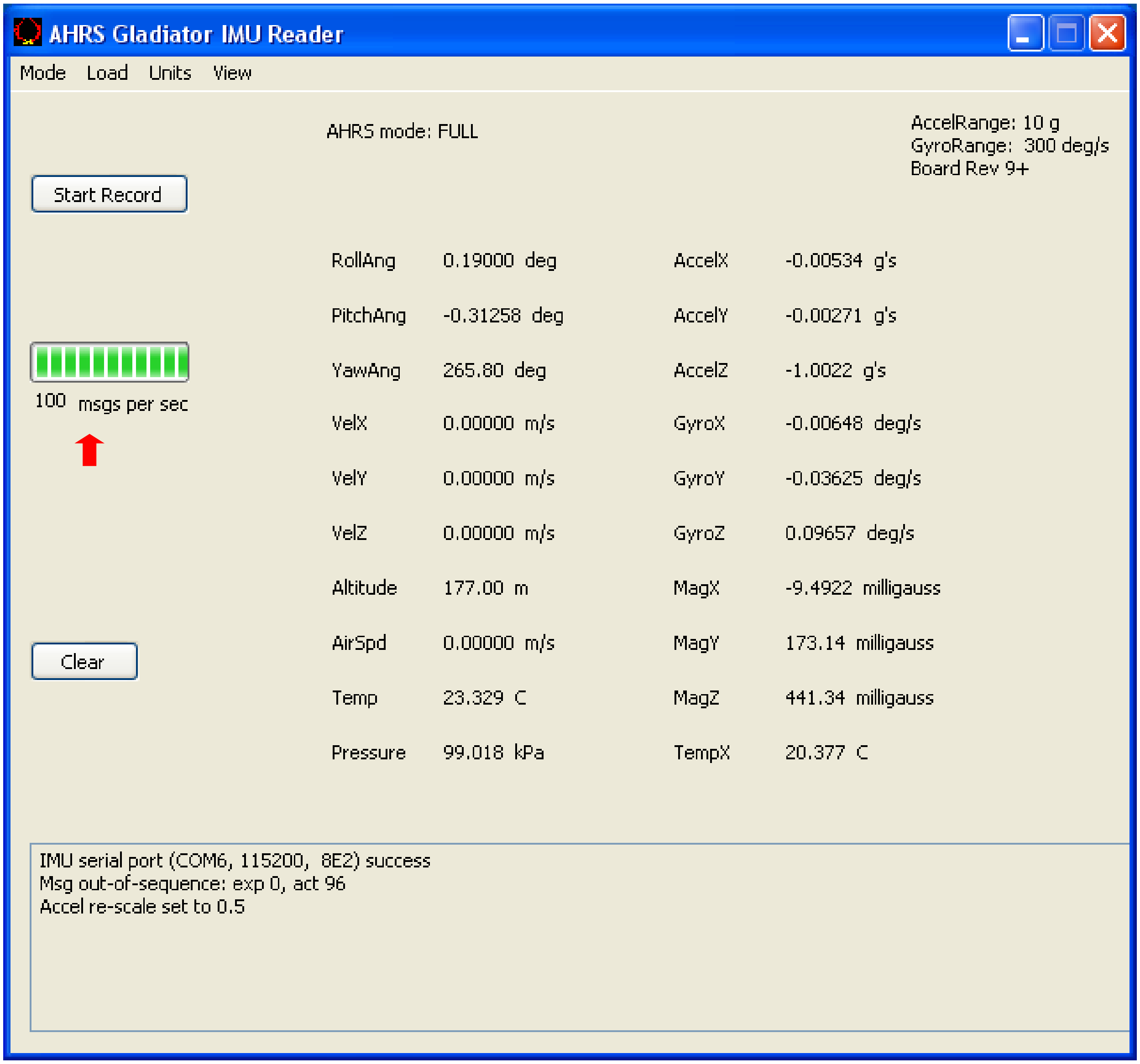


Figure 37: AHRS Data in Full Mode at 100Hz Data Rate

The message shown in the lower left of the box as: “IMU serial port (COM6, 115200, 8E2) success” indicates that the GLAMR program is reading the port. The next message “Msg out-of-sequence: exp 0, act 96” indicates that the program saw a skip in the message count. This case will happen at start-up and can be ignored. The last message “Accel re-scale set to 0.5” indicates that the program detected a 10g range Accel and rescaled the LSB to take into account a 0.5mg LSB scaling to display and record the units in g’s.

11.6 *Self-Test in GLAMR*

GLAMR now includes a self-test function. The user can initiate the self-test by the on-off switch contained within the RS485 to USB cable that is included in the AHRS Development Kit. Press the switch ON to activate self-test of all the gyros. The GLAMR display will now show SELF-TEST is activated while also showing the data outputs. You should see a delta change in the X, Y and Z outputs when you initiate self-test per the data sheet.

Figure 38: Self-Test Momentary Switch & Power ON/ OFF

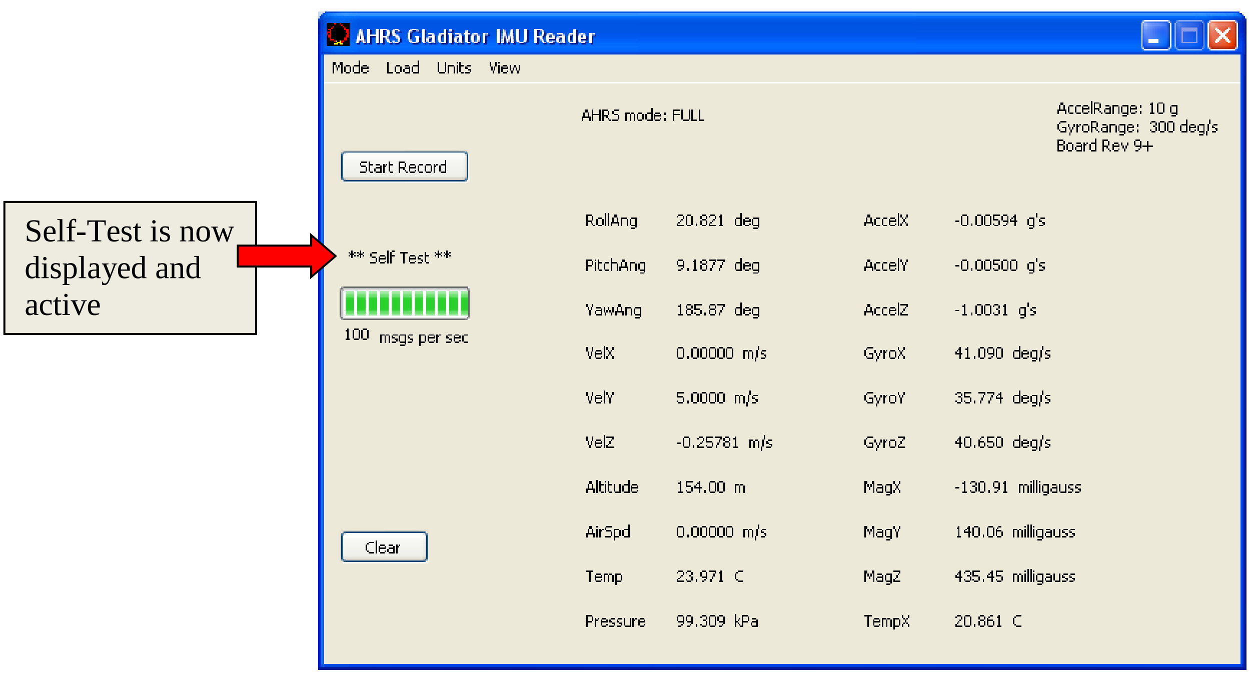
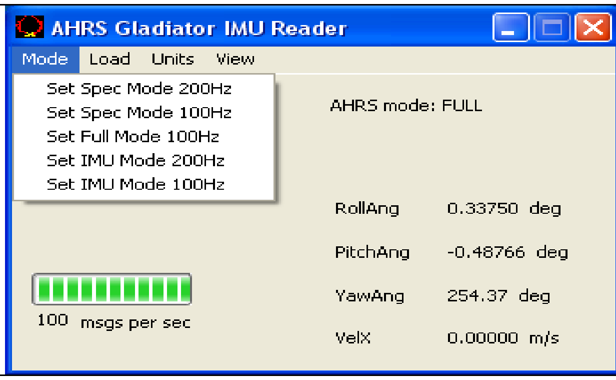


Figure 39: Self-Test Display When Activated ON

11.7 *Setting the Mode and Data Rate*

The SDK software also has a data rate adjustment and data set selection. This feature is selected under Mode as shown. This allows a reduced data set in Spec mode.



MODE SELECTION

SPEC MODE AT 200 HZ DATA RATE – HIGH BW USES

SPEC MODE AT 100 HZ DATA RATE – LOWER BW USES

FULL MODE (ONLY AT 100 HZ DATA RATE) – ALL DATA

NOTE: SPEC MODE ONLY SUPPLIES THE DATA SHOWN BELOW

Figure 40: Mode Selection / Data Rate

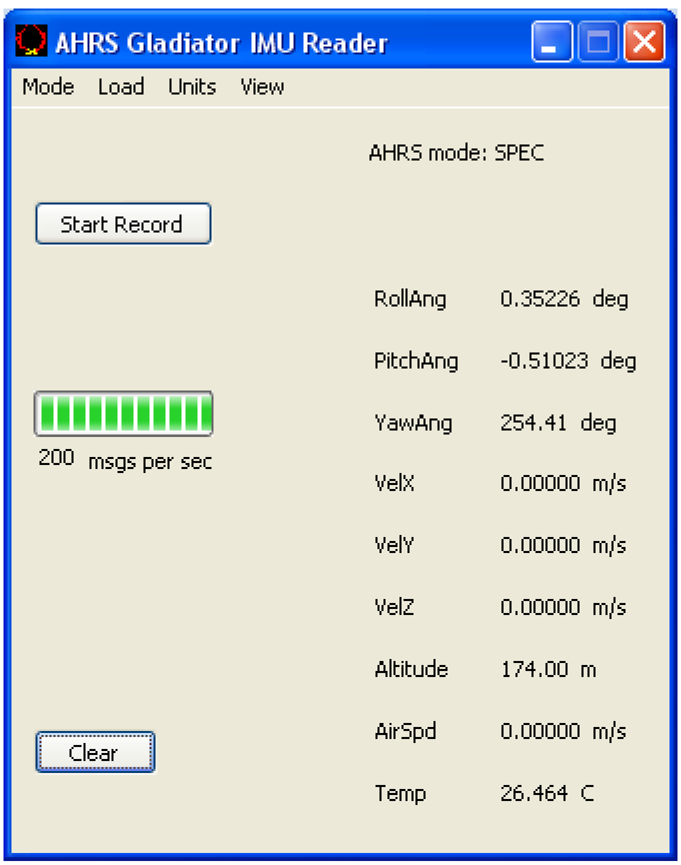


Figure 41: Spec Mode at 200 Hz Data Rate

11.8 *Unit Display Options*

The SDK software also can set the dimensional units of the display. This is selected under Units.

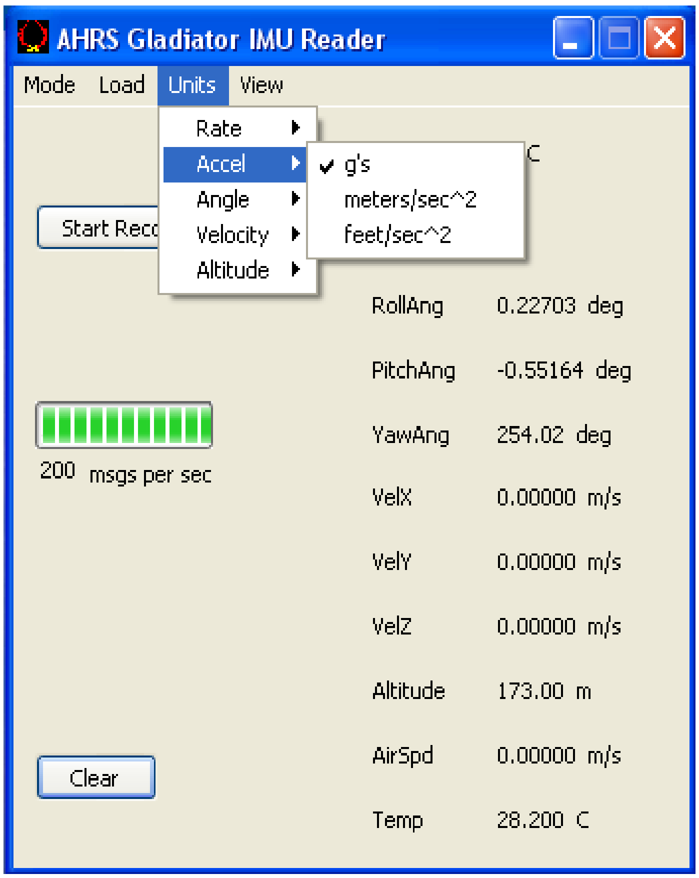


Figure 42: Units of Measure Selection Options

11.9 *Data Record Feature*

The SDK software also has a data record feature that captures data outputting from the AHRS and puts in .CSV format. This enables the user to easily convert these data files to EXCEL or database format.

The user should select with their mouse the Start Recording button to initiate data record function. When they wish to stop recording simply click the Stop Recording button.

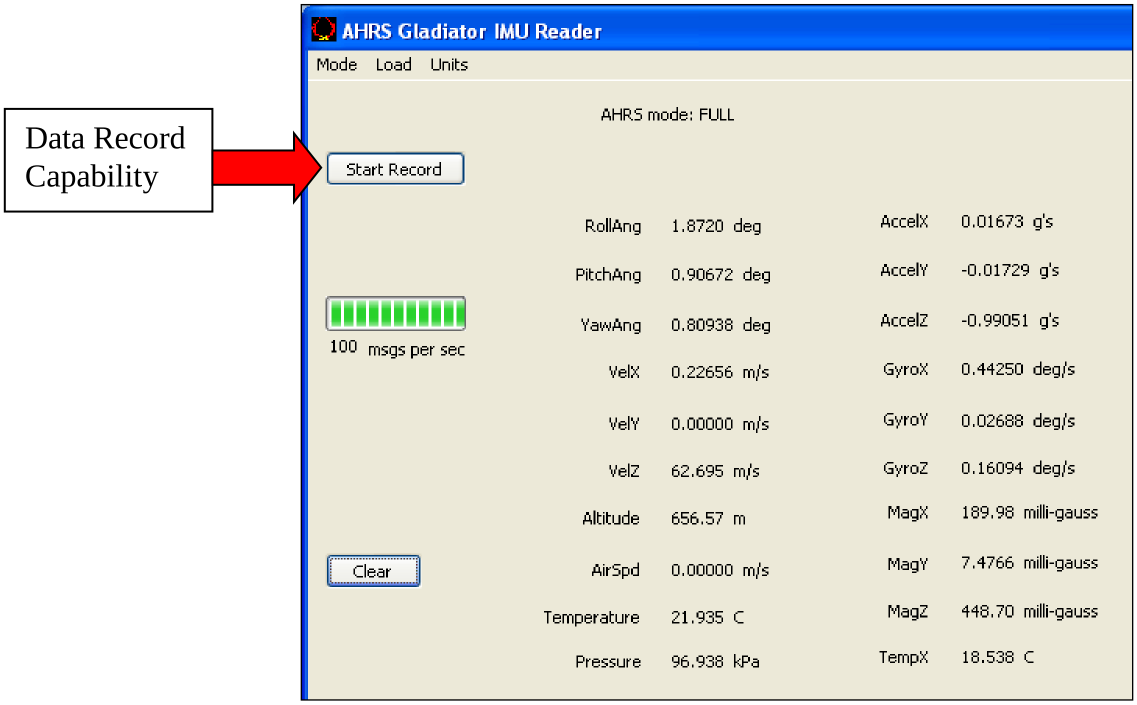


Figure 43: Data Record Capability

Select "Start Record" and designate the file name and location before the recording begins. To begin data record function click on Open:

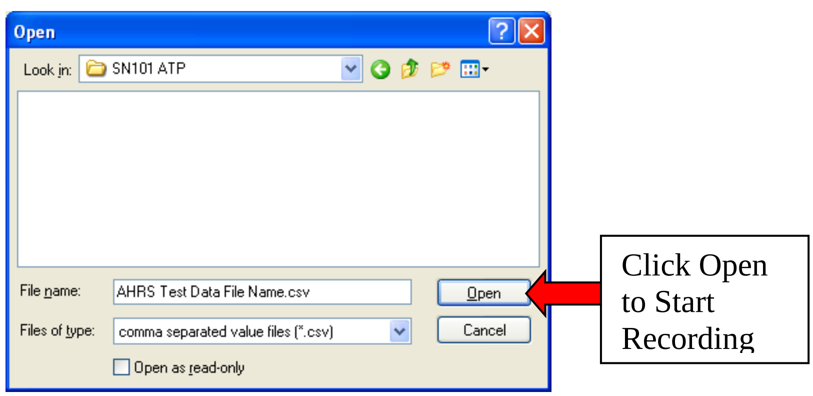


Figure 44: Saving Data Record Files

11.10 *Bandwidth Filtering Capability*

<u>Bandwidth vs. Noise</u>

One thing to be aware is that our standard LandMark™ 10/20/40 AHRS is optimized for high bandwidth, so the gyros are set at 140Hz. True bandwidth with the -3dB point is approximately 50Hz when the 100Hz sample system is included. These are the settings for the standard unit when shipped and the noise may not be optimized for an end-user's specific application. The high bandwidth is ideal for dynamic applications where the high bandwidth would be required to close control loops in flight control in a UAV for example. However, in UAV navigation a lower bandwidth would be possible and we would see an improvement in noise. Laboratory uses, automotive monitoring or stabilization applications would likely prefer improved noise and could tolerate reduced bandwidth.

Effective with AHRS SDK, Gladiator offers the end-user the capability to set bandwidth filtering in permanent memory that enables the end-user to set lower bandwidth levels than 50Hz and benefit from the reduced noise of the sensors in the AHRS. To utilize this capability select Load from the drop down menu.

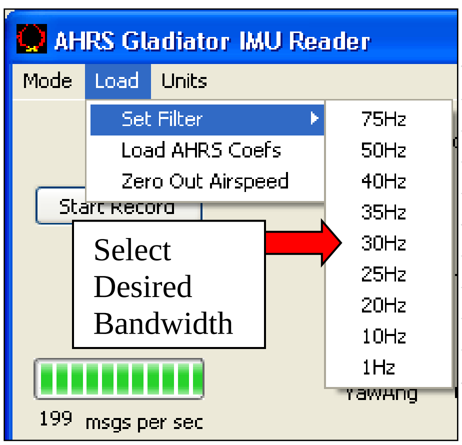


Chart	Load Hz	Actual BW
1	75	50
0.91	50	35
0.8	40	25
0.73	35	20
0.66	30	16
0.58	25	13
0.49	20	10
0.27	10	5
0.031	1	0.5

Figure 45: Select Desired Bandwidth Filter from Drop Down Menu

Then select the desired true bandwidth of the gyros with the software filter. The user can select from 75Hz (standard units are shipped with this setting) or from the other bandwidth options all the way down to 1Hz. Once this is set and the user takes and confirms data with this new setting the AHRS bandwidth filter setting will remain at the setting until the user changes it in the same manner as detailed above.

11.11 *Zeroing Out the Airspeed*

Upon receipt of the unit from the factory the user should reset the airspeed by selecting out the Zero Out Airspeed Icon pictured below.

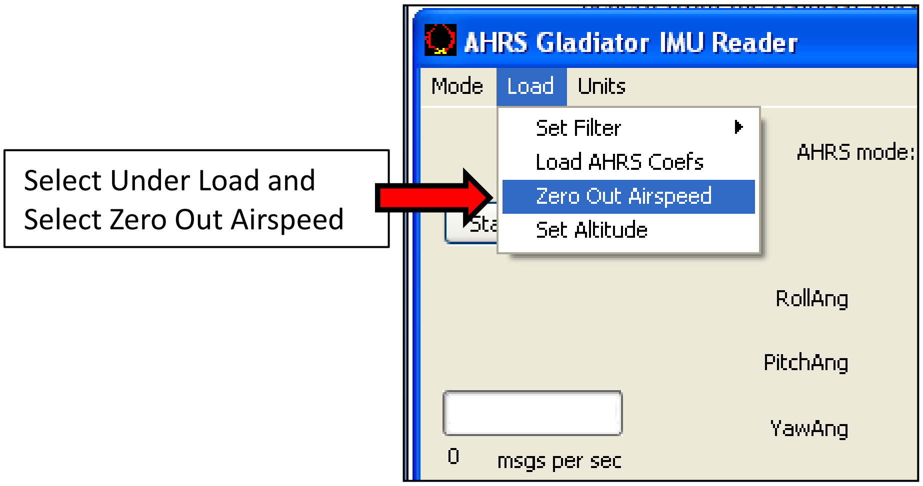


Figure 46: Zero Out Airspeed

11.12 *Loading Initial Parameters*

The AHRS SDK provides the user with the capability of loading initial parameters. The options are shown under Load as shown and results in reading the prior coefficients that were loaded into the AHRS and then can be updated per the table.

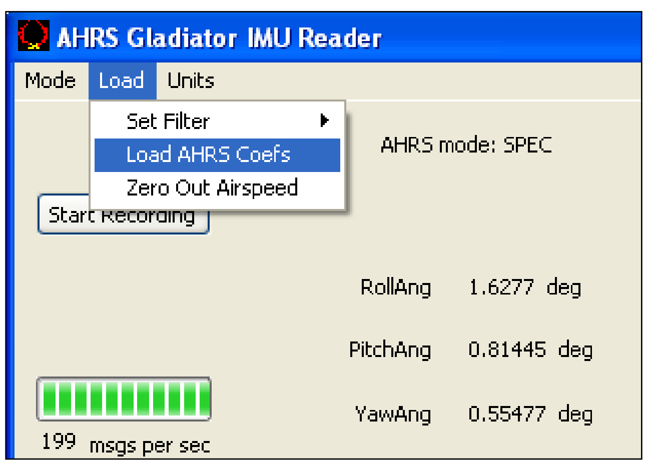
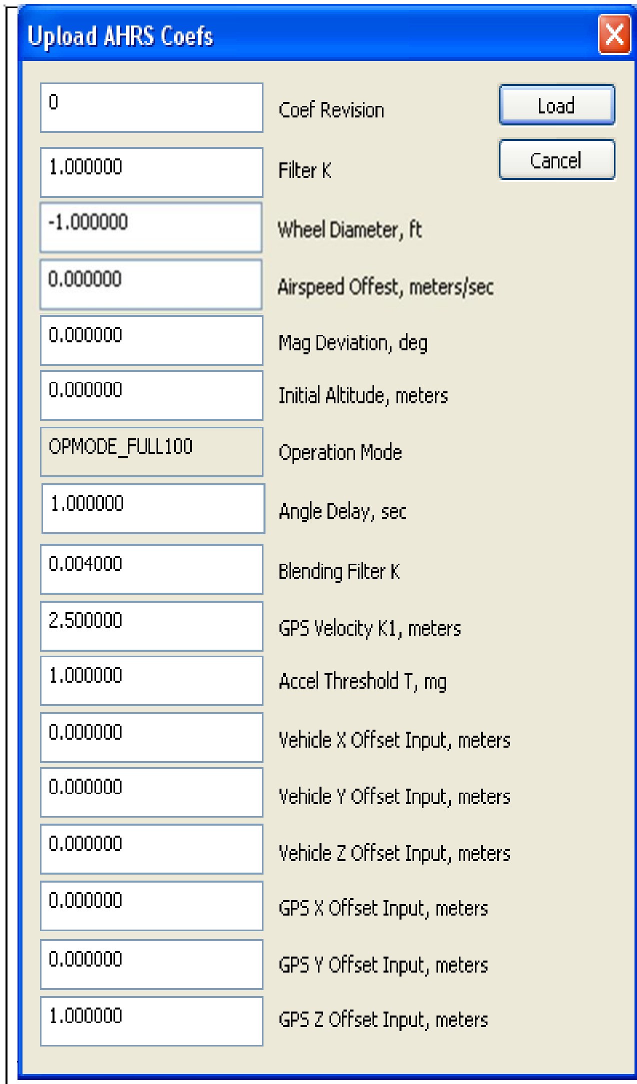


Figure 47: Loading AHRS Coefficients



Definitions:

Coef Revision – Enter Number or Letter

Filter K – Value of Filter Constant

Wheel Diameter in feet – See Table below

Airspeed Offset in meters/sec

Magnetic Deviation from True North in degrees

Initial Altitude in meters of starting point

Operational Mode Selected (Readout)

Blending Filter Gain – Do not change

GPS Velocity Average - Do not change

Accel Threshold mg - Do not change

X Offset Input in meters from vehicle CG forward

Y Offset Input in meters from vehicle CG to the right

Z Offset Input in meters from vehicle CG up

X Offset Input in meters of GPS antenna forward

Y Offset Input in meters of GPS antenna to the right

Z Offset Input in meters of GPS antenna CG up

Figure 48: Definitions for Uploading AHRS Coefficients

11.12.1 *Wheel Diameter – **IMPORTANT***

The AHRS incorporates an algorithm correction for turning error. The data and display reflects this turning error correction and will work properly when you port into the unit external velocity through the spare external data port and it will show your roll angle accurately. When inputting a value into the wheel diameter the user has several options available depending upon their application:

1. If you input Wheel Diameter as a positive number then the unit will determine that you are using a wheel counter for external velocity input.
2. If you input Wheel Diameter as a ZERO then the unit will be scaled to use a differential input of 1.45 differential psi via a pitot tube analog voltage input of 0V to 5V = 500Knots.
3. If you input Wheel Diameter as a negative number then the unit will be scaled as 0 to 5 Volts scaled to 0 to 500 Knots linear voltage proportional to true air speed.

Case	Wheel Diameter Value	Condition
1	+ Diameter in feet	Uses logic level pulses of 3.3 to 5V rising edge per one turn and computes velocity as π times dia divided by period measured between pulses
2	Zero Diameter	Airspeed 0V to 5V analog input, 1.45 differential pressure sensor from pitot tube input
3	-1 Diameter	Airspeed 0V to 5V analog input, linear velocity from 0 to 500 knots Assumes GPS update rate of 4Hz (same as -4 in case 5 below).
4	-2 Diameter	Airspeed 0V to 5V analog input, linear velocity from 0 to 500 knots
5	-3 Assumes 3Hz Update -4 Assumes 4Hz Update -5 Assumes 5Hz Update -10 Assumes 10Hz Update -20 Assumes 20Hz Update -50 Assumes 50Hz Update -100 Assumes 100Hz Update	Airspeed 0V to 5V analog input, linear velocity from 0 to 500 knots Assumes GPS update rate of 3Hz (-3) up to 100Hz (-100) and all cases shown (-5 is 5Hz update etc.)

Figure 49: External Air/Wheel Speed Input Conditions

11.13 *GUI Attitude Indicator Display –Laboratory Use Only ** <u>NOT Flight Certified</u>***

The latest versions of the LandMark™ 10/20/40 AHRS SDK includes new GUI software including attitude indicator display, heading, airspeed (if ported into the AHRS) and altitude (the user will need to set the barometric pressure as indicated in other sections of the User Guide for correct readings).

After downloading the "GlamrAHRS.exe" executable contained in the AHRS SDK. You will know it has been downloaded correctly when you see the GLAMR Icon pictured here:

The User will also need to click SetupGlamrAHRS_5p61.msi and Demo Read me.txt to install and use the attitude indicator display feature.

Then open the Glamr application and power up the AHRS. Click on the task bar “View” and Select Demo and the new attitude display on the LandMark™ 10/20/40 AHRS SDK should appear and move as you move the AHRS. Should you have any questions or comments please contact us at your convenience.

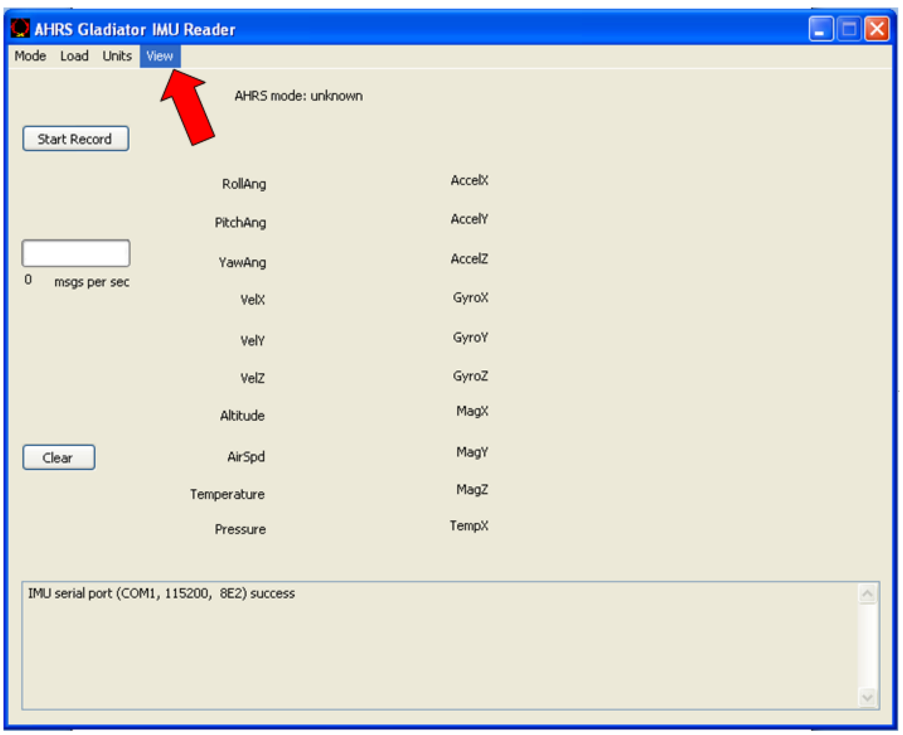


Figure 50: Glamr Display Software (Click View on the Toolbar to Activate)

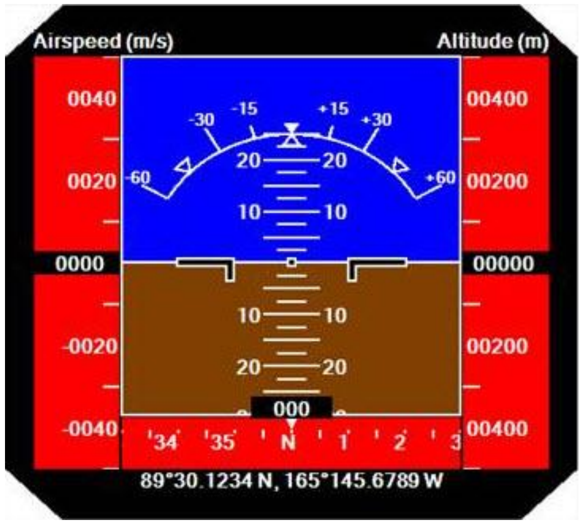


Figure 51: GUI Attitude Indicator Display

12 Mounting

Mounting for the LandMark™ 10/20/40 AHRS accommodates both metric and U.S. mounting screws. Mount the unit to a flat surface with 4ea Number 8 screws (U.S.) or 4ea Number 4 metric stainless steel screws. These screws are part of the factor calibration so there is no need to use any other type such as nylon. Be sure that the surface that you are mounting to is as clean and as level as possible in order to eliminate potential alignment errors. Avoid mounting near magnetic materials as this will degrade the heading accuracy (see sections below for more information).

13 Magnetometer Sensitivity

It is important for users to be aware of the magnetometer sensitive where large masses of steel or motors will affect heading accuracy of magnetometer-based systems. Also, exposure to high magnetic field greater than 20 gauss may magnetize nearby materials that can cause a heading error in the unit. Gladiator can provide in-field magnetometer calibration correction coefficients for both hard and soft-iron errors with a simple in-field procedure upon request. Users should note that even by moving magnetic materials away even a small distance (if the mass is small) can significantly reduce errors by $1/\text{Distance}^3$.

14 Centrifugal Force Error Effects with Constant Turns

Users should be aware that during constant turns Centrifugal Force can significantly affect Roll and Pitch accuracy of *ALL* AHRS systems. It is important that a forward velocity input be input into these systems to correct for this centrifical force error. The LandMark™ 10/20/40 AHRS has built-in forward velocity input functionality, which includes altitude and temperature compensation, to accept an analog Pitot tube input (standard differential 1.45psi 5 volts full scale) from 0 to 500 knots. Optional linear airspeed input can also be accepted. For land vehicles, it has similar built-in forward velocity input functionality to accept a digital pulse edge, such as a wheel counter, (wheel diameter needs to be input into the AHRS). Once either is supplied by the user, the LandMark™ 10/20/40 AHRS has full internal mathematical corrections to compensate for centrifugal force errors.

15 Operation and Troubleshooting

15.1 *Authorized Distributors and Technical Sales Representatives:*

http://www.gladiatortechnologies.com/info_salesRepresentatives.htm

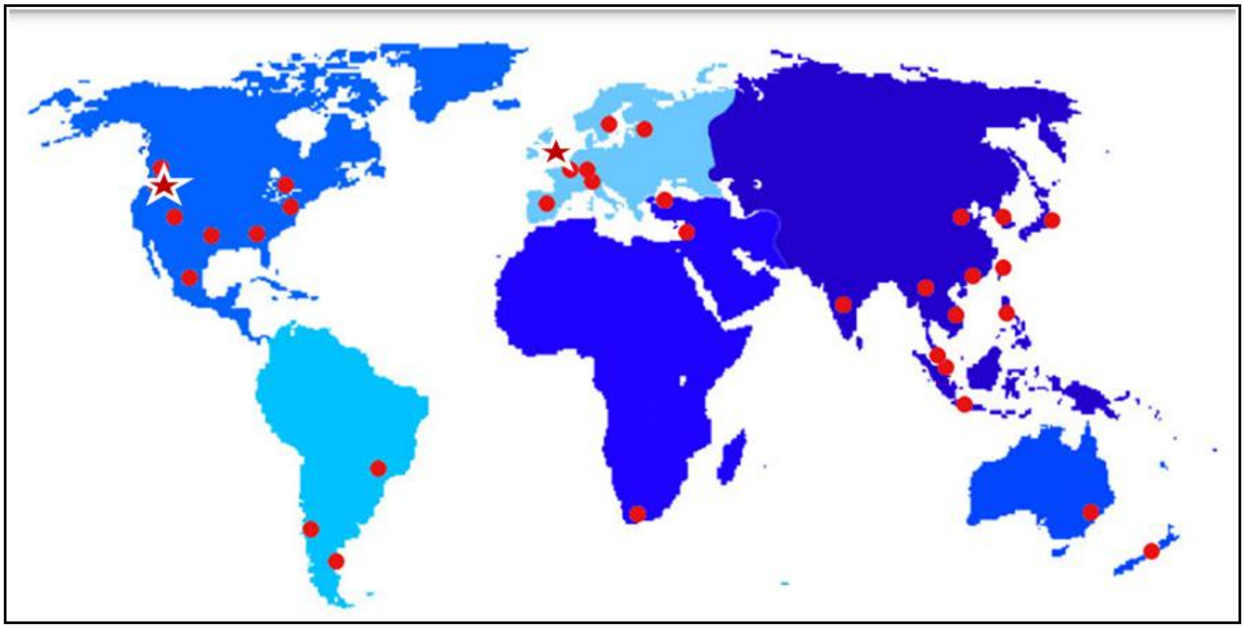


Figure 52: Contact Information & Global Support Locations

15.2 *Technical Assistance*

Please contact us at our website, directly at the factory or your local Gladiator Technologies sales representative's office for technical assistance.

Technical Support - Factory
Gladiator Technologies, Inc. **Attn: Technical Support** 8022 Bracken Place SE Snoqualmie, WA 98065 USA Tel: 425-396-0829 x222 Fax: 425-396-1129 Email: techsupport@gladiatortechnologies.com Web: www.gladiatortechnologies.com

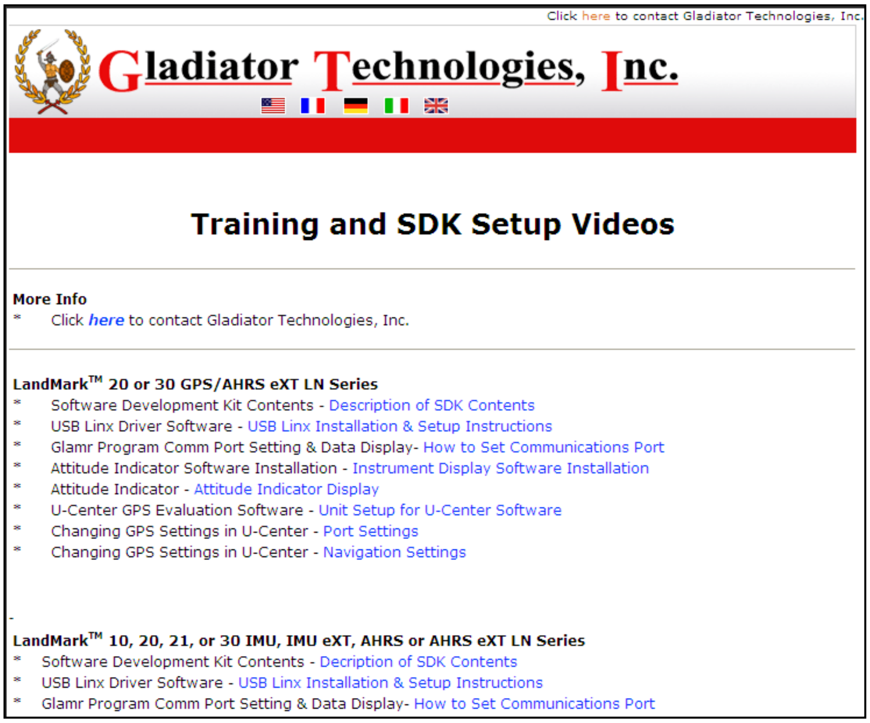
Figure 53: Factory Contact Information

15.3 *Technical Support Website*

Our Technical support webpage has user training videos, the latest software downloads as well as Remote Desktop Assistance.

Figure 54: Homepage - Technical Support Link

Figure 55: Technical Support Web Page



Click here to contact Gladiator Technologies, Inc.

Gladiator Technologies, Inc.

Training and SDK Setup Videos

More Info

* Click ***here*** to contact Gladiator Technologies, Inc.

LandMark™ 20 or 30 GPS/AHRS eXT LN Series

* Software Development Kit Contents - Description of SDK Contents
* USB Linx Driver Software - USB Linx Installation & Setup Instructions
* Glamr Program Comm Port Setting & Data Display- How to Set Communications Port
* Attitude Indicator Software Installation - Instrument Display Software Installation
* Attitude Indicator - Attitude Indicator Display
* U-Center GPS Evaluation Software - Unit Setup for U-Center Software
* Changing GPS Settings in U-Center - Port Settings
* Changing GPS Settings in U-Center - Navigation Settings

LandMark™ 10, 20, 21, or 30 IMU, IMU eXT, AHRS or AHRS eXT LN Series

* Software Development Kit Contents - Decription of SDK Contents
* USB Linx Driver Software - USB Linx Installation & Setup Instructions
* Glamr Program Comm Port Setting & Data Display- How to Set Communications Port

Figure 56: Training & Setup Videos Web Page

Gladiator Technologies, Inc.

SDK DEMO KIT Software Downloads

More Info

* Click ***here*** to contact Gladiator Technologies, Inc.

USB Converter from RS485

- USB Linx Driver Read Me Guide - USB Linx Installation & Setup Instructions
- USB Linx Driver Downloads - USB Linx Driver Downloads
- Link to **7-Zip** open source website to download Zip Applications - 7-Zip open source download

IMU SDK Demo Kit Software Download

- LandMark™ 10/20/21/30/40 IMU - Download GLAMR Software Rev. GlamrIMU_5p58.exe

Attitude/Heading/Airspeed/Altitude DISPLAY Software Download

- DEMO ATTITUDE DISPLAY - Download 30 Day Trial Attitude Indicator Software_Airs.exe

VERTICAL GYRO "VG" SDK Demo Kit Software Download

- LandMark™ 10/20/21/30/40 VG - Download GLAMR Software Rev. GlamrVGIMU_5p58.exe

AHRS SDK DEMO KIT Software Downloads

- LandMark™ 10/20/21/30/40 AHRS - Download GLAMR Software Rev. GlamrAHRS_5p58.exe

GPS-AIDED Vertical Gyro SDK DEMO KIT Software Downloads

- LandMark™ 10/20/30/40 VG/GPS - Download GPSGLAMR Software Rev. GlamrVGGPS_3p58.exe

GPS-AIDED AHRS SDK DEMO KIT Software Downloads

- LandMark™ 10/20/30/40 GPS/AHRS - Download GPSGLAMR Software Rev. GlamrGPSA_3p58.exe

INS/GPS SDK DEMO KIT Software Downloads

- LandMark™ 30/40 INS/GPS - Download GPSGLAMR Software Rev. GlamrINSGPSA_3p58.exe

Figure 57: SDK Software Downloads Web Page

Figure 58: Remote Desktop Support Web Page

Figure 59: Web Conferencing Web Page

16 Typical Sample Test Data

Please contact factory for sample test data. Typical data would include

- Gyro Noise Angle Random Walk (ARW)
- Accelerometer Noise Velocity Random Walk (VRW)
- Gyro In-Run Bias
- Accelerometer In-Run Bias
- Gyro Bias Over Temperature
- Accelerometer Bias Over Temperature
- Gyro Scale Factor Over Temperature
- Accelerometer Scale Factor Over Temperature
- Gyro Random Vibration VRC
- Accel Random Vibration VRC
- Magnetometer Performance in Rotation, Pitch Up/Down, +/- Roll
- ATP Spin Test: X,Y & Z Gyro Nominal Scale Factor at Ambient
- ATP Spin Test: X, Y & Z Gyro misalignment (in deg/sec and in mrad)
- ATP Temperature Tumble Test (T^3): X, Y & Z gyro and X, Y & Z accelerometer bias
- ATP Temperature Tumble Test (T^3): nominal X,Y & Z accelerometer scale factor
- ATP Temperature Tumble Test (T^3): X, Y & Z g-sensitivity (in deg/sec/g)
- ATP Temperature Tumble Test (T^3): X, Y & Z accelerometer misalignment (in mrad)
- ATP GPS: Various GPS Performance Data

17 GLOSSARY OF TERMS

Gladiator Technologies has attempted to define terms as closely as possible to the IEEE Gyro and Accelerometer Panel Standards for Inertial Sensor Terminology. Please note that in some instances our definition of a term may vary and in those instances Gladiator Technology's definition supersedes the IEEE definition. For a complete listing of IEEE's standard for inertial sensor terminology please go to www.ieee.org.

17.1 *Abbreviations and Acronyms*

6DOF: six degrees-of-freedom

AHRS: Attitude and Heading Reference System

CVG: Coriolis Vibratory Gyro

ESD: Electro Static Discharge

IEEE: The Institute of Electrical and Electronics Engineers

IMU: Inertial Measurement Unit

MEMS: Micro Electro-Mechanical Systems

NLR: No License Required

17.2 *Definitions of Terms*

Acceleration-insensitive drift rate (gyro): The component of environmentally sensitive drift rate not correlated with acceleration.
NOTE—Acceleration-insensitive drift rate includes the effects of temperature, magnetic, and other external influences.

Acceleration-sensitive drift rate (gyro): The components of systematic drift rate correlated with the first power of a linear acceleration component, typically expressed in (°/h)/g.

Accelerometer: An inertial sensor that measures linear or angular acceleration. Except where specifically stated, the term accelerometer refers to linear accelerometer.

Allan variance: A characterization of the noise and other processes in a time series of data as a function of averaging time. It is one half the mean value of the square of the difference of adjacent time averages from a time series as a function of averaging time.

Angular acceleration sensitivity:
(accelerometer): The change of output (divided by the scale factor) of a linear accelerometer that is produced per unit of angular acceleration input about a specified axis, excluding the response that is due to linear acceleration.
(gyro): The ratio of drift rate due to angular acceleration about a gyro axis to the angular acceleration causing it.
NOTE—In single-degree-of-freedom gyros, it is nominally equal to the effective moment of inertia of the gimbal assembly divided by the angular momentum.

Bias:

(accelerometer): The average over a specified time of accelerometer output measured at specified operating conditions that have no correlation with input acceleration or rotation. Bias is expressed in [m/s^2, g].
(gyro): The average over a specified time of gyro output measured at specified operating conditions that have no correlation with input rotation or acceleration. Bias is typically expressed in degrees per hour (°/h).
NOTE—Control of operating conditions may address sensitivities such as temperature, magnetic fields, and mechanical and electrical interfaces, as necessary.

Case (gyro, accelerometer): The housing or package that encloses the sensor, provides the mounting surface, and defines the reference axes.

Composite error (gyro, accelerometer): The maximum deviation of the output data from a specified output function. Composite error is due to the composite effects of hysteresis, resolution, nonlinearity, non-repeatability, and other uncertainties in the output data. It is generally expressed as a percentage of half the output span.

Coriolis acceleration: The acceleration of a particle in a coordinate frame rotating in inertial space, arising from its velocity with respect to that frame.

Coriolis vibratory gyro (CVG): A gyro based on the coupling of a structural, driven, vibrating mode into at least one other structural mode (pickoff) via Coriolis acceleration.
NOTE—CVGs may be designed to operate in open-loop, force-rebalance (i.e., closed-loop), and/or whole-angle modes.

Cross acceleration (accelerometer): The acceleration applied in a plane normal to an accelerometer input reference axis.

Cross-axis sensitivity (accelerometer): The proportionality constant that relates a variation of accelerometer output to cross acceleration. This sensitivity varies with the direction of cross acceleration and is primarily due to misalignment.

Cross-coupling errors (gyro): The errors in the gyro output resulting from gyro sensitivity to inputs about axes normal to an input reference axis.

Degree-of-freedom (DOF) (gyro): An allowable mode of angular motion of the spin axis with respect to the case. The number of degrees-of-freedom is the number of orthogonal axes about which the spin axis is free to rotate.

Drift rate (gyro): The component of gyro output that is functionally independent of input rotation. It is expressed as an angular rate

Environmentally sensitive drift rate (gyro): The component of systematic drift rate that includes acceleration-sensitive, acceleration-squared-sensitive, and acceleration-insensitive drift rates.

Full-scale input (gyro, accelerometer): The maximum magnitude of the two input limits.

G: The magnitude of the local plumb bob gravity that is used as a reference value of acceleration.
NOTE 1—g is a convenient reference used in inertial sensor calibration and testing. NOTE 2—In some applications, the standard value of g = 9.806 65 m/s^2 *may be specified.*

Gyro (gyroscope): An inertial sensor that measures angular rotation with respect to inertial space about its input axis(es).
NOTE 1—The sensing of such motion could utilize the angular momentum of a spinning rotor, the Coriolis effect on a vibrating mass, or the Sagnac effect on counter-propagating light beams in a ring laser or an optical fiber coil.

G sensitivity (gyro): the change in rate bias due to g input from any direction.

hysteresis error (gyro, accelerometer): The maximum separation due to hysteresis between upscale-going and down-scale-going indications of the measured variable (during a full-range traverse, unless otherwise specified) after transients have decayed. It is generally expressed as an equivalent input.

Inertial sensor: A position, attitude, or motion sensor whose references are completely internal, except possibly for initialization.

Input angle (gyro): The angular displacement of the case about an input axis.

Input axis (IA):
(accelerometer): The axis(es) along or about which a linear or angular acceleration input causes a maximum output.
(gyro): The axis(es) about which a rotation of the case causes a maximum output.

Input-axis misalignment (gyro, accelerometer): The angle between an input axis and its associated input reference axis when the device is at a null condition.

Input limits (gyro, accelerometer): The extreme values of the input, generally plus or minus, within which performance is of the specified accuracy.

Input range (gyro, accelerometer): The region between the input limits within which a quantity is measured, expressed by stating the lower- and upper-range value. For example, a linear displacement input range of ±1.7g to ±12g.

Input rate (gyro): The angular displacement per unit time of the case about an input axis. For example, an angular displacement input range of ±150°/sec to ±300°/sec.

Input reference axis (IRA) (gyro, accelerometer): The direction of an axis (nominally parallel to an input axis) as defined by the case mounting surfaces, or external case markings, or both.

Linear accelerometer: An inertial sensor that measures the component of translational acceleration minus the component of gravitational acceleration along its input axis(es).

Linearity error (gyro, accelerometer): The deviation of the output from a least-squares linear fit of the input-output data. It is generally expressed as a percentage of full scale, or percent of output, or both.

Mechanical freedom (accelerometer): The maximum linear or angular displacement of the accelerometer's proof mass, relative to its case.

Natural frequency (gyro, accelerometer): The frequency at which the output lags the input by 90°. It generally applies only to inertial sensors with approximate second-order response.

Non-gravitational acceleration (accelerometer): The component of the acceleration of a body that is caused by externally applied forces (excluding gravity) divided by the mass.

Nonlinearity (gyro, accelerometer): The systematic deviation from the straight line that defines the nominal input-output relationship.

Open-loop mode (Coriolis vibratory gyro): A mode in which the vibration amplitude of the pickoff is proportional to the rotation rate about the input axis(es).

Operating life (gyro, accelerometer): The accumulated time of operation throughout which a gyro or accelerometer exhibits specified performance when maintained and calibrated in accordance with a specified schedule.

Operating temperature (gyro, accelerometer): The temperature at one or more gyro or accelerometer elements when the device is in the specified operating environment.

Output range (gyro, accelerometer): The product of input range and scale factor.

Output span (gyro, accelerometer): The algebraic difference between the upper and lower values of the output range.

Pickoff (mechanical gyro, accelerometer): A device that produces an output signal as a function of the relative linear or angular displacement between two elements.

Plumb bob gravity: The force per unit mass acting on a mass at rest at a point on the earth, not including any reaction force of the suspension. The plumb bob gravity includes the gravitational attraction of the earth, the effect of the centripetal acceleration due to the earth rotation, and tidal effects. The direction of the plumb bob gravity acceleration defines the local vertical down direction, and its magnitude defines a reference value of acceleration (g).

Power spectral density (PSD): A characterization of the noise and other processes in a time series of data as a function of frequency. It is the mean squared amplitude per unit frequency of the time series. It is usually expressed in $(°/h)^2/Hz$ for gyroscope rate data or in $(m/s^2)^2/Hz$ or g2/Hz for accelerometer acceleration data.

Principal axis of compliance (gyro, accelerometer): An axis along which an applied force results in a displacement along that axis only.

Proof mass (accelerometer): The effective mass whose inertia transforms an acceleration along, or about, an input axis into a force or torque. The effective mass takes into consideration rotation and contributing parts of the suspension.

Quantization (gyro, accelerometer): The analog-to-digital conversion of a gyro or accelerometer output signal that gives an output that changes in discrete steps, as the input varies continuously.

Quantization noise (gyro, accelerometer): The random variation in the digitized output signal due to sampling and quantizing a continuous signal with a finite word length conversion. The resulting incremental error sequence is a uniformly distributed random variable over the interval 1/2 least significant bit (LSB).

Random drift rate (gyro): The random time-varying component of drift rate.

Random walk: A zero-mean Gaussian stochastic process with stationary independent increments and with standard deviation that grows as the square root of time.

Angle random walk (gyro): The angular error buildup with time that is due to white noise in angular rate. This error is typically expressed in degrees per square root of hour [$°/\sqrt{h}$].

Velocity random walk (accelerometer): The velocity error build-up with time that is due to white noise in acceleration. This error is typically expressed in meters per second per square root of hour [(m/s)/$\sqrt{h}$].

Rate gyro: A gyro whose output is proportional to its angular velocity with respect to inertial space.

Ratiometric output: An output method where the representation of the measured output quantity
(e.g., voltage, current, pulse rate, pulse width) varies in proportion to a reference quantity.

Rectification error (accelerometer): A steady-state error in the output while vibratory disturbances are acting on an accelerometer.

Repeatability (gyro, accelerometer): The closeness of agreement among repeated measurements of the same variable under the same operating conditions when changes in conditions or non-operating periods occur between measurements.

Resolution (gyro, accelerometer): The largest value of the minimum change in input, for inputs greater than the noise level, that produces a change in output equal to some specified percentage (at least 50%) of the change in output expected using the nominal scale factor.

Scale factor (gyro, accelerometer): The ratio of a change in output to a change in the input intended to be measured. Scale factor is generally evaluated as the slope of the straight line that can be fitted by the method of least squares to input-output data.

Second-order nonlinearity coefficient (accelerometer): The proportionality constant that relates a variation of the output to the square of the input, applied parallel to the input reference axis.

Sensitivity (gyro, accelerometer): The ratio of a change in output to a change in an undesirable or secondary input. For example: a scale factor temperature sensitivity of a gyro or accelerometer is the ratio of change in scale factor to a change in temperature.

Stability (gyro, accelerometer): A measure of the ability of a specific mechanism or performance coefficient to remain invariant when continuously exposed to a fixed operating condition.

Storage life (gyro, accelerometer): The non-operating time interval under specified conditions, after which a device will still exhibit a specified operating life and performance.

Strapdown (gyro, accelerometer): Direct-mounting of inertial sensors (without gimbals) to a vehicle to sense the linear and angular motion of the vehicle.

Third-order nonlinearity coefficient (accelerometer): The proportionality constant that relates a variation of the output to the cube of the input, applied parallel to the input reference axis.

Threshold (gyro, accelerometer): The largest absolute value of the minimum input that produces an output equal to at least 50% of the output expected using the nominal scale factor.

Turn-on time (gyro, accelerometer): The time from the initial application of power until a sensor produces a specified useful output, though not necessarily at the accuracy of full specification performance.

Warm-up time (gyro, accelerometer): The time from the initial application of power for a sensor to reach specified performance under specified operating conditions.

Zero offset (restricted to rate gyros): The gyro output when the input rate is zero, generally expressed as an equivalent input rate. It excludes outputs due to hysteresis and acceleration.