Attitude and Heading Reference System

AHRS-II

DEMO PROGRAM “AHRS-II DEMO”

User’s Manual

Revision 1.8
<table>
<thead>
<tr>
<th>Revision</th>
<th>Date</th>
<th>Author</th>
<th>Description</th>
</tr>
</thead>
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<tr>
<td>1.0</td>
<td>Jul.03, 2015</td>
<td>AK</td>
<td>Released version.</td>
</tr>
<tr>
<td>1.1</td>
<td>Jul.15, 2015</td>
<td>ON</td>
<td>1. Updated “Device Options” window (Fig.4.2). 2. Added explanation text to section “4.4. Swaying compensation”. 3. Deleted section “4.5. VR sensor options”. 4. Changed information about other items of the Run menu in section 5.5. 5. Added description of “Open” item from “File” menu in section 6.1. 6. Deleted field “Mag_interf” in sect.10.4.2, Table 10.1 7. Added Fig.D.1. Coordinate system of the Inertial Labs™ AHRS-II to Appendix D.</td>
</tr>
<tr>
<td>1.2</td>
<td>Aug.06, 2015</td>
<td>ON</td>
<td>Realized auto start option that allows start of AHRS-II operation and data output in NMEA format after device power on (since AHRS-II firmware version 1.0.1.8.).</td>
</tr>
<tr>
<td>1.3</td>
<td>Aug.26, 2015</td>
<td>ON</td>
<td>Implemented auto start option with choice of desirable variant of output data format after device power on (since AHRS-II firmware version 1.0.2.0.).</td>
</tr>
<tr>
<td>1.4</td>
<td>Aug.31, 2015</td>
<td>CS</td>
<td>Grammar, spelling, and formatting review</td>
</tr>
<tr>
<td>1.5</td>
<td>Oct.22,2015</td>
<td>AK</td>
<td>For AHRS-II Demo version 2.0.13.48 and higher.  1. Updated “Device options” windows (Fig.4.2, Fig.4.5) 2. Added section “4.5. Magnetometers calibration options”. 3. Updated section “10.2. Features of Altitude and Heave calculation”. 4. Parameters of adaptive algorithm of heave calculation are added to “Correction options” window (Fig.4.12) and described in section “10.2.1. Adjustment of the algorithm of heave calculation” (affected since AHRS-II firmware version 2.0.1.2).</td>
</tr>
</tbody>
</table>
| 1.6      | Nov.26, 2015 | AK     | 1. Added “The most important notes” section.  2. For AHRS-II Demo version 2.0.13.49 and higher – GNSS receiver tab in the “Device options” menu was hidden therefore section “4.2.2. GNSS receiver tab” was removed. 3. Fig.4.2 and Fig.4.5 changed due to item 2. 4. Corrected TSS1 data format description in Appendix “B.2. Text presentation of output data formats”.
<p>| 1.7      | Feb.05,2016   | AK     | 1. Added possibility of automatic creation of new data folder for each run, see section 4.1 (for AHRS-II Demo |</p>
<table>
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<th>Version</th>
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<th>Location</th>
<th>Changes</th>
</tr>
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| 1.8     | Mar.24, 2016 | AK, ON   | 1. Added new output data format “AHRS-II Quaternion Data” and its description – for AHRS-II Demo version 2.0.18.71 from 02/26/2016 and higher.  
2. Added sections “4.2.3. Change of the COM port baud rate” and “4.2.4. Limitation of the AHRS-II maximum measurement rate” – for AHRS-II Demo version 2.0.19.78 from 03/18/2016 and higher.  
3. Added APPENDIX B. Installation of the MOXA Serial-to-USB converter drivers (for AHRS-II with RS-422 interface). |
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Inertial Labs, Inc™ Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com
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Introduction

This manual is designed to review over the software and uses of the Inertial Labs™ AHRS-II.

Use of the AHRS-II should be restricted to only those who have read its user manual and are following the safety measures specified in that user manual.

Fig. 1.1. Inertial Labs™ AHRS-II
## The most important notes

<table>
<thead>
<tr>
<th>Subject</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>To view and edit AHRS-II parameters</td>
<td>AHRS-II must be connected to computer and powered. Serial port number to which AHRS-II is connected and its baud rate should be chosen in the “Test options” menu (see section 4.1).</td>
</tr>
<tr>
<td>Measurement rate</td>
<td>It can be changed in the “Device options” menu, but it must not exceed maximum value shown in the Table 4.1 (see section 4.2.1).</td>
</tr>
<tr>
<td>Object hard and soft iron compensation</td>
<td>Do not forget to calibrate AHRS-II on hard and soft iron after mounting on carrier object (see section 10.3).</td>
</tr>
<tr>
<td>True or magnetic heading</td>
<td>If the magnetic declination is set correctly then AHRS-II outputs true heading, if magnetic declination is set to zero then AHRS-II outputs magnetic heading (see section 4.2.1).</td>
</tr>
<tr>
<td>Altitude or heave calculation</td>
<td>User can select kind of vertical position measurement – altitude or heave (for marine applications). See section 10.2.</td>
</tr>
<tr>
<td>Pressure sensor</td>
<td>If the AHRS-II has no access to the ambient external pressure (for example, if it is installed inside a pressurized cabin) or if the AHRS-II pressure sensor can be exposed to speed air streams, please uncheck the “Baro-altimeter enabled” checkbox in the &quot;Pressure sensor&quot; tab &quot; of &quot;Device options&quot; menu. In such case the AHRS-II doesn’t measure altitude, but heave still can be calculated though with a bit less accuracy.</td>
</tr>
<tr>
<td>To increase measurement accuracy at object swaying</td>
<td>Use “Swaying compensation options…” from the “Options” menu (see section 4.4).</td>
</tr>
<tr>
<td>Automatic start</td>
<td>AHRS-II has ability to start operation automatically after power on, with continuous output data in desirable output data format (see section 10.5).</td>
</tr>
</tbody>
</table>
1. General information

Operating system. This version of the Demo software is fully compatible with Microsoft XP, Vista, 7, and 8.1.

Working with the software. The “Inertial Labs AHRS-II Demo” software is a Win32 application, and keyboard and mouse are required to use it. The directory structure necessary to store data is created by the user. All necessary configuration and calibration coefficients are stored in the AHRS-II in nonvolatile memory and are automatically loaded into the AHRS-II microprocessor. Calibration coefficients are set by the AHRS-II developer, and should only be changed under the guidance of the AHRS-II developer. When the “Inertial Labs AHRS-II Demo” software is closed, it creates a file named default .prm file for its operation, which it uses to store the latest parameters of the microprocessor and shell. When working with the AHRS-II, the system will automatically create files with the extensions .prm, .dat, and .bin when saving text or graphical data. Additionally, the operator can create files with the extensions .txt and .rtf.

Requirements to the system resources. The software requires 6 Mbytes of RAM for proper operation. It requires approximately 25 Mbytes of hard drive space for the demo software files, and additional space for files saved during operation (usually no more than 100 Mbytes). The recommended minimum screen resolution is 1280x1024 pixels. The AHRS-II is connected to the PC through either a COM port or a USB port when using the COM-to-USB converter. If using a COM-to-USB converter, reliability of signal reception/transmission between a PC and the AHRS-II can depend greatly on the quality of the COM-to-USB converter and on correct configuration of its driver. AHRS-II manufacturer guarantees reliable operation of the AHRS-II if it is connected directly to the COM port. Appendix A contains descriptions for installation and configuration of drivers for one of the possible COM-to-USB converters.

Requirements to operators. The AHRS-II Demo software uses a standard Windows operating system. Therefore, operators should know the basic principles of PC operation to use the Demo software, and they should be able to use the Windows operating system.
2. Installation of drivers and configuration of PC parameters

The “Inertial Labs AHRS-II Demo” software does not require any installation. Just copy the software folder to the working directory and launch the application.

If you connect the AHRS-II to a standard computer COM port, drivers are not needed. If the AHRS-II is connected to a USB port with a COM-to-USB converter see “Appendix A. Installation of the COM-to-USB converter drivers and configuration of PC parameters” for more details.

If you use the AHRS-II with RS-422 interface you need to install RS422-to-USB converter driver. See “Appendix B. Installation of the MOXA Serial-to-USB converter drivers (for AHRS-II with RS-422 interface)”

To know the numbers of the PC COM ports click «Device Manager» in the «Hardware» tab of the «System Properties» window (Fig.2.1). In the opened «Device Manager» window (Fig.2.2) you will see the COM ports which will be marked as «Communications Port (COMN)» or «USB Serial Port (COMN)» or «MOXA USB Serial Port (COMN)». Number N in the port name is assigned by OS.
3. Main menu of the program

The main menu of the “Inertial Labs AHRS-II Demo” software contains the following items (see Fig.3.1).

**File** Menu contains standard Windows file management commands (Fig.3.2).

**Run** Menu contains the AHRS-II control commands (Fig.3.3).

**Parameters** Menu contains operations with AHRS-II parameters (Fig.3.4).

**Plugins** Menu contains the AHRS-II Demo plugins (Fig.3.5).

**Convert** Menu contains conversion of binary data to the text format (Fig.3.6).

**Options** Menu contains the AHRS-II configuration commands (Fig.3.7).
Icons for the most often used commands are placed on toolbars.

**Run:**
- AHRS-II visualization, F4;
- Stop AHRS-II;

**Parameters:**
- Save parameters;
- Restore parameters;

**Convert:**
- Report of experiment, F8;

**Options:**
- Test options…;
- Device options…;
- Correction options…;
- Swaying compensation options;
- Magnetometers calibration options.
4. Options Menu

4.1. Test options

To set operation parameters of the AHRS-II, COM port, format of output data, select «Test options...» (Fig.3.7) from the «Options» menu (or click button). A «Test Options» dialog box (Fig.4.1) will be opened.

![Test Options dialog box](image)

Fig.4.1

You can set the following parameters in the «Test Options» window:

- Serial port – is the COM port number to which AHRS-II is connected.
- Baud rate – is the set rate of computer COM port for connection of AHRS-II unit

- Allow data saving checkbox – allows to record the test data to file. If it is unchecked then no file will be created and no message «Data are writing in file» will be displayed.

- Enable debug log – allows recording to the log file of a test run. In case of the AHRS-II Demo crash it can be used to debug errors. The log file contains information about commands that were sent by the AHRS-II Demo and errors that appeared. In case of errors this file should be sent to the Inertial Labs with a brief description of user actions.

- Allow auto start checkbox – allows operation with AHRS-II which was already started before the running of the AHRS-II Demo software. See section 10.5 for details.

- Create separate run folder – allows automatic creation of separate data folder for each run. On default this option is disabled.

- Record time – sets data recording time in hours:minutes:seconds format. The parameter is active when data is being saved to file. Values of hours, minutes, seconds can be changed with the arrows or by entering the required value from a keyboard.

- Number data for average – the quantity of averaged data. This can be used for smoothing of viewed data. Note that averaging relates to the data output on the screen only and is not applied to the data written in a file. The minimal value for the parameter is 1 and changed with the arrows to ±1 or by entering the required value from a keyboard. The default value is 1.

- Operating Mode – defines AHRS-II’s output method, Continuous or stepped On Request. The default value is Continuous.

- Output Data Format – sets format of the AHRS-II output data. Select one of the formats: «AHRS-II Full Output», «AHRS-II Calibrated Data», «AHRS-II Quaternion Data», «AHRS-II Minimal Data», «AHRS-II NMEA», «TSS1». For more information on the output data format see Appendix C. The default value is «AHRS-II Calibrated Data» output format.
4.2. Devices options

To set and control of AHRS-II operation parameters, select «Devices options…» from the «Options» menu (Fig.3.7), or click button (Fig.3.1). A «Devices Options» (Fig.4.2) dialog box will be opened. There are two tabs “IMU” and “Pressure sensor”.

![Device Options Window](Fig.4.2)

4.2.1. “IMU” tab

There are options for the Inertial Measurement Unit (IMU). You can check or set the following parameters in the “IMU” tab of the «Devices Options» window Fig.4.2:

- IMU type is "AHRS". This parameter cannot be changed.
- COM Port bps – sets baud rate of the AHRS-II COM port (see section “4.2.3. Change of the COM port baud rate” for details).
- Measurement rate (Hz) – sets data measurement rate in Hertz. Minimal value of the parameter is 1, maximal value is 200; it is changed with
the arrows to ±10 or by entering the required value from a keyboard. Default value is set to 100.

**Important note:** the maximum measurement rate is limited by chosen baud rate of the COM port which the AHRS-II unit is connected to, and also it depends on chosen output data format (see Fig.4.1) because of different number of transferred bytes. See section “4.2.4. Limitation of the AHRS-II maximum measurement rate” for details.

- Initial alignment time (sec) – sets the initial alignment time in seconds. The AHRS-II output data will be displayed in its respective windows only after the time set in this parameter is over. During initial alignment the AHRS-II must be absolutely stationary relative to the Earth. Minimum value of the parameter is 1 and it can be changed to ±1 with arrows or by entering the necessary value from a keyboard. Default value is set to 30.

- IMU name – specifies the name of the IMU inside the AHRS-II unit. This parameter cannot be changed.

- AHRS-II name – specifies the name of the AHRS-II in use. This parameter cannot be changed.

- Device firmware version – the firmware version of the AHRS-II in use. It consists of symbols of the firmware type, firmware version and date of this version issue separated by blanks. This parameter cannot be changed.

- Magnetic declination (deg.) – magnetic declination at the place where the AHRS-II operates. The parameter value is changed by entering the required value from a keyboard or by automatic calculation by click on «Auto» button, using Latitude, Longitude, Altitude and Date values. Default value of the magnetic declination is set to 0.

**Notes:**


2. If the magnetic declination is set correctly then AHRS-II outputs **true heading**, if magnetic declination is set to zero then AHRS-II outputs **magnetic heading**.

- Latitude (deg.) – latitude of the AHRS-II operating location.

- Longitude (deg.) – longitude of the AHRS-II operational location.
- Altitude (meters) – altitude above sea level of the AHRS-II operational location.

- Date – day, month and year when the AHRS-II is used.

**Note:** You need to set current latitude, longitude, altitude, year, month, day only if you want to calculate magnetic declination for current place or to calibrate the AHRS-II.

- Alignment angles (deg.) – angles between the AHRS-II axes and the carrier object are set after AHRS-II mounting, see “Appendix E. Variants of the Inertial Labs™ AHRS-II mounting relative to object axes”. Default values are set to 0 degrees.

- Vertical position – specifies variant of vertical position calculation (see Fig.4.3). Default value is “Relative altitude”. See section 10.2 for details.

![Vertical position](Fig.4.3)

- Auto start – enables or disables automatic start of the AHRS-II and data output after power on without any command from the host computer. Specifies output data format See section 10.5 for details.

Before working with the «Options» menu, it is desirable to select «Stop AHRS-II» in the «Run» menu or press F7 key (Fig.3.3).

**Note:** you can select «Device option…» item only if AHRS-II is powered and connected to computer, and COM port number and its baud rate are chosen properly. In the other case the error window with message «Cannot read parameters!» appears over above window (see Fig.4.4). Click «OK», then close «Device Options» window and choose the correct COM port number (see section 4.1. Test options).
4.2.2. “Pressure sensor” tab

There are settings for the pressure sensor that is used for altitude calculation in the AHRS-II (see Fig.4.5).

![Fig.4.4](image)

You can set the following parameters in the “Pressure sensor” tab of «Devices Options» window:

- “Baro-altimeter enabled” checkbox – allows to enable or disable using of the pressure sensor for calculation of barometric altitude. On default it is enabled.
Calibration coefficients are used for calculation of pressure and temperature using raw data from the pressure sensor. These coefficients can't be changed.

See section 10.2. Features of Altitude and Heave calculation in the AHRS-II, for more detailed explanation of operations with the pressure sensor.

4.2.3. Change of the COM port baud rate

The default baud rate for AHRS-II COM port is set to 115200 bps (maximum for the standard COM-port). If the host computer requires other baud rate for the AHRS-II connection, then user can choose one from the next list: 4800, 9600, 14400, 19200, 38400, 57600, 115200, 230400, 460800, 921600 bps. The same baud rate must be set in the «Test Options» of the AHRS-II Demo Program.

Notes:
1. Baud rate change is implemented in the AHRS-II firmware version since 2.2.0.0 and it is supported by AHRS-II Demo Program since version 2.0.19.78 from 03/18/2016.
2. To allow baud rate change the AHRS-II unit must be connected to computer and powered.
3. Standard COM-port of a host computer (PC) does not support baud rate greater than 115200 bps. Therefore some Serial-to-USB adapter should be used for AHRS-II connection to the host computer.
4. Baud rate must be set the same both for AHRS-II unit and in the AHRS-II Demo Program to allow this software to control AHRS-II unit.

At the first, set correct COM port baud rate in the «Test Options» (see Fig.4.1). It must be the same as it set in the AHRS-II unit. If COM port baud rate in the AHRS-II unit is unknown then click «Auto» button. After several seconds window with caption “Serial port baud rate XXXXXX was successfully determined” will appear (see Fig.4.5) and determined baud rate will appear in the «Test Options» window.
To change COM port baud rate in the AHRS-II unit go to the «Devices Options», “IMU” tab (see Fig.4.2) and choose necessary baud rate from the list as Fig.4.6 shows.

After the baud rate choice click «OK» button to load changed parameters to the AHRS-II nonvolatile memory. Then the information windows shown on the Fig.4.7 and Fig.4.8 appear. Click «OK» button to close these windows. Note COM port baud rate in the «Test Options» will change to chosen value, too, to keep communication between the AHRS-II Demo software and AHRS-II unit.
4.2.4. Limitation of the AHRS-II maximum measurement rate

When setting of the measurement rate for the AHRS-II unit in the «Devices Options», “IMU” tab (see Fig.4.2) it is essential to ensure the chosen baud rate is capable of handling the data throughput with desirable data rate. The maximum measurement rate (Hz) can be calculated using the baud rate and data package length:

$$\text{max\_meas\_rate} = \frac{\text{COM\_baud\_rate}}{\text{bits\_per\_byte} \times \text{package\_length}},$$  \hspace{1cm} (4.1)

where COM\_baud\_rate is COM port baud rate (bits/s); bits\_per\_byte = 11 bits per one transferred byte of data; package\_length for binary data = payload length plus 8 bytes of overhead. See Appendix C, Table C.1 to Table C.4 for payload length of binary output data formats. The package\_length of the text output data formats correspond to their structure shown in Appendix C.

Table 4.1 contains data package length for each output data format and also maximum measurement rate calculated using formula (4.1), with some spare. Note the maximum measurement rate of AHRS-II data is limited by 200 Hz.

<table>
<thead>
<tr>
<th>Output data format</th>
<th>Data package length, bytes</th>
<th>COM-port baud rate, bps</th>
<th>Maximum measurement rate, Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHRS-II Full Output Data</td>
<td>52+8</td>
<td>10 20 50 115200 230400</td>
<td>160 200</td>
</tr>
<tr>
<td>AHRS-II Calibrated Data</td>
<td>54+8</td>
<td>10 20 50 115200 230400</td>
<td>160 200</td>
</tr>
<tr>
<td>AHRS-II Quaternion Data</td>
<td>56+8</td>
<td>10 20 50 115200 230400</td>
<td>160 200</td>
</tr>
<tr>
<td>AHRS-II Minimal Data</td>
<td>34+8</td>
<td>20 40 80 115200 230400</td>
<td>200 200</td>
</tr>
<tr>
<td>NMEA Output</td>
<td>58</td>
<td>10 30 60 115200 230400</td>
<td>180 200</td>
</tr>
<tr>
<td>TSS1 Output</td>
<td>27</td>
<td>30 60 120 115200 230400</td>
<td>200 200</td>
</tr>
</tbody>
</table>

AHRS-II Demo Program controls correctness of the measurement rate setting. If user sets measurement rate in the «Devices Options» (see
Fig. 4.2) which exceeds limits shown in Table 4.1, then warning window Fig. 4.9 appears.

![Warning Window](image)

**Fig. 4.9**

Click “Yes” button to correct entered measurement rate or “No” to ignore this warning. The last case makes sense if user wants to choose another output data format in the «Test Options» with less length of data package. But in any case AHRS-II controls acceptable measurement rate onboard at start to not allow excess of maximum value.

If user choose output data format in the «Test Options» window that does not match to set measurement rate then warning window Fig. 4.10 appears.

![Warning Window](image)

**Fig. 4.10**
4.3. Correction options

There are parameters for adjustment of the AHRS-II algorithm of orientation and altitude calculation. Select "Correction options..." from the «Options» menu (Fig.3.7), or click button (Fig.3.1). A «Correction Options» dialog window will be opened (see Fig.4.11). There are three tabs:

- “Kalman filter” tab contains parameters for Kalman filter used in the AHRS-II algorithm (see Fig.4.11). Please don’t change any parameters in this tab without agreement with Inertial Labs.

- “Heave calculation” tab contains parameters for algorithm of heave calculation (see Fig.4.12).

- “Additional” tab contains “Extrapolation time” parameter (see Fig.4.13). Since AHRS-II Demo Software ver.2.0.15 from 01/15/2016 it is possible to use prediction of orientation angles for time which is specified in “Extrapolation time” parameter. Extrapolation adds noise to the signal therefore it should be used only on tests with smooth motion.

See section 10.2. Features of Altitude and Heave calculation in the AHRS-II, for detailed explanation of parameters in the “Heave calculation” tab.
Fig. 4.11

Fig. 4.12
4.4. Swaying compensation

It is possible to increase the AHRS-II accuracy at object swaying if to compensate linear acceleration at place of the AHRS-II mounting. For this purpose select «Swaying compensation options...» from the «Options» menu (Fig.3.7) or click button (Fig.3.1). A «Swaying compensation options» dialog box (Fig.4.14) will be opened that allow you to set the lever of the AHRS-II mounting relative to the center of the object Swaying (usually this is object center of gravity).

The lever must be set in the carrier object axes – on the right, forward and up. If after the AHRS-II mounting its axes X, Y, Z are parallel to the carrier object lateral, longitudinal and vertical axes, then the AHRS-II position should be measured in the directions of the AHRS-II X, Y and Z axes. If the AHRS-II unit is mounted on the object in another known position (up to upside-down, upright etc., see Appendix E. Variants of the Inertial Labs™ AHRS-II mounting relative to the object axes), then set the AHRS-II position just in the object axes (on the right, forward and up directions), but not in the AHRS-II axes.
4.5. Magnetometers calibration options

The Inertial Labs AHRS-II software allows compensation of influence of the carrier object hard and soft iron on the heading angle calculation accuracy. For this purpose, calibration of the AHRS-II magnetometers is provided. It is necessary to set group of parameters “Magnetometers field calibration”. For this purpose select «Magnetometers calibration options...» from the «Options» menu (Fig.3.7) or click button (Fig.3.1). A «Magnetometers calibration options» dialog box (Fig.4.15) will be opened that allow you to set the level of the AHRS-II mounting relative to the center of the object Swaying (usually this is object center of gravity).

![Magnetometers calibration options dialog box]

- **Start with** – specifies with what set of calibration parameters the AHRS-II starts. There are four sets: “Last AHRS-II Clb”, “Factory Clb”, “2D-2T, 3D, 2D Clb”. Usually “Start with” parameter is set automatically after last calibration performed.

- **Mag Disp threshold** specifies calibration data that should be deleted from calibration procedure because of AHRS-II was not moved at this procedure. Default value 1000 nT^2 is set by developers and can be changed after agreement with them.

- **Inclination threshold** is valid for 2D and 2D-2T calibration types and determines acceptable pitch and roll deviation from their median in the calibration run. AHRS-II data over this threshold are not used at calculation.
of calibration parameters. Default value is 1.5 degrees. This parameter can be changed after agreement with developer.

- Success threshold is acceptable value of magnetic field calibration error to have successful result of the 3D calibration if its accuracy cannot be estimated in degrees. Default value is 2500 nT. This parameter can be changed after agreement with developer.

The next thresholds in the right part of the “Magnetometers calibration on hard & soft iron” section are used to estimate the calibration quality in terms of possible AHRS-II heading accuracy:

- H-filter time constant is parameter for filtration of measured horizontal component of the Earth magnetic field. Default value is 0.6 seconds.
- Pitch/Roll threshold is used for detection of control circuit in the 3D calibration procedure. Default value is 20 degrees.

See section 10.3. Calibration of the AHRS-II for detailed description of Magnetometers calibration procedure.
5. Run Menu

Control of the AHRS-II is done by the commands in the “Run” menu (Fig.3.3). This menu contains next items:

- “AHRS-II visualization” opens appropriate tab with different variants of visualization of the AHRS-II operation;
- “Stop AHRS-II” stops the AHRS-II;
- “Device Information” shows main information about connected device;
- “Get BIT” opens tab with the AHRS-II Built-in-Test (BIT) status (temperature and the USW, see Appendix D. The Unit Status Word definition).

There are four styles of visualization of the AHRS-II outputs:

- AHRS-II 3D Demo;
- Cockpit;
- Snapshots (for the on-the-fly accuracy test);
- Data graphs.

5.1. AHRS-II 3D Demo

“AHRS-II 3D Demo” is default variant of the AHRS-II visualization in which current orientation angles of the AHRS-II are shown as spatial orientation of an airplane (see Fig.5.1). To go to this visualization stile select “AHRS-II visualization” from the “Run” menu (Fig.3.3), select ▶️ on the toolbar, or press F4 button.

Some additional 3D models may be used for visualization of the AHRS-II orientation (see below Section 11. Choice of 3D model for visualization of the AHRS-II orientation).
In the opened “AHRS-II visualization” tab, four control buttons (active “Start” and inactive yet: “Stop”, “Write” and “Snapshot”) appear in the left vertical toolbar. If the “On Request” option is chosen in the “Test Options” menu, then the “Request” button appears inactive. Two icons appear in the status bar: “Warnings” and “Failures”.

Warning and failure messages are generated by AHRS-II in its Unit Status Word (see Appendix C) and appear near icons. You can close these messages by clicking on them.

“AHRS-II visualization” tab consists from two vertical parts. Visualization panel of the AHRS-II outputs is situated on the left part of the tab. The right part displays text data from AHRS-II and additional information, it is the same for all visualization styles.

“Start” button starts the AHRS-II with parameters saved in the AHRS-II’s microprocessor. Next initial alignment of the AHRS-II is performed with
displayed message “Initial alignment. Please wait”. Also a progress bar of initial alignment will appear in the status line of the main window. During the initial alignment the AHRS-II has to be stationary relative to the Earth. Once the initial alignment time is over, observe changes in numeric data and graphical evolutions of an object.

**Note.** For visual convenience of the AHRS-II position perception displayed on the monitor and the AHRS-II real position, it is recommended to place the AHRS-II in parallel with the monitor before the beginning of work as follows: direct lateral axis X to the monitor and direct longitudinal axis Y in parallel with the monitor on the left.

Once the “Start” button is pressed, buttons “Stop”, “Write”, and “Snapshot” become active. If the “On Request” option was chosen in the “Test Options” menu, then the button “Request” becomes active too.

Upon clicking the “Write” button the measured data is saved, which is signified by the message «Data are writing in file!» in the text part of the window. Note that the data are saved in binary file and can be used in two ways:

- visualization through opening the file in “File” menu (see item 10.1.1. Data viewer);
- conversion to text file using “Report of experiment” from “Convert” menu item.

The “Stop” button stops data output to the screen and data saving procedure with no data losses.

The “Snapshot” button is used for fixing the current values of measured data during continuous run (see item 8.3.2. On-the-fly accuracy test).

If in the menu “Options” the data output method “On Request” is chosen, then getting data from the AHRS-II is performed by clicking the button. In case of data saving (if the “Write” button is pressed), the measured data are written in one file sequentially.

Current orientation angles are displayed in the upper right part of the tab (Fig.5.1). Additional displayed data depend on selected output data format.
(see Appendix B for details). If the “AHRS-II Calibrated data“ format is chosen then next data are displayed in the right part of the tab (Fig.5.1):

a) Orientation angles “Heading”, “Pitch” and “Roll”. In the “AHRS-II” column, angles calculated in the AHRS-II’s microprocessor using the embedded main algorithm are output. The “Magn/Acc” column shows orientation angles calculated in the AHRS-II Demo Software using simplified algorithms based on magnetometers and accelerometers data. Angles in the “Magn/Acc” column are auxiliary; they are used by developers only to control operation of the main algorithm.

Note: If the magnetic declination is set correctly in the «Device Options» (see Fig.4.2) then AHRS-II outputs true heading, if magnetic declination is set to zero then AHRS-II outputs magnetic heading.

b) Output signals of the AHRS-II sensors: “Rate (deg/sec)“ – angular rate values in deg/sec measured by angular rate sensors, “Accel (g)“ – linear acceleration values in g measured by accelerometers, “Magn (nT)“ – magnetic field intensity values measured by magnetometers in nT. Originally all sensors data are in AHRS-II axes (X is lateral axis, Y is longitudinal axis, Z is vertical axis). Axes X, Y, Z are object axes if non-zero alignment angles are set for AHRS-II mounting (see Appendix E. Variants of the Inertial Labs™ AHRS-II mounting relative to object axes).

c) Total measured magnetic field value in nT “Total magnetic field“.

d) Current temperature “Temperature (degC)“ inside the AHRS-II.

e) The set value of the magnetic declination “Mdec (deg)“.

f) Input supply voltage of the AHRS-II in VDC “Vinp (V)“.

g) Format of output data “Output Data Format: …“. This format is set by operator in the «Test Option» window (Fig.4.1).

h) Current mode of the AHRS-II operation (Readiness or Sleep).

i) Linear motion “Altitude” (or “Heave”), “Surge”, “Sway” (m).

j) Linear rate on “Altitude” (or “Heave”), “Surge”, “Sway” (m/s).

k) Barometric data: “Press.” – pressure (Pa), “Alt.” – altitude (m). Note “Temp.” – temperature (deg C) is shown only at the “AHRS-II Full Output “ data format,
To stop data output from the AHRS-II click the “Stop“ button ．

To leave the AHRS-II visualization mode click the  in the title of current tab.

For other styles of visualization of the AHRS-II outputs there are clickable previews in the upper part of the “AHRS-II visualization” tab (Fig.5.2). It is possible to switch between visualization styles at any time of the AHRS-II operation by simple clicking on its preview.

![Fig.5.2](image-url)
5.2. Cockpit style of visualization

“Cockpit” window allows to show current attitude of the AHRS-II in “Cockpit display” style (see Fig.5.3). To switch visualization to this mode click on preview shown in the Fig.5.2b and window shown in the Fig.5.3 will appear.

There is heading indicator in the upper left corner of the tab. In the center part of the tab an attitude indicator (artificial horizon) is shown. Its vertical scale corresponds to pitch, limb corresponds to roll.

To switch to other than “Cockpit” style click on appropriate preview in the upper part of the “AHRS-II visualization” tab (Fig.5.2).

To stop data output from the AHRS-II click the “Stop” button  

![Fig.5.3](image-url)
5.3. On-the-fly accuracy style of visualization

“On-the-fly accuracy” feature is designed for checking the AHRS-II accuracy during its ordinary operation when the AHRS-II can be directed to points with known orientation.

To switch visualization to this mode click on preview shown in the Fig.5.2c and window shown in the Fig.5.4 will appear.

For more information about this type of visualization see section "10.4.2. On-the-fly accuracy test".

![Fig.5.4](image-url)
5.4. Data graphs style of visualization

“Data graphs” window allows to show graphs of current AHRS-II outputs (see Fig.5.5). To switch visualization to this mode click on preview shown in the Fig.5.2d and window shown in the Fig.5.5 will appear.

It is possible to select the signals you want to display by right-click on the graphs area. As a result window shown in the Fig.5.6 will appear.

Plotted graphs are scalable. To zoom in click and hold the left button on the mouse and drag mouse in down-right direction. Click and hold right button on mouse to shift plot. To zoom out click and hold the left button on the mouse and drag mouse in up-left direction. The legend is located in the upper left corner of the tab. This legend shows mean value, STD and the names of displayed signals.
You can select or deselect signals by clicking on their titles:

- **AHRS-II heading (deg)** – plots Heading angle calculated in the AHRS-II, in degrees;
- **AHRS-II pitch (deg)** – plots Pitch angle calculated in the AHRS-II, in degrees;
- **AHRS-II roll (deg)** – plots Roll angle calculated in the AHRS-II, in degrees;
- **Mag/Acc heading (deg)** – plots Heading angle calculated in the AHRS-II Demo Software based on the AHRS-II magnetometers and accelerometers data, in degrees;
- **Accel pitch (deg)** – plots Pitch angle calculated in the AHRS-II Demo Software based on the AHRS-II accelerometers data, in degrees;
- **Accel roll (deg)** – plots Roll angle calculated in the AHRS-II Demo Software based on the AHRS-II accelerometers data, in degrees;
- **Gyro X (deg/sec)** – plots output signal of the gyro X in deg/sec;
- **Gyro Y (deg/sec)** – plots output signal of the gyro Y in deg/sec;
- **Gyro Z (deg/sec)** – plots output signal of the gyro Z in deg/sec;
- **Accelerometer X (g)** – plots output data of the accelerometer X in g;
- **Accelerometer Y (g)** – plots output data of the accelerometer Y in g;
- **Accelerometer Z (g)** – plots output data of the accelerometer Z in g;
- **Magnetometer X (nT)** – plots output data of the magnetometer X in nT;
- **Magnetometer Y (nT)** – plots output data of the magnetometer Y in nT;
- **Magnetometer Z (nT)** – plots output data of the magnetometer Z in nT;
- **Magnetic module (nT)** – plots full module of the measured magnetic-field vector in nT;
- **Temperature (deg C)** – plots current temperature inside the AHRS-II in Celsius degrees;
- **Linear motion altitude (m)** – plots linear motion altitude in meters;
- **Linear motion surge (m)** – plots linear motion surge in meters;
- **Linear motion sway (m)** – plots linear motion sway in meters;
- Baro Temp. (degC) – plots barometric temperature in Celsius degrees;
- Baro Press. (Pa) – plots barometric pressure in Pa;
- Baro Alt. (m) – plots barometric altitude in meters.

5.5. Other items of the Run menu

- **Stop AHRS-II** – stops the AHRS-II. In most cases it is used for correct termination of completed operations. For this command the hot key F7 can be also pressed or the button ❌ can be clicked.

- **Device Information** – opens tab with the AHRS-II main information: integrated device (AHRS-II) serial number and firmware version; AHRS serial number and firmware version; parameters of GNSS receiver; GPS reference week number; pressure sensor presence (see Fig.5.7).

Note the Inertial Labs™ AHRS-II does not include GNSS receiver, so related fields in the Device Information on Fig.5.7 are empty, and GPS reference week number = 0. If you need in AHRS with GNSS receiver please order the Inertial Labs™ INS.

![Fig.5.7](image-url)
6. File Menu

“File” menu enable to work with already saved tests results. There are such items in the "File" menu:

- “Open”;
- “Save as”;
- “Exit”.

6.1. “Open” item

You can visualize data saved to files during an AHRS-II run. To open the saved *.bin file choose the “Open” option (Fig.3.2) or press F3. The standard window Windows “Open…” will appear, in which it is necessary to choose needed *.bin file saved previously when the AHRS was operating in its standard mode. After selection of file, data are read from it and new tab “Data viewer” shown in the Fig.6.1 will open. It is possible to select the data you want to display by right-click on the graphs area. As a result window shown in the Fig.5.6 will appear where you can select or deselect showed data by clicking on their titles.

![Fig.6.1](image-url)
Plotted graphs are scalable. To zoom in please click and hold left button on mouse and drag mouse in down-right direction. To zoom out please click and hold left button on mouse and drag mouse in up-left direction. Click and hold right button on mouse to drag the plot.

Legend is located at the left upper corner of the tab. This legend shows mean value, STD (standard deviation) and name of displayed data.

To close graphs please click the icon in the title of current tab.

6.2. “Save as” item

You can preset the name of the file for data writing. For this select the “Save as” item (Fig.3.2) and enter a desirable file name.

7. Parameters menu

“Parameters” menu enables working with the AHRS-II parameters. There are the following items in the “Parameters” menu:

- Load block parameters;
- Read block parameters;
- Restore parameters;
- Save parameters;
- Preset parameters.

7.1. “Load block parameters” and “Read block parameters” items

These items are used to check operation of appropriate commands of the AHRS-II. AHRS-II Demo software allows more convenient means to load the AHRS-II parameters to the AHRS-II nonvolatile memory (see section 7.2).
7.2. Restore parameters

“Restore parameters” command (see Fig.3.4) is used to quickly load the AHRS-II parameters to the AHRS-II nonvolatile memory. When «Restore parameters» command is selected, or button is clicked, a standard Windows «Open» window opens; in this window operator selects one of the previously saved files with .prm extension. Consequently, the parameters are automatically saved to the AHRS-II nonvolatile memory and to the Demo-Program shell. The same way is used to restore the factory settings of the AHRS-II parameters. In this case you should select original file with .prm extension that comes on CD with Inertial Labs AHRS-II.

7.3. Save parameters

If you have changed some parameters of the AHRS-II (in «Device options…» window from the «Options» menu or other menus), and you want to save these parameters as variant for future work, you can save the AHRS-II current parameters in binary file with .prm extension. For this use «Save parameters» command (see Fig.3.4) or click button. After that a standard Windows «Save as …» window is opened; in this window operator is suggested to save current parameters of the AHRS-II to a «File of parameters» with .prm extension.

7.4. Preset parameters

In the Inertial Labs AHRS-II Demo ver.14.7.9.14 it provides presets of the AHRS-II parameters that adjust AHRS-II algorithm for some specific conditions of operations to get better dynamic accuracy of the AHRS-II. The latest AHRS-II Demo version contains preset parameters for the next conditions of the AHRS-II operations:

- Ordinary device parameters;
- Marine device parameters;
- Operation at vibrations;
- Loaded from file.

To modify AHRS-II parameters select “Preset parameters” item from the «Parameters» menu (Fig.3.4). The window Fig.7.1 will be opened. Select one of variants of the AHRS-II operations and click “OK” to update the AHRS-II parameters according to selected variant.
**Note:** you are able to apply “Preset parameter variants” only if the AHRS-II is powered and connected to computer, and COM port number and its baud rate are chosen properly.

![Preset parameter variants](image)

**Fig.7.1**

**Ordinary device parameters** correspond to those loaded in the AHRS-II by manufacturer and provides correct AHRS-II operation in the most of applications. The original file with .prm extension that comes on CD with the Inertial Labs AHRS-II also contains parameters of the AHRS-II algorithm for ordinary AHRS-II operation.

**Marine device parameters** provides accurate initial alignment of the AHRS-II at _slow_ swaying vehicle. Note that ordinary algorithm parameters require AHRS-II stationary during the initial alignment procedure (see section “10.1. The main operation modes of the AHRS-II”). The initial alignment procedure of the AHRS-II with “marine parameters” takes 90 seconds. During this period don’t accelerate the AHRS-II, only slow swaying is admissible.

Parameters for the AHRS-II operation at _vibrations_ allows to get better dynamic accuracy of the AHRS-II at intensive vibrations than ordinary parameters of the AHRS-II algorithm. Possible shortcoming of the “vibration parameters” is decreasing of the AHRS-II dynamic accuracy at long-duration accelerations of the vehicle.

Please pay attention to possibility of increasing the AHRS-II accuracy with respect to object swaying via compensation for linear acceleration at the
location of the AHRS-II mounting (see section “4.4. Swaying compensation”).

Loaded from file item allows to adjust the AHRS-II algorithm for specific conditions of operation that are not in the list of variants shown on Fig.7.1. In such case Inertial Labs can provide additional .prm file with specific set of the AHRS-II parameters. Select the “Loaded from file” check box to load parameters of specific algorithm from .prm file without changing the individual AHRS-II parameters. Then “Load Parameters” button appears (see Fig.7.2).

![Fig.7.2](image)

Click on the “Load Parameters” button. The standard window Windows “Open…” menu will appear, in which it is necessary to choose needed file with *.prm extension. After selecting the file, two checkboxes “IMU” and “AHRS-II” will appear in the “Preset parameters” window (Fig.7.3).

Then “IMU” or (and) “AHRS-II” checkbox should be chosen. Click “OK” button to load chosen parameters from file to the AHRS-II. After that parameters are loaded the information window shown on the Fig.7.4 appears.

Or you can click the “Cancel” button to close “Preset parameters” window without loading parameters.
Note: It is possible to use “Loaded from file” item since AHRS-II Demo Software ver.15.0.60 from 01/26/2016.
8. Plugins Menu

"Plugins" menu enable to run additional parts of the Demo software. There are such items in the "Plugins" menu:

- Embedded;
- Mag field calibration;
- Angles accuracy.

8.1. Embedded

The AHRS-II Demo software allows taking into account influence of the soft and hard iron of the carrier object on the heading calculation accuracy. For this purpose, field calibration of the AHRS-II magnetometers is provided. There are two ways to calibrate the AHRS-II: to use AHRS-II embedded procedures or procedures provided by AHRS-II Demo software.

The last way is more convenient (see section 6.2. Magnetometers field calibration). For AHRS-II embedded calibration procedure the “Embedded” menu item is used. As a result of selection of this item the "Embedded Mag Field Calibration" window will appear (see Fig.8.1).

![Fig.8.1](image-url)
Buttons on the toolbar are used to send commands for the AHRS-II calibration that are described in the AHRS-II ICD. Below is list of these buttons and corresponding commands:

<table>
<thead>
<tr>
<th>Icon</th>
<th>Command</th>
<th>Command code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Get</td>
<td>GetClbRes</td>
<td>0x2A</td>
<td>Views the last calibration results stored in the AHRS-II memory</td>
</tr>
<tr>
<td>Clear</td>
<td>ClearClb</td>
<td>0x2F</td>
<td>Clears calibration parameters</td>
</tr>
<tr>
<td>Read</td>
<td>–</td>
<td>–</td>
<td>Reads out the AHRS-II flash memory</td>
</tr>
<tr>
<td>Start</td>
<td>Start2DClb</td>
<td>0x21</td>
<td>Starts the 2D calibration</td>
</tr>
<tr>
<td></td>
<td>Start2D2TClb</td>
<td>0x22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Start3DClb</td>
<td>0x23</td>
<td></td>
</tr>
<tr>
<td>StopRun</td>
<td>StopClbRun</td>
<td>0x20</td>
<td>Early stops data accumulation in the calibration run before set accumulation time is reached</td>
</tr>
<tr>
<td>Next</td>
<td>StartClbRun</td>
<td>0x2B</td>
<td>Starts new run of the 2D-2T calibration</td>
</tr>
<tr>
<td>FinishClb</td>
<td>FinishClb</td>
<td>0x2C</td>
<td>Finishes the calibration procedure with multiple runs (like 2D-2T)</td>
</tr>
<tr>
<td>Accept</td>
<td>AcceptClb</td>
<td>0x2E</td>
<td>To accept the calibration parameters and to save them to the AHRS-II nonvolatile memory</td>
</tr>
<tr>
<td>Exit</td>
<td>ExitClb</td>
<td>0xFE</td>
<td>To exit from the calibration without calculations and saving calibration parameters</td>
</tr>
<tr>
<td>Clear response</td>
<td>–</td>
<td>–</td>
<td>Clears the response window</td>
</tr>
<tr>
<td>Save response</td>
<td>–</td>
<td>–</td>
<td>Saves data from the response window to *.log file</td>
</tr>
</tbody>
</table>

**Note:** Command code in this table is payload of the command with 9-bytes structure.
When the AHRS-II answers on above commands then these answers appear in the Response window (see Fig.8.2).

Different buttons will be active depending on calibration type.

See additional document for detailed description of the embedded calibration procedures.

8.2. Magnetometers field calibration

Another and more convenient way for AHRS-II hard and soft iron calibration is provided by AHRS-II Demo software.

Before calibration please check in the «Test Options» dialog box (Fig.4.1) correct COM port number to which the AHRS-II is connected.

To start the calibration select “Plugins” menu and then “Mag Field Calibration” item (see Fig.3.4) from the main menu. “Mag Field Calibration” window will open (see Fig.8.3).
Important note. For correct calibration it is necessary to set right coordinates “Latitude”, “Longitude”, “Altitude” and “Date” in accordance with place where AHRS-II is calibrated. Their values are set in the «Device Options» window (see Fig.4.2).

Fig.8.3

In the “Calibration Type” field choose from a list the type of the calibration – 2D, 2D-2T or 3D (see section 10.3 for explanation of these types).

The “Accumulation Time” field in window Fig.8.3 sets the time which is necessary to perform calibration procedure including at least one full 360° turn rotation in horizon plane (at least 2 full turns are recommended). This time can be set using arrows or by entering the necessary value from a keyboard. The default value is 60.

In “Calibration status” window the captions are highlighted that show current states of AHRS-II calibration and actions that can be performed.

See section 10.3 for detailed description of the AHRS-II calibration procedure.
If place of the AHRS-II mounting on the carrier object is changed, or if the carrier is changed, then calibration matrices for magnetometer biases and scale factors in AHRS-II memory should be cleared by clicking on the «Clear» button (see Fig.8.3).

8.3. Angles accuracy

To check accuracy of the AHRS-II set precisely its attitude in orientation angles with the help of special equipment and compare orientation angles produced by AHRS-II with the set angles.

To start the accuracy check select “Plugins” menu and then “Angles accuracy” item (Fig.3.4) from the main menu. After that the next window will appear (see Fig.8.4).

Fig.8.4

In a pulldown list in the left top corner there is the capability to choose an orientation angle (Heading, Pitch or Roll) on which the AHRS-II will be tested. Depending on the chosen parameter the accuracy check window name which is shown in the Fig.8.4 will change.
The check for the AHRS-II heading (azimuth) angle accuracy is carried out by rotating the AHRS-II around the vertical on angles specified in the column “Angles” Fig.8.4.

The check for AHRS-II pitch angle accuracy is carried out by rotating the AHRS-II around the horizontally located lateral axis X of the AHRS-II on angles specified in the column “Angles” (see Fig.8.4). It is necessary to note that the accuracy control in angles 90°, 270° and close to them is not carried out because of uncertainty of two other orientation angles – Heading and Roll in this position.

The check for roll angle accuracy is carried out by rotating the AHRS-II around the horizontally located longitudinal axis Y of the AHRS-II on angles specified in the column “Angles” (see Fig.8.4).

In the left part of check accuracy window there is a button “Devices”, by clicking on which the window “Devices Properties” is opened (see Fig.8.5). In this window the operator in line “Number of Devices” sets the necessary quantity of simultaneously tested AHRS-II units. The minimal size of parameter 1 changes on $\pm 1$ by means of arrows or by keyboard necessary value input. The size by default is 1. Then in the column “COM-port” the operator chooses in dropdown list “COMN” to which the AHRS-II units are connected and in a column “Baud rate” he chooses COM-port speed which has the default value 115200 bps.

After that the operator clicks the button “Scan”. The Demo software serially polls specified COM-ports, and in column “Device Name” names of found AHRS-II units are displayed and button “OK” becomes active. By clicking the button “OK” (see Fig.8.5) names found in window “Devices Properties” are transferred to the left of a check accuracy window (Fig.8.4) instead of label “NoName”. Clicking the button “Cancel” or button “X” closes the window “Devices Properties” Fig.8.5.

In a check accuracy window there are control buttons. The button “Angles” opens the window “Angles Properties” Fig.8.6, in which the operator sets the necessary time “Accumulation Time” of data acquisition while the measurement in each position of the AHRS-II, checks accuracy angles “Accuracy checking points” and chooses the sensor, with the help of which the temperature control “Temperature Sensor” will be carried out. The minimal size of parameter “Accumulation Time” 1 changes on $\pm 1$ with the
help of arrows or by means of necessary value keyboard input. The default value is 20.

During accuracy tests it is possible to take into account misalignment angles of the AHRS-II installation on a test bench platform on which AHRS-II is tested. Such a situation is possible if during AHRS-II installation on a test bench platform intermediate adaptations are used, for example a tilter. If deviation angles of the tilter adjusting bases for AHRS-II relatively to test bench platform are known, they are necessary for considering at accuracy check. For this purpose “Tilter” fields are used in the right bottom window corner Fig.8.4. Here it is possible:

- “(None)” is not to consider deviations of bases;
- “(Auto)” is to consider deviations for tilter used for Inertial Labs internal tests “Tilter Ne” and a corresponding cell (“Position”) in this tilter;
- “(Manual)” is to consider manually bases deviation angles on corresponding angles “\( \psi \)”, “\( \theta \)” и “\( \gamma \)”. 
Fields “Tilter” are used by the developer for internal tests of the AHRS-II. The question on their use for external tests should be coordinated with the developer – Inertial Labs company.

The button “Accumulate Data” (see Fig.8.4) consistently starts AHRS-II units for operation. Automatically, in the top part of the check accuracy window the page “Current angle, deg” opens in which in the form of the graph the current measured angle (Heading, Pitch or Roll) is plotted. Upon completion of data collecting there is an averaging the measured data and switching on a following controllable angle, and in a folder where there is file AHRS-II_Demo.exe, the file of the report like Accuracy_*.txt is kept. It is a service file which can be used for continuation of testing AHRS-II after any possible failure in work. In that case for loading the previous measured data the button “Load Data” is used.

**Notes.**

1. The filename Accuracy_*.txt consists of the word Accuracy_ and 8-12 numbers of year, month, date, hour and minutes when the work was carrying out.
2. The button “Load Data” opens the standard window Windows “Open…”, in which it is necessary to choose and download a file Accuracy_*.txt with the last measured data.

In the pages “Heading, deg”, “Pitch, deg”, “Roll, deg”, “Temperature, codes” the current same AHRS-II parameters are displayed in the form of graphs.

After the end of the accuracy test cycle the page “Angle Error, deg” is opened automatically, where Angle is Heading, Pitch or Roll, depending on the angle on where the test was carried out. In the page window the graph of given angle calculation error is displayed, and the minimal and maximal error values during the test, its root-mean-square value (RMS) are indicated. Also standard deviation (STD) of measurement noise at last position of the AHRS-II is displayed.

**Note.** Page “Current Heading, deg” changes its name on “Current Pitch, deg” or “Current Roll, deg” and the page “Heading Error, deg” changes its name on “Pitch Error, deg” “Roll Error, deg” depending on the chosen controlled parameter in left top corner of the window “Accuracy” (see Fig.8.4).
9. Convert Menu

There is one item «Report of experiment» which is used to convert saved binary data to text file.

When «Report of experiment» item is selected, or button is clicked, or F8 button is pressed (see Fig.3.6), a standard Windows «Open» window is opened. In this window operator selects one of the *.bin files saved previously when the AHRS-II was operating in its ordinary mode. Consequently, a report file with same name but with .txt extension is created. Note that file with an extension .prm and the same name as .bin should be present as well.

The «Report of experiment» creates text file according to the output data format of data in the binary *.bin file. The necessary data format is set by user in the «Test Options» window. A description of the text file is done in the “Appendix C.2. Text presentation of output data formats”.
10. The AHRS-II operation

10.1. The main operation modes of the AHRS-II

Step 1. Connect a power cable and data transfer cable to the AHRS-II. Connect the other end of the data transfer cable to either COM port or USB port of the host computer. If connection between the computer and the AHRS-II is done through a USB port, a driver for a COM-to-USB converter needs to be installed. See Appendix A ‘Installation of the COM-to-USB converter drivers and configuration of PC parameters’ for details on the installation procedure. If it is connected to a standard PC COM port, then there are no needs to install any drivers. Note that AHRS-II manufacturer guarantees reliable operation of the AHRS-II if it is connected directly to the COM port.

Step 2. Start AHRS-II_Demo.exe file to begin working with the Demo software. The main menu will appear (Fig.3.1).

Step 3. Select «Test options…» from the «Options» menu (see Fig.3.7) or click button. «Test option» window (Fig.4.1) will open.

Step 4. Set the correct COM port number in the «Serial port» field and its baud rate as Fig.4.1 shows.

Step 5. (Not obligatory) In «Test option» window (Fig.4.1), if you need, you can set «Record time» of data writing when data is being saved to file and «Number data for average» (the quantity of averaged data) that can be used for smoothing of viewed data. Note that averaging relates to the data output on the screen only and is not applied to the data written in a file.

Note: For the number of the COM port to which the AHRS-II is connected, see «2. Installation of drivers and configuration of the PC parameters» and «Appendix A. Installation of the COM-to-USB converter drivers and configuration of the PC parameters».

Step 6. In «Test option» window (Fig.4.1) set (check) data output mode in the «Operating Mode» group, and also «Output Data Format» (see Appendix B for more information on the output data format). Click «OK».

Step 7. (Not obligatory) If you want to change some parameters of the AHRS-II or its operation select «Device options…» or «Swaying
compensation options...» from the «Options» menu – see Fig.3.7. Appropriate window (Fig.4.2 or Fig.4.13) will open. Set the necessary AHRS-II operation parameters. Click «OK».

Step 8. Select «AHRS-II Visualization» from the «Run» menu (Fig.3.3) or click button on the toolbar, or press F4. The window shown in Fig.5.1 will appear. You can switch to other visualization style by clicking on its preview on the tab. Depending on the selected style windows shown in Fig.5.3 – Fig.5.5 will appear.

Step 9. Click the «Start» button. Initial alignment of the AHRS-II will start. This is signified by the message «Initial alignment. Please wait». Also a progress bar of initial alignment will appear in the status line of the main window. During the initial alignment the AHRS-II has to be stationary relative to the Earth. Once the initial alignment time is over, observe changes in numeric data and graphical evolutions of the object.

Note: For visual convenience of AHRS-II position perception displayed on the monitor and the AHRS-II real position, it is recommended to place the AHRS-II in parallel with the monitor before the beginning of work as follows: direct lateral axis X to the monitor and direct longitudinal axis Y in parallel with the monitor on the left.

Step 10. If you have selected the «On Request» operating mode, click the «Request» button to get data from the AHRS-II each time if you want. Observe changes in numeric data and graphical evolutions of the object.

Step 11. To save data click «Write» button. Caption «Data are writing in file!» will appear. Also a progress bar of data writing and timer will appear in the status line of the main window.

In the «On Request» operating mode data is written in a file sequentially with the each click of the «Request» button.

Note: To allow data sawing the appropriate checkbox should be set in the «Test Options» window (see Fig.4.1).

Step 12. To stop the AHRS-II click the «Stop» button. If the data were being written to a file then the writing is stopped too.

The default directory for saved files is the “data” subdirectory placed in the directory where the file AHRS-II_Demo_*.exe is located. The default name
of the file with saved data is generated automatically and consists of the
AHRS-II serial number, date and time digits separated by dash symbols
where the first 4 digits are the year, the next 2 digits are the month, then 2
digits of day, next digits are hours, minutes and seconds of operation start.
When saving the data, two files of the same name with .bin and .prm
extensions are saved in the specified folder. In .bin files the measured data
is saved, and in .prm files the AHRS-II microprocessor parameters, at which
this data was obtained, are saved. For example, A1240013-2012-11-20-12-
14-26.bin corresponds to data saved from the AHRS-II s/n A1240013 on

Note. You can preset name of file for data writing. For this select item «Save as» in the
«File» menu and enter desirable file name.

Step 13. Repeat Step 9 – Step 12 as many times as you need.
Step 14. To close standard operation mode window (Fig.5.1 – Fig.5.5)
click the icon in the title of current tab.
Step 15. Select «Stop AHRS-II» (Fig.3.3) from the «Run» menu, or
click button.

To get the saved data as text file, do the following:

(Fig.3.6) or press F8 in the main menu or click button (Fig.3.1). A
standard Windows «Open» window will open.

Step 17. Select the necessary file with extension .bin. Click «OK».
A .txt file will be created with the same name and in the same folder as the
selected .bin file, with format set in Step 6.

Note. When large file data is processed then some time is necessary for text file saving.
If you will start new operations with Demo software before end of text file saving, then
Demo software will appear as not responding or locked. Just wait some time for saving
end, after that Demo software will be unlocked.

Also you can plot saved AHRS-II binary data using “File” menu. See
section 6.1 for more details.
10.2. Features of Altitude and Heave calculation in the AHRS-II

At its operation the AHRS-II calculates altitude and heave.

Altitude is calculated in the AHRS-II Kalman filter using accelerometers and orientation data with correction from barometric altitude calculated using pressure sensor data. Note the relation between altitude and pressure is dependent on many factors, the most important is the “weather”. At calculation of the barometric altitude the AHRS-II compares measured pressure to the reference pressure – static atmospheric pressure $P_0$ at mean sea level, that unfortunately varies with weather change.

Therefore AHRS-II uses two variants of the barometric altitude calculation:

a) absolute barometric altitude at the standard pressure $P_0=101325$ Pa at sea level;
b) barometric altitude at known initial altitude stored in the AHRS-II nonvolatile memory. This minimizes error of the reference pressure.

Initial altitude is set in the “IMU” tab of the «Devices Options» window (see Fig.4.2).

Also the AHRS-II calculates heave for marine applications. Heave is a ship motion along the vertical axis.

All output data formats (see Fig.4.1 and Appendix B) contain data about either altitude or heave depending on the switch “Barometric altitude” in the “Pressure sensor” tab of the «Devices Options» window (see Fig.4.2).

- “Absolute” – output of absolute barometric altitude at the pressure 101325 Pa at sea level;
- “At known initial value” – output of barometric altitude at known initial altitude stored in the AHRS-II nonvolatile memory;
- “Heave” – output of heave.

Default variant is altitude output “At known initial value”.

Important note: to measure barometric altitude the pressure sensor in the AHRS-II must have access to the ambient external pressure. Also the pressure sensor must not be exposed to high speed air streams. So if the AHRS-II is installed inside a pressurized cabin or outside the high-speed object, measured altitude will be wrong. In that case deselect the check-box “Baro-altimeter enabled” in the “Pressure sensor” tab of «Devices Options» window Fig.4.4. In such case the AHRS-II doesn’t measure altitude, but heave still can be calculated though with a bit less accuracy.
10.2.1. Adjustment of the algorithm of heave calculation

To calculate the heave as the AHRS-II vertical position with respect to its equilibrium position, the vertical acceleration is doubly integrated. However, because signals from accelerometers always contain a DC component as well as spurious low frequency components, after integration the heave error is accumulated and increases with time significantly. To avoid such error, integrated signals are filtered by High-Pass (HP) filter. Also, to decrease noise the Low-Pass (LP) filter can be applied.

Values of HP and LP cutoff frequencies, \( f_{h,\text{HP}} \) and \( f_{h,\text{LP}} \) for the heave filter can be set in the “Heave calculation” tab of the «Correction Options» window (see Fig.4.12).

The main adjustment parameter is cutoff frequency for heave HP filter, \( f_{h,\text{HP}} \). It must be much less than the main frequency of a ship vertical motion. But very low value of the \( f_{h,\text{HP}} \) allow accelerometers’ bias instability to affect the heave accuracy. The default value is \( f_{h,\text{HP}} = 0.05 \text{ Hz} \) that should be enough for intensive vertical motion of a ship.

Value of the \( f_{h,\text{LP}} \) must be not less than \( f_{h,\text{HP}} \).

For switch-off HP or LP filter please set to zero appropriate cutoff frequency \( f_{h,\text{HP}} \) or \( f_{h,\text{LP}} \). The default values are \( f_{h,\text{HP}} = 0.05 \text{ Hz} \); \( f_{h,\text{LP}} = 0 \).

The “Target position relative to the IMU (m)” parameters determine the position of target relative to the IMU in meters.

Since firmware version 2.0.1.2 it is possible to use the adaptive algorithm of heave calculation. For that purpose set parameters in the “FFT Settings” field.

\( \text{Power}_\text{fft\_min} \) - the threshold of fast Fourier transform (FFT) spectrum power at which the lead-lag filter parameters are recalculated. \( F_{\text{fft}} \) parameter sets the frequency of the FFT usage for lead-lag filter parameters recalculation. The default values are \( \text{Power}_\text{fft\_min} = 10 \) and \( F_{\text{fft}} = 0.04 \).

**Notes**

1. The FFT settings can be changed, but only under guidance of the AHRS-II developer.
2. Initialization of the adaptive algorithm takes approximately 100 seconds. During this initialization heave is calculated roughly.
10.2.2. Heave calculation for chosen point of the carrier object

Usually heave is calculated for place of the AHRS-II mounting on the carrier object. But it is possible to set desirable point on the carrier object for heave calculation. For this purpose please set coordinates of this point relative to the AHRS-II position, in the object axes – on the right, forward and up – in the “Heave calculation” tab of the «Correction Options» window (see Fig.4.12).

10.3. Calibration of the AHRS-II

For correct operation of the AHRS-II it is necessary that the calibrated sensors are not distorted by external influences. It is particularly important to provide non-distortion of the AHRS-II magnetic channel, as, due to the presence of the carrier’s hard and soft iron in the vicinity to the AHRS-II, its magnetometers will be outputting inaccurate data on the actual Earth magnetic intensity vector, and, accordingly, inaccurate carrier’s heading angle value.

The Inertial Labs AHRS-II software allows compensation of influence of the carrier object soft and hard iron on the heading angle calculation accuracy. For this purpose, field calibration of the AHRS-II magnetometers is provided. This calibration does not require any additional equipment, but it requires turns of the carries object on which the AHRS-II is mounted.

The AHRS-II can be calibrated using 2D, 3D or 2D-2T calibration procedure.

2D calibration is designed for carrier objects that move with small pitch and roll angles (not more than a few degrees). The calibration procedure involves a few full 360° rotations in the horizon plane of the carrier object with the installed AHRS-II (see Fig.10.1). During this calibration pitch and roll angles must be as close to zero as possible.

3D calibration is designed for carrier objects that can operate with large pitch and roll angles. For this calibration the carrier object is rotated in the horizon plane (the Z-axis is up) with periodical stops about each 90 degrees for tilting in pitch and roll (see Fig.10.1 – Fig.10.3). After full 360° rotation the object with the AHRS-II is turned over (the Z-axis is down) and the
procedure described above should be repeated. During this calibration the range of pitch and roll angles changing must be as much as possible.

2D-2T calibration is designed instead of 3D calibration for carrier object that operates with limited range of pitch and roll angles. This calibration involves several (two or more) 2D calibration procedures but with different pitch angles. During every 2D calibration run with set pitch angle, tilt angles must be constant as possible. In the calibration those AHRS-II readings are used only in which pitch and roll differ from their median not more than inclination threshold set in appropriate field Fig.4.3.
10.3.1. Description of the 2D, 3D and 2D-2T calibration procedures

Step 1 – Step 2. Perform Step 1 – Step 2 from the item 10.1.

Step 3. Set correct coordinates "Latitude", "Longitude", "Altitude" and "Date" in accordance with place where AHRS-II is calibrated. Their values are set in the «Device Options» window (see Fig.4.2).

Step 4. Select «Mag Field Calibration» item from the «Plugins» menu (Fig.3.4). «Mag Field Calibration» window (Fig.10.2) will open.

Step 5. Select «2D», «2D-2T», or «3D» calibration from drop-down list in the «Calibration Type» field.

Step 6. Using arrows or entering the necessary value from a keyboard set the time required for accumulating data which would be sufficient to accomplish the calibration procedure, in the «Accumulation time» window. Please set time which is enough for 1…3 full 360° turns of the carrier object in horizon plane. Usually 60 seconds for 2D calibration and 120 sec for 3D calibration are enough.
Step 7. Click «Start» button. In “Calibration status” window a few captions are highlighted (see Fig.10.4):

![Magnetic field calibrations](image)

**Fig.10.4**

IS_STARTED – reports that calibration procedure is started;
NEXT_REQUESTED – asks to click the «Next» button to start the calibration run;
STOP_REQUESTED – informs you can click «Stop» button to stop calibration run;
EXIT_REQUESTED – informs you can click «Exit» button to exit from the calibration procedure.

Step 8. Press “Next” button. Initial alignment of the AHRS-II will start, signified by the highlighted caption **INIT_ALIGMENT** (see Fig.10.5). During the initial alignment, the **AHRS-II should be stationary relative to the Earth.**
Once the initial alignment is completed, the AHRS-II starts accumulating data. This is signified by the highlighted caption \textbf{DATA\_ACCUMULATING} and the progress bar of data accumulation in the status line (see Fig.10.6). At this time, rotation of the carrier object with the AHRS-II should be made.

If the \textbf{2D calibration} is chosen then rotation of the object with the AHRS-II in the horizon plane should be performed (see Fig.10.1). After time of the data accumulation expires then result window will appear (see Fig.10.7)
For **3D calibration** the carrier object is rotated in the horizon plane (the Z-axis is up) with periodical stops about each 90 degrees for tilting in pitch and roll (see Fig.10.1 – Fig.10.3), and then the carrier with the AHRS-II is turned over (the Z-axis is down) and the procedure described above should be repeated. Tilt angles range depends on the carrier object, but to obtain the better result increase the angles range as much as possible.

**Note:** the AHRS-II Demo Software provides estimation of 3D calibration quality in terms of possible AHRS-II heading accuracy. To allow this possibility it is necessary to include additional rotation of the AHRS-II with the carrier object in the horizon plane on about 360 degrees or more with pitch and roll near the level. Acceptable pitch and roll change are set by the “Pitch/Roll threshold” parameter in the “Device Options” window Fig.4.2.

After time of the data accumulation expires then result window will appear (see Fig.10.7).

Result window Fig.10.7 includes the next information:

- success of the calibration;
- calibration error is predicted maximum (3 sigma) heading error of the AHRS-II at accepting the calibration;
- used points is percent of accumulated data used at calculations.
The **2D-2T calibration** consists of several runs. Set the object with the AHRS-II to specific pitch angle (for example, to the minimum pitch angle). Rotate object in azimuth with approximately constant pitch and roll. After time of the first run of the AHRS-II rotation will be reached result window will appear (see Fig.10.8). Based on the calibration accuracy it is necessary to accept or decline this run. Then it is necessary to set the AHRS-II to the next pitch angle and repeat calibration procedure as the next run.

Quality of the 3D calibration will be estimated in terms «Excellent calibration!», «Good calibration» or «Acceptable calibration» (see Fig.10.9) instead of predicted AHRS-II heading error if 3D calibration run did not include additional rotation of the AHRS-II in the horizon plane on about 360 degrees or more with pitch and roll near the level (see above Note).
If the AHRS-II detected not successful initial alignment or other mistakes in AHRS-II operation, then the error like «Non-zero USW was detected 0000000000000001» appears Fig.10.10. Meaning of other non-zero bits of USW see in Appendix D. The Unit Status Word definition. In case of non-zero USW the calibration run should be not accepted.

If calibration quality is acceptable caption ACCEPT_REQUESTED is highlighted (see Fig.10.11).

If the AHRS-II detected not successful initial alignment or other mistakes in AHRS-II operation, then repeat Step 8.

For the next run of the 2D-2T calibration the object with AHRS-II should be turned to the next pitch angle. Click «Next» button on window Fig.10.11 and repeat calibration procedure as in the second stage.

2D-2T calibration allows making as many stages with different pitch angles as needed.

Note: Rotation of the object with the AHRS-II in the horizon plane both for 2D, 2D-2T and 3D calibration must include one or more full 360° turns. Please, correct the time required for saving data in the «Accumulation time» window to attain necessary rotations.
Step 9. Once the data accumulation time is over at 2D, 3D calibration, or 2D-2T calibration is stopped after any stage, then window Fig.10.11 appears where graphs of errors before and after calibration are shown. Plotted graphs are scalable. To zoom in please click and hold left button on mouse and drag mouse in down-right direction. Click and hold right button on mouse to shift plot. To zoom out please click and hold left button on mouse and drag mouse in up-left direction. Legend is located at the left upper corner of the tab. This legend shows mean value, STD and name of displayed graphs. It is possible to select the graphs you want to display by right-click on the graphs area.

Step 10. Estimate the calibration quality. If the calibration was successful and predicted heading accuracy is acceptable on window Fig.8.8 or captions «Excellent calibration!» or «Good calibration» appear in the window Fig.10.9, then click «Accept» button (Fig.10.11) to accept calibration parameters. «Acceptable calibration» caption is satisfactory too but we recommend to recalibrate the AHRS-II.

There are two highlighted captions:
ACCEPt_REQUESTED – informs you can click «Accept» button to accept calibration parameters; EXIT_REQUESTED – informs you can click «Exit» button to exit from the calibration procedure without saving of calibration parameters.

If to click the «Accept» button, then calibration matrix of the magnetometer biases and scale factors will be calculated and saved to the AHRS-II nonvolatile memory automatically.

If calibration results were accepted then in the directory in which the AHRS-II_Demo.exe file is located, files with .prm, and .amd extensions will be created.

**Notes.**

1. Filename consists of the AHRS-II serial number, text _MagField_ and 6 digits that indicates time when the file was saved (2 digits of hours, 2 digits of minutes, 2 digits of seconds). The last symbols in filename corresponds to type of the performed calibration: _2D_ corresponds to data of 2D calibration; _3D_ – for 3D calibration; _2D_2T_ – for 2D_2T calibration. Example of files name: 106A0016_MagField_140838_2D.prm, 106A0016_MagField_140838_2D.amd.

2. Default directory for saved files is “data” subdirectory placed in the directory where file AHRS-II_Demo_*.exe is located.

Step 11. If the calibration is unsuccessful, then window Fig.10.12 appears with a caption «Unsuccessful calibration. Try again!».

One reason for unsuccessful calibration may be small range of angles of the AHRS-II real rotation. In this case a caption «Calibration failure! Rotation of the device is required!» appears (see Fig.10.13). To avoid this please repeat calibration procedure with rotation of the AHRS-II as it is described in the beginning of this section. Some more reasons of unsuccessful calibration are discussed in the section “10.3.3.Conditions of successful calibration of the AHRS-II”.

![Fig.10.12](image-url)
Step 12. If you want to finish the calibration without accepting of calibration result click «Exit» button on the calibration window. Calculated calibration parameters are not saved to the AHRS-II nonvolatile memory and no files are created with calibration results.

Step 13. Click « ✓ » button to close the calibration window.

10.3.2. Clearing of the soft and hard iron calibration parameters

To remove results of magnetometers field calibration from the AHRS-II memory, follow Step 1, Step 2 from the item 10.1. Then select «Mag Field Calibration» item from the «Plugins» menu and click the «Clear» button in opened window (see Fig.8.3). Soft and hard iron calibration parameters will be removed from AHRS-II memory. The window with message «Magnetic field calibration parameters were cleared successfully!» appears over above window (see Fig.10.14). Click «OK» and close calibration window.

After parameters removing the file *.prm will be created with name *_CLEAR.prm (for example 106A0016_MagField_115942_CLEAR.prm).

You must clear parameters of the soft and hard iron calibration if you uninstall the AHRS-II from carrier object to avoid incorrect heading calculation. Please remember that performed soft and hard iron calibration is valid until the AHRS-II is mounted on the object with which the calibration was performed.
When calibration was accepted then during operation with AHRS-II in the “AHRS-II visualization” window (see Fig.7.1) a capture “Soft/hard iron corrected” appears in the lower right part of this window. If calibration parameters are cleared in the AHRS-II, then capture “Soft/hard iron corrected” disappears.

**10.3.3. Conditions of successful calibration of the AHRS-II**

Success of the AHRS-II calibration on soft and hard iron of the carrier object essentially depends on magnetic environment at the place where this calibration is performed.

The best results will be got if calibration is performed in homogeneous magnetic environment where the magnetic force lines are parallel to each other. In this case only influence of the carrier object on the AHRS-II magnetometers take place, and this influence can be compensated after calibration procedure.
However, magnetic environment often is not homogeneous at place where calibration of the AHRS-II is performed. This may lead to degradation of the calibration results since AHRS-II magnetometers are disturbed both by iron of the carrier object and by curved outward magnetic field. In this case it may be very difficult to separate influence of these 2 disturbance sources on the AHRS-II.

Inertial Labs engineers have develop special calibration procedure for separation of these sources of magnetic disturbance to take into account and compensate just influence of the magnetic field of the carrier object. But residual influence of non-uniformity of environmental magnetic field may still decrease calibration accuracy. After a lot of experiments Inertial Labs engineers have determined acceptable limits of non-uniformity of environmental magnetic field at which the AHRS-II heading accuracy after calibration is satisfactory.

If the AHRS-II calibration procedure was performed in the strict accordance with procedure described in section 10.3 but calibration is unsuccessful, then place of the calibration has large distortion of the Earth uniform magnetic field. To repair this problem please change place of the calibration. For example, usually bad places for the calibration are office room, laboratory with large quantity of computers and other electronics equipment, road with underground communications or pipelines, place near electric mains, etc.

But even in bad magnetic environment the calibration can be successful if the AHRS-II rotates around its magnetometers (around the point about 15 mm away from the AHRS-II forward end). In this case influence of non-uniformity of environmental magnetic field is minimal.

Finally, please remember that if the carrier object is changed or if place of the AHRS-II mounting on the carrier object is changed, the new calibration should be performed. If the AHRS-II will be used alone without mounting on any object then calibration results should be cleared by clicking on the «Clear» button (see Fig.8.3).
10.4. Accuracy test of the AHRS-II

To check AHRS-II accuracy it is recommended to use “Inertial Labs AHRS-II Demo” software, which allows to estimate accuracy of a AHRS-II in given range of orientation angles. At the same time it is necessary to use special device allowing to set angular positions of the AHRS-II strong with respect to tested angles. The AHRS-II should be rotated just in plane of one of its base surfaces.

The “Inertial Labs AHRS-II Demo” software allows two variants of AHRS-II accuracy test:

- **Angles accuracy**, at which the AHRS-II restarts each time after it set on new reference angle;

- **On-the-fly accuracy** when AHRS-II operates continuously at setting and changing of reference angles (See section "5.3. On-the-fly accuracy style of visualization").

“Angles accuracy” is more convenient for further analysis. In this case separate data file is created for each tested AHRS-II position. “On-the-fly accuracy” is designed for continuous AHRS-II operation at it setting to different reference angles. This have sense at magnetic interference tests, for example.

### 10.4.1. Separate accuracy test for each reference angle

Step 1. Carefully set AHRS-II by two reference surfaces on platform of the test bench designed for accuracy check.

Step 2 - Step 5 – Perform Step 1 - Step 4 from the item 10.1.

Step 6. Select “Angles Accuracy” from the ”Plugins” menu (Fig.3.4). Accuracy check window will appear (Fig.8.4). In the left upper corner of the dropdown window choose orientation angle (Heading, Pitch or Roll) for the AHRS-II testing.

Step 7. Click the «Devices…» button. «Devices Properties…» window (Fig.8.5) will appear.

Step 8. Select required amount of the tested AHRS-II units in «Number of Devices» field.
Step 9. In the column «COM-port» in dropdown windows «COMN» choose COM-ports to which the AHRS-II units are connected. Click «Scan» button. In the column «Device Name» AHRS-II units are determined in accordance with chosen COM-ports. Button «OK» becomes active.

Step 10. If all AHRS-II units under test successfully determined, click the «OK» button. The «Devices Properties…» window will close and found connected AHRS-IIs will appear in the accuracy check window instead of label “NoName”.

Step 11. If orientation angles of the AHRS-II indicated in the column «Angles…» correspond to angles with which testing will be carried out, then this step can be omitted. Otherwise, click the button “Angles” and window “Accuracy Properties” will appear (see Fig.8.6), in which the operator sets check accuracy angles “Accuracy checking points”, the necessary time “Accumulation Time” of data collecting while the measurement in each position of the AHRS-II, and chooses (if necessary) «Temperature Sensor» for the temperature control.

Step 12. If angles of obliquity of the AHRS-II set on the test bench platform are known, input their values in fields of the «Tilter» window.

Step 13. With the help of special setup device set sequentially angular positions of the AHRS-II in accordance with the values indicated in «Angles» column. Then click on “Accumulate Data” button to start AHRS-II. See in the window the behavior of AHRS-II angle. After time of run complete, the window is opened with averaged errors of the AHRS-II.

Step 14. Repeat Step 13 for each reference angle indicated in the «Angles» column.

Step 15. After the end of the accuracy test cycle in all positions given in the column «Angles», on the page “Angle Error, deg” the plot of given angle calculation error is displayed and the minimal and maximal error values during the test, its root-mean-square value (RMS) are indicated. Also standard deviation (STD) of measurement noise at last position of the AHRS-II is displayed.

Step 16. To close the accuracy check window (Fig.8.4) click button «x» in the right upper corner of the window. At this window is appeared with question about saving plot of error to .bmp file.
For each run the .txt file is created with saved AHRS-II data in the “data” subdirectory. File name consists of s/n of AHRS-II, indication what AHRS-II angle was tested (H – heading, P – pitch, R – roll), reference angle, reference temperature, time of run. For example, file "106A0016_H(38.22)_T(+27)_1831.txt" corresponds to data saved from the AHRS-II s/n 106A0016 at Heading accuracy test for target angle 38.22° at 18:31.

Also the file of the report like Accuracy_2010991830.txt is created where numbers are year, month, day, hours, minutes of performed test. there are averaged data for each AHRS-II run at accuracy test. In the first column of this file there is AHRS-II s/n, second column is number of reference angle starting from zero, 6th – 7th columns are averaged Heading, Pitch and Roll measured by AHRS-II.

10.4.2. On-the-fly accuracy test

Step 1. Carefully set AHRS-II by two reference surfaces on platform of the test bench designed for accuracy check.

Step 2 - Step 7 – Perform Step 1- Step 6 from the item 10.1.

Step 8. Select “AHRS-II visualization” in the “Run” menu (Fig.3.3) and then click on the “Snapshots” preview shown in the Fig.5.2c. Window shown in the Fig.5.4 will appear.

Step 9. Click the «Start» button. Initial alignment of the AHRS-II will start. This is signified by the message «Initial alignment. Please wait». Also a progress bar of initial alignment will appear in the status line of the main window. During the initial alignment the AHRS-II has to be unmovable relative to the Earth. After initial alignment completes, see changes in numeric data of AHRS-II.

Step 10. (Not obligatory) To save AHRS-II data click «Write» button. See a progress bar of data writing and timer will appear in the status line of the main window. Note the accuracy test data are written to file *.csv independently on saving the AHRS-II main data.

Step 11. When the AHRS-II is set in necessary position and is ready to save data, click the “Snapshot” button. Window shown in Fig.10.15 will appear.
Depending on known target orientation (its relative or absolute azimuth and pitch/elevation) select “Heading” or/and “Pitch” checkboxes (see Fig.10.15).

Enter values according to true reference angles. This angles can be set using arrows or by entering the necessary value from a keyboard.

If no checkboxes are checked then only current AHRS-II angles are saved.

Then press “OK” button. New tab “Snapshots” like shown in Fig.10.16 will open. Return to previous tab by clicking on its title “AHRS-II visualization”
Step 12. Rotate AHRS-II in the next position and repeat Step 11 as many times as you need. Azimuth value for each new position can be entered in the “Heading” field directly or as relative azimuth in the right field. It is measured by means of object sight unit or separate device (like theodolite). Azimuth of these relative position can be set in degrees or in mils depending on chosen item in drop-down list «(deg) / (mils)». Relative azimuth in degrees is considered to be positive in case of clockwise rotation from reference to calibration point and negative in case of counter-clockwise rotation. Relative azimuth in mils is positive in case of counter-clockwise rotation from reference to calibration point and negative in case of clockwise rotation (according to sight unit scale).

You can verify all snapshots data by clicking on the arrow button. After each snapshot calculation is performed and graph Heading Error is plotted (Fig.10.17). “Heading error (deg)” graph shows difference between AHRS-II measurements and reference angles.

Plotted graph is scalable. To zoom in please click and hold left button on mouse and drag mouse in down-right direction. To zoom out please click and hold left button on mouse and drag mouse in up-left direction. Click and hold right button on mouse to shift plot.
Fig. 10.17

Step 13. To stop the accuracy test click the «Stop» button. Alternatively, if the AHRS-II data was writing and the time set in «Record time» in the «Options \ Test option» menu was reached then accuracy test will be stopped too.

Step 14. To close the “On-the-fly accuracy” tab simple go to the other visualization style or close “AHRS-II visualization” tab by clicking the in the title of current tab.

Accuracy test data are automatically saved to the *.csv file. Its name consists of “TestFullData” word, date and time digits separated by dash symbols where the first 4 digits are the year, the next 2 digits are the month, then 2 digits of day, next digits are hours, minutes and seconds of operation (f.e. TestFullData-2013-03-05-15-44-47.csv).

This is common text file with comma-separated values of test data for each snapshot. Example of the *.csv file is shown in the Table 10.1.
### Table 10.1. Example of the *.csv file created at accuracy test

<table>
<thead>
<tr>
<th>Snapshot</th>
<th>hrs:min:sec</th>
<th>Measured_H</th>
<th>Measured_P</th>
<th>Measured_R</th>
<th>Mag_H</th>
<th>Target_H</th>
<th>Target_P</th>
<th>Mag_Dec</th>
<th>Vdd</th>
<th>USW(L)</th>
<th>USW(H)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15:44:47</td>
<td>200.09</td>
<td>-0.33</td>
<td>-0.09</td>
<td>200.11</td>
<td>200.06</td>
<td>nan</td>
<td>0</td>
<td>5.917</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>15:45:08</td>
<td>210.04</td>
<td>-0.29</td>
<td>-0.15</td>
<td>210.07</td>
<td>210.07</td>
<td>nan</td>
<td>0</td>
<td>5.918</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>15:45:29</td>
<td>220.07</td>
<td>-0.25</td>
<td>-0.21</td>
<td>220.1</td>
<td>220.08</td>
<td>nan</td>
<td>0</td>
<td>5.918</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>15:45:52</td>
<td>230.04</td>
<td>-0.2</td>
<td>-0.26</td>
<td>230.07</td>
<td>229.99</td>
<td>nan</td>
<td>0</td>
<td>5.918</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

This file includes 13 columns:
1. “Snapshot” – number of snapshot;
2. “hrs:min:sec” – time when the snapshot was made;
3. “Measured_H” – measured heading angle;
4. “Measured_P” – measured pitch angle;
5. “Measured_R” – measured roll angle;
6. “Mag_H” – value of the heading angle based on the AHRS-II magnetometers;
7. “Target_H” – reference (true) heading;
8. “Target_P” – reference (true) pitch;
9. “Mag_Dec” – the magnetic declination;
10. “Vdd” – input voltage of the AHRS-II;
11. “USW (L) “– Unit Status Word (low byte), see Appendix C for details.
12. “USW (H) “– Unit Status Word (high byte), see Appendix C for details.
10.5. AHRS-II automatic start

The Inertial Labs™ AHRS-II has ability to start operation automatically after power on, with continuous output data in desirable output data format. Note before firmware version 1.0.2.0 the AHRS-II could output data according to the “NMEA Output” data format only. See Appendix B for more details about data formats.

The auto start option can be enabled or disabled in the drop-down list “Auto start” in the “IMU” tab of the «Devices Options» window – see Fig.4.2. To allow this option the AHRS-II should be connected to PC and powered.

The drop-down list “Auto start” contains list of all available output data formats, see Fig.10.18. Please choose desirable output data format for the AHRS-II auto start. Default is “No Auto start” option that disables automatic start.

Fig.10.18
Usually just AHRS-II Demo software is used to start and stop the AHRS-II operation. To allow the AHRS-II Demo to receive data from the AHRS-II that was started automatically, it is necessary to select the “Allow auto start” checkbox in the «Test options» window – see Fig.4.1. After the “Allow auto start” checkbox is selected, it is necessary to close the AHRS-II Demo and start it again to apply this setting.

Operation with automatically started AHRS-II is close to those described in the section 10.1, with a little difference.

Step 1. Connect the AHRS-II to PC and power on. The AHRS-II LED indicator will light yellow during less than 1 second until the primary initialization of the AHRS-II microprocessor is completed. After that the AHRS-II starts calculations and its LED indicator changes color to green.

Step 2. Wait not less than set time for the initial alignment (30 seconds on default) and run the AHRS-II Demo program. If the COM port number was set correctly and “Allow auto start” checkbox was selected then AHRS-II Demo will show the AHRS-II continuous data in chosen output data format.

The next possible steps are the same as described in section 10.1, steps 11 – 17. For example, you can:

Step 3. To save data to file please click the «Write» button.

Step 4. To stop the AHRS-II click «Stop» button. If the data were being written in a file then the writing is stopped too.
11. Continuous self-monitoring of the AHRS-II health

The Inertial Labs AHRS-II has continuous built-in monitoring of the AHRS-II health. In the main mode the AHRS-II sends out Unit Status Word (USW) in each data block (see also Appendix B).

The low byte (bits 0-7) of USW indicates failure of the AHRS-II. If this byte is 0 then the AHRS-II operates correctly, if it is not 0, see “Appendix D. The Unit Status Word definition” for type of failure or contact the developers directly.

The high byte (bits 8-15) contains a warning or is informative for the user. Status of each bit of the USW warning byte is specified in the “Appendix D. The Unit Status Word definition”.

12. Control of compatibility between the AHRS-II firmware and AHRS-II Demo versions

Firmware of the Inertial Labs AHRS-II is developing continuously. The AHRS-II hardware also can be changed. Sometimes the AHRS-II features are so new that are not supported by old versions of the AHRS-II Demo software. On the other hand, some functions of the old AHRS-II Demo software were deleted from the new software versions.

We recommend strongly to use version of the AHRS-II Demo software that comes on CD with the AHRS-II until the AHRS-II firmware is updated.

If the AHRS-II has too old firmware version then before execution of any command sent from the Demo Software to the AHRS-II the warning window appears (see Fig.12.1) that informs about incompatible version of the AHRS-II firmware. Click “OK” and continue work.

![Warning Window](image-url)
13. Choice of 3D model for visualization of the AHRS-II orientation

The AHRS-II Demo software allows the use of different 3D models for visualization of the AHRS-II orientation angles when the «AHRS-II visualization» option is selected from the «Run» menu.

The default 3D model is an aircraft as Fig.5.1 shows. Other models are on CD in the subfolder “3D_Models” of the folder with the AHRS-II Demo software. There are files model.mgl which contain these models and appropriate screenshot files.

To set desirable 3D model for the AHRS-II visualization, just copy the file model.mgl from appropriate folder of 3D models to the “configs” subfolder in folder with AHRS-II Demo software. At this you should replace existing file.

Some examples of 3D models for the AHRS-II visualization are shown on Fig.13.1.

![Helicopter](image1)

![Ferrari_F40](image2)

![Clipper](image3)

![Submarine](image4)

Fig.13.1
14. Troubleshooting

14.1. How to repair the AHRS-II parameters

Need to repair of the AHRS-II parameters appears in some cases, for example at incorrect loading of parameters into the AHRS-II memory.

You can use original file with .prm extension that comes on CD with the Inertial Labs AHRS-II, or use own files created by «Save parameters» command (if these files contain valid data of course).

Follow next steps to restore AHRS-II parameters.

1. Connect the AHRS-II to PC and power it.
2. Start the AHRS-II Demo software. The main menu will appear (see Fig. 3.1).
3. Select «Test options…» from the «Options» menu (or click button) – see Fig. 3.7. «Test options» window (Fig. 4.1) will open.
4. Select the correct COM port number and its rate «Baud rate: 115200». Click «OK».

Note. For the number of the COM port to which the AHRS-II is connected, see items «2. Installation of drivers and configuration of the PC parameters» and «Appendix A. Installation of the COM-to-USB converter drivers and configuration of the PC parameters».

5. Select «Restore parameters» in the «Parameters» menu (see Fig. 3.4) or click button. A standard Windows «Open» window will open.
6. Select file with extension .prm containing the factory settings of the AHRS-II parameters or own file created by «Save parameters» command (if this file contains valid data of course). Click «OK». These parameters will be loaded into AHRS-II memory automatically.

14.2. What do you have to do at strange behavior of the AHRS-II

If you see strange behavior of the AHRS-II, first check whose parameters are loaded in the connected AHRS-II. This may occur, for example, if you have restored parameters that corresponds to another AHRS-II with an
improper serial number. Please use «Restore parameters...» command accurately to avoid wrong parameters loading into the AHRS-II's memory.

To check whose parameters are loaded in the connected AHRS-II please select «Device options ...» from the «Options» menu (or click button) – see Fig.3.7. «Device options» window will open:

In the field “AHRS-II name” you will see serial number of the AHRS-II. It must correspond to serial number that is placed on label on AHRS-II's nose.

If “AHRS-II name” doesn’t correspond to serial number of the connected AHRS-II then you must restore original parameters as that described in above section.

If “AHRS-II name” corresponds to the AHRS-II serial number, but you continue see strange behavior of the AHRS-II in heading, then this may be due to improper hard/soft iron calibration parameters are loaded into AHRS-II’s memory.

If you have removed the AHRS-II from its carrier object, then you must clear the parameters of soft/hard iron calibration. See section “10.3.2. Clearing of the soft and hard iron calibration parameters” for details.
If you mount the AHRS-II in another place in carrier object, or move it to another carrier object, then you must repeat soft/hard iron calibration procedure as it described in section “10.3. Calibration of the AHRS-II”.

14.3. What do you have to do if messages “Cannot read parameters!”, “Cannot load parameters!”, or “Cannot start AHRS-II” appear

When you use Inertial Labs AHRS-II Demo Software, the most of operations are started with reading data from the AHRS-II nonvolatile memory to control correct AHRS-II status. For this purpose the AHRS-II should be powered and connected to COM-port or USB-port using COM-to-USB adapter.

When you see one of messages that Fig.14.1 shows, then you should check the next items:

- The AHRS-II is powered and its LED indicator lights red.
- The AHRS-II is connected to COM-port or USB-port using COM-to-USB adapter.
- The number of COM-port and its baud rate are set correctly in the «Serial port» field in «Test options...» window from the «Options» menu as Fig.4.1 shows.

Then simply click the «OK» button and repeat your operation.

![Fig.14.1](image-url)
APPENDIX A.
Installation of the COM-to-USB converter drivers and configuration of PC parameters

Inertial Labs AHRS-II developer highly recommends connection of the AHRS-II with RS-232 interface to a computer through a standard COM-port for guaranteed reliable operation of the AHRS-II. If connection of the AHRS-II to a computer is done through a USB port, it is necessary to install a COM-to-USB converter driver. The converter driver is in the folder COM_to_USB_Driver placed on the CD provided with the AHRS-II. Sequence of the converter driver installation is as follows:

– Connect the converter to a computer. The computer automatically starts a search and installation program for the necessary drivers of the connected device. A window (Fig.A.1) opens. Select «No, not this time» from the menu and click on the «Next» button.

![Fig.A.1](image-url)
Window (Fig.A.2) will appear on the display. Select «Install from a list or specific location (Advanced)» from the menu and click on the «Next» button.

![Found New Hardware Wizard](image)

- Fig.A.2

Window (Fig.A.3) will appear on the display. Check «Include this location in the search:» and click on «Browse». Show the path to the converter drivers folder in the window (Fig.A.4) which appears on the top of the previous one (folder name may differ from the name in Fig.A.4) and click «OK» (if a folder containing no driver files is selected, «OK» button will remain inactive). Next, in the window Fig.A.3, which will be looking like the window in Fig.A.5, a path will be defined. Using this path the installation program will search for the necessary converter driver. Press «Next» to continue installation.
Found New Hardware Wizard

Please choose your search and installation options.

- Search for the best driver in these locations.
  
  Use the check boxes below to limit or expand the default search, which includes local paths and removable media. The best driver found will be installed.

  - [x] Search removable media (floppy, CD-ROM...)
  - [x] Include this location in the search:

    F:

- Don't search. I will choose the driver to install.
  
  Choose this option to select the device driver from a list. Windows does not guarantee that the driver you choose will be the best match for your hardware.

Fig.A.3

Browse For Folder

Select the folder that contains drivers for your hardware.

- My Documents
- My Computer
  - Local Disk (C:)
  - DVD Drive (D:)
  - Inernalabs_AHRS (E:)
  - COM_to_USB_Driver
  - Documentation
  - Inernalabs_AHRS_Demo_Program

To view any subfolders, click a plus sign above.

[OK] [Cancel]

Fig.A.4
If the program finds the necessary files, it will automatically start the driver installation. If installation is completed successfully, the window in Fig.A.6 will appear on the screen. Press «Finish» to complete installation procedure for the COM-to-USB converter driver.
If the necessary drivers are not installed, an error message (Fig.A.7) will appear. In this case, click «Back» and set the correct path to the driver files in the window in Fig.A.3.

**Fig.A.7**

Once the converter driver is installed, you will need to know the number of the additional COM-port set by the system and configure parameters of this port for correct operation of the AHRS-II. To do this, press the «Device Manager» button in the «System Properties» window, in the «Hardware» page. In the opened «Device Manager» window (Fig.A.8) the additionally set COM-port will be marked as «USB serial port (COMN)». Number N in the port name will be assigned by the computer.
Next, open the Properties window of this port «USB serial port (COMN) Properties» (Fig.A.9) and press the «Advanced» button. In the opened «Advanced Settings for COMN» window set the parameters:

- Latency Timer (msec) to 1;
- Minimum Read Timeout (msec) to 100;
- Minimum Write Timeout (msec) to 100;

as it is shown in Fig.A.10, and click «OK».
In the case of problems in COM-to-USB driver operation please make one more adjustment of the driver. In the «Device Manager» window (see Fig.A.9) go to the «Universal Serial Bus controllers» section, item «USB Serial Controller» (see Fig.A.11). Twice click on this item to set its properties. The window «USB Serial Controller Properties» will be opened where go to «Advanced» tab and check «Load VCP» box (see Fig.A.12).

![Device Manager](image)

**Fig.A.11**
Fig. A.12
APPENDIX B.
Installation of the MOXA Serial-to-USB converter drivers (for AHRS-II with RS-422 interface)

The Inertial Labs™ AHRS-II with RS-422 interface can be connected to PC USB port using Serial-to-USB MOXA 1130 converter, which is supplied with the AHRS-II unit by the Inertial Labs. In this case it is necessary to install appropriate driver which can be downloaded from the official MOXA site. Make sure that driver completely suits your operating system.

Sequence of the MOXA 1130 converter driver installation is as follows:

Click twice on icon of downloaded driver window shown on the Fig.B.1 will appear.

![Fig.B.1](image-url)
Click «Next» button and window shown on the Fig.B.2 will appear. In the address box put the exact location where the drivers have been installed to.

![Fig.B.2](image)

Click «Next» to continue installation. Then window shown on the Fig.B.3 will appear. In the address box put location and name of the program’s shortcuts and click «Next» button.

Window Fig.B.4. will appear where you can check the correctness of settings. If data are correct click «Install» button. In the other case click «Back» button to review and change any settings. If installation completed successfully window shown on the Fig.B.5 will appear. Click «Finish» button to close installation window.
The next step is configuration of the installed driver. To do this, press the «Device Manager» button in the «System Properties» window, in the «Hardware» page. In the opened «Device Manager» window (see Fig.B.6) select device «Uport 1130» in the «Multiport serial adapters» group.

Double click on this device to show its properties where go to the «Ports Configuration» tab (see Fig.B.7). Please check that there is set RS-422 interface as Fig.B.7 shows. If other interface is set then click on the «Port Setting» button, and in opened window Fig.B.8 select just RS-422 interface. Click «OK» button to accept configuration.
Fig. B.6
Once the converter driver is installed and configured, you will need to know the number of the additional COM-port set by the system and configure parameters of this port for correct operation of the AHRS-II. To do this, go again to the «Device Manager» window Fig.B.6 and look the «Ports (COM & LPT)» list. There additional COM-port is appeared, «MOXA USB serial port (COMN)» (see Fig.B.9). Number N in the port name is the necessary port number assigned by the computer.
APPENDIX C.
Description of data files

The Inertial Labs AHRS-II Demo software creates data files if “Write” button is pressed after AHRS-II start. These are two binary files with the same name and extensions .prm and .bin, where .prm file contains the AHRS-II parameters, and .bin file contains the AHRS-II outputs. Select «Report of experiment» from the “Convert” menu of the AHRS-II Demo or press F8 or click button to convert these binary data to text file (see section 7 for more details).

Structure of binary and text files is described below. Note that text file is more convenient for analysis.

C.1. Structure of binary file

If user has possibility to work with binary file directly, below is description of the binary .bin file. This file structure copies structure of the AHRS-II output data that is described in the Inertial Labs AHRS-II Interface Control Document (ICD).

The first 50 bytes of the *.bin file are results of the AHRS-II initial alignment, see Table C.1.

<table>
<thead>
<tr>
<th>Byte</th>
<th>Parameter</th>
<th>Format</th>
<th>Length</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-11</td>
<td>Gyros bias</td>
<td>float</td>
<td>3*4</td>
<td>3 numbers in ADC codes</td>
</tr>
<tr>
<td>12-23</td>
<td>Average acceleration</td>
<td>float</td>
<td>3*4</td>
<td>3 numbers in ADC codes</td>
</tr>
<tr>
<td>24-35</td>
<td>Average magn. field</td>
<td>float</td>
<td>3*4</td>
<td>3 numbers in ADC codes</td>
</tr>
<tr>
<td>36-39</td>
<td>Initial Heading</td>
<td>float</td>
<td>4</td>
<td>degrees</td>
</tr>
<tr>
<td>40-43</td>
<td>Initial Roll</td>
<td>float</td>
<td>4</td>
<td>degrees</td>
</tr>
<tr>
<td>44-47</td>
<td>Initial Pitch</td>
<td>float</td>
<td>4</td>
<td>degrees</td>
</tr>
<tr>
<td>48-49</td>
<td>USW</td>
<td>word</td>
<td>2</td>
<td>0 – successful initial alignment; ≠0 – unsuccessful</td>
</tr>
</tbody>
</table>

Notes:
1. USW is Unit Status Word (see Appendix D. The Unit Status Word definition, for details).
2. In the Table C.1 and in all next there is denoted:
word = unsigned 2 byte integer;
sword = signed 2 byte integer.
3. The low byte is the first.

All the remaining data in the *.bin file are blocks of the AHRS-II output data written at AHRS-II operation with set data rate (100 Hz default). Each data block has structure according to the chosen output format – «AHRS-II Full Output», «AHRS-II Calibrated Data», «AHRS-II Quaternion Data», «AHRS-II Minimal Data», «AHRS-II NMEA», «TSS1». Structure of data block is described in Tables C.2 – C.6 for each output data format.

**Table C.1.** The message payload at AHRS-II Full Output Data format

<table>
<thead>
<tr>
<th>Byte number</th>
<th>0 – 1</th>
<th>2 – 3</th>
<th>4 – 5</th>
<th>6 – 23</th>
<th>24 – 25</th>
<th>26 – 27</th>
<th>28 – 29</th>
<th>30 – 31</th>
<th>32 – 33</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Heading</td>
<td>Pitch</td>
<td>Roll</td>
<td>Ugyro, Uacc, Umag</td>
<td>Reserved</td>
<td>Reserved</td>
<td>USW</td>
<td>Vdd</td>
<td>Utermo</td>
</tr>
<tr>
<td>Length</td>
<td>2 byte word</td>
<td>2 byte sword</td>
<td>2 byte sword</td>
<td>9+2 byte sword</td>
<td>2 byte word</td>
<td>2 byte word</td>
<td>2 byte word</td>
<td>2 byte word</td>
<td></td>
</tr>
<tr>
<td>Note</td>
<td>Orientation angles, deg*100</td>
<td>Raw sensor data (gyros, accelerometers, magnetometers)</td>
<td>Combined voltage</td>
<td>Temperature in each sensor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table C.1 (continued)**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Altitude or Heave</td>
<td>Surge</td>
<td>Sway</td>
<td>Altitude or Heave rate</td>
<td>Surge rate</td>
<td>Sway rate</td>
<td>UP</td>
<td>UT</td>
</tr>
<tr>
<td>Length</td>
<td>4 byte integer</td>
<td>2 byte sword</td>
<td>2 byte sword</td>
<td>2 byte sword</td>
<td>2 byte sword</td>
<td>2 byte word</td>
<td>2 byte word</td>
<td></td>
</tr>
<tr>
<td>Note</td>
<td>m*100</td>
<td>m*100</td>
<td>m*100</td>
<td>m/s*100</td>
<td>m/s*100</td>
<td>m/s*100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes**

1. USW is unit status word (see Appendix D. The Unit Status Word definition, for details).
2. The following data are recorded in the field «Vdd» sequentially:
   - the AHRS-II input voltage, Vinp, VDC*100;
   - stabilized voltage supplied to the AHRS-II sensors, Vdd, VDC*1000;
3. In the «Utermo» field ADC codes are recorded sequentially from 7 temperature sensors inside gyros, accelerometers and magnetometers.

4. Choice of altitude or heave and appropriate rate for output depends on switch “Barometric altitude” (see section 10.2 for details).

5. UP and UT are raw data from the pressure sensor – pressure and temperature.

6. The low byte is transmitted by first.

**Table C.2.** The message payload at AHRS-II Calibrated Data format

<table>
<thead>
<tr>
<th>Byte number</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 1</td>
<td>Heading</td>
<td>Pitch, Roll</td>
</tr>
<tr>
<td>2 – 3</td>
<td>GyroX, GyroY, GyroZ</td>
<td>AccX, AccY, AccZ</td>
</tr>
<tr>
<td>4 – 5</td>
<td>MagX, MagY, MagZ</td>
<td>Reserved</td>
</tr>
<tr>
<td>6 – 11</td>
<td>Reserved</td>
<td>USW, Vinp, Temper</td>
</tr>
<tr>
<td>12 – 17</td>
<td>3× 2 byte word</td>
<td>3× 2 byte word</td>
</tr>
<tr>
<td>18 – 23</td>
<td>2 byte word</td>
<td>2 byte word</td>
</tr>
<tr>
<td>24 – 25</td>
<td>2 byte word</td>
<td>2 byte word</td>
</tr>
<tr>
<td>26 – 27</td>
<td>2 byte word</td>
<td>2 byte word</td>
</tr>
<tr>
<td>28 – 29</td>
<td>2 byte word</td>
<td>2 byte word</td>
</tr>
<tr>
<td>30 – 31</td>
<td>2 byte word</td>
<td>2 byte word</td>
</tr>
</tbody>
</table>

**Note**

Orientation angles, deg*100
Angular rates, deg/s*KG
Accelerations, g*KA
Magnetic fields, nT/10
Supply voltage, VDC*100
Temperature, ºC*10

**Table C.2 (continued)**

<table>
<thead>
<tr>
<th>Byte number</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>34 – 37</td>
<td>Altitude or Heave</td>
<td>Surge, Sway, Altitude or Heave rate, Surge rate</td>
</tr>
<tr>
<td>38 – 39</td>
<td>4 byte integer</td>
<td>2 byte word, 2 byte word</td>
</tr>
<tr>
<td>40 – 41</td>
<td>m*100</td>
<td>m*100</td>
</tr>
<tr>
<td>42 – 43</td>
<td>m/s*100</td>
<td>m/s*100</td>
</tr>
<tr>
<td>44 – 45</td>
<td>m/s*100</td>
<td>Pa/2</td>
</tr>
<tr>
<td>46 – 47</td>
<td>m*100</td>
<td></td>
</tr>
<tr>
<td>48-49</td>
<td>m*100</td>
<td></td>
</tr>
</tbody>
</table>

**Notes**

1. Values of KG, KA are scale factors depending on gyro and accelerometer range:

<table>
<thead>
<tr>
<th>Gyro range, deg/sec</th>
<th>KG</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 or 300</td>
<td>100</td>
</tr>
<tr>
<td>500</td>
<td>50</td>
</tr>
<tr>
<td>1000</td>
<td>20</td>
</tr>
<tr>
<td>2000</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accelerometer range, g</th>
<th>KA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>10000</td>
</tr>
<tr>
<td>6</td>
<td>5000</td>
</tr>
<tr>
<td>8</td>
<td>1000</td>
</tr>
</tbody>
</table>

2. Angular rates, linear accelerations and magnetic fields are in the carrier object axes (X is lateral axis, Y is longitudinal axis, Z is vertical axis). The AHRS-II orientation relative to the carrier object axes is set by alignment angles (see Appendix E. Variants of the Inertial Labs™ AHRS-II mounting relative to the object axes).
3. USW is unit status word (see Appendix D. The Unit Status Word definition, for details).
4. Vinp is input voltage of the AHRS-II.
5. Temper is averaged temperature in 3 accelerometers.
6. Choice of altitude or heave and appropriate rate for output depends on switch “Barometric altitude” (see section 10.2 for details).
7. H_bar is barometric height. Its value depends on switch “Barometric altitude” (see section 10.2 for details).
8. The low byte is transmitted by first.

**Table C.3. The message payload at AHRS-II Quaternion Data format**

<table>
<thead>
<tr>
<th>Byte number</th>
<th>0-7</th>
<th>8 – 13</th>
<th>14 – 19</th>
<th>20 – 25</th>
<th>26 – 27</th>
<th>28 – 29</th>
<th>30-31</th>
<th>32 – 33</th>
<th>34 – 35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Lk0, Lk1, Lk2, Lk3</td>
<td>GyroX, GyroY, GyroZ</td>
<td>AccX, AccY, AccZ</td>
<td>MagX, MagY, MagZ</td>
<td>Reserved</td>
<td>Reserved</td>
<td>USW</td>
<td>Vinp</td>
<td>Temper</td>
</tr>
<tr>
<td>Length</td>
<td>4×2 byte sword</td>
<td>3×2 byte sword</td>
<td>3×2 byte sword</td>
<td>2 byte word</td>
<td>2 byte word</td>
<td>2 byte word</td>
<td>2 byte word</td>
<td>2 byte word</td>
<td></td>
</tr>
<tr>
<td><strong>Note</strong></td>
<td>Quaternion of orientation *10000</td>
<td>Angular rates, deg/s *KG</td>
<td>Accelerations, g*KA</td>
<td>Magnetic fields, nT/10</td>
<td>Supply voltage, VDC*100</td>
<td>Temperature, ºC*10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table C.3 (continued)**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Altitude or Heave</td>
<td>Surge</td>
<td>Sway</td>
<td>Altitude or Heave rate</td>
<td>Surge rate</td>
<td>Sway rate</td>
<td>Pressure</td>
<td>H_bar</td>
</tr>
<tr>
<td>Length</td>
<td>4 byte integer</td>
<td>2 byte sword</td>
<td>2 byte sword</td>
<td>2 byte sword</td>
<td>2 byte word</td>
<td>2 byte word</td>
<td>4 byte integer</td>
<td></td>
</tr>
<tr>
<td><strong>Note</strong></td>
<td>m*100</td>
<td>m*100</td>
<td>m*100</td>
<td>m/s*100</td>
<td>m/s*100</td>
<td>m/s*100</td>
<td>Pa/2</td>
<td>m*100</td>
</tr>
</tbody>
</table>

**Notes**

1. The “AHRS-II Quaternion Data” format is implemented in AHRS-II firmware since version 2.1.2.0.
2. See detailed description for correct relationship between orientation angles and quaternion in the AHRS-II ICD, rev.1.7 or higher, “APPENDIX D. Forms of the Inertial Labs™ AHRS-II orientation presentation”.
3. Values of KG, KA are scale factors depending on gyro and accelerometer range:

```
Gyro range, deg/sec | 250 or 300 | 500 | 1000 | 2000
```
4. Angular rates, linear accelerations and magnetic fields are in the carrier object axes (X is lateral axis, Y is longitudinal axis, Z is vertical axis). The AHRS-II orientation relative to the carrier object axes is set by alignment angles (see Appendix E. Variants of the Inertial Labs™ AHRS-II mounting relative to the object axes).

5. USW is unit status word (see Appendix D. The Unit Status Word definition, for details).

6. Vinp is input voltage of the AHRS-II.

7. Temper is averaged temperature in 3 accelerometers.

8. Choice of altitude or heave and appropriate rate for output depends on switch “Barometric altitude” (see section 10.2 for details).

9. H_bar is barometric height. Its value depends on switch “Barometric altitude” (see section 10.2 for details).

10. The low byte is transmitted by first.

Table C.4. The message payload at AHRS-II Minimal Data format

<table>
<thead>
<tr>
<th>Byte number</th>
<th>0 – 1</th>
<th>2 – 3</th>
<th>4 – 5</th>
<th>6 – 11</th>
<th>12 – 17</th>
<th>18 – 23</th>
<th>24–27</th>
<th>28 – 29</th>
<th>30 – 31</th>
<th>32 – 33</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Heading</td>
<td>Pitch</td>
<td>Roll</td>
<td>GyroX, GyroY, GyroZ</td>
<td>AccX, AccY, AccZ</td>
<td>MagX, MagY, MagZ</td>
<td>Altitude or Heave</td>
<td>USW</td>
<td>Vinp</td>
<td>Temper</td>
</tr>
<tr>
<td>Length</td>
<td>2 byte word</td>
<td>2 byte word</td>
<td>2 byte word</td>
<td>3× 2 byte word</td>
<td>3× 2 byte word</td>
<td>3× 2 byte word</td>
<td>4 byte integer</td>
<td>2 byte word</td>
<td>2 byte word</td>
<td>2 byte word</td>
</tr>
<tr>
<td>Note</td>
<td>Orientation angles, deg*100</td>
<td>Angular rates, deg/s *KG</td>
<td>Accelarations, g*KA</td>
<td>Magnetic fields, nT/10</td>
<td>m*100</td>
<td>Supply voltage, VDC*100</td>
<td>Temper</td>
<td>°C*10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes

1. Values of KG, KA are scale factors depending on gyro and accelerometer range:

<table>
<thead>
<tr>
<th>Gyro range, deg/sec</th>
<th>250 or 300</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>KG</td>
<td>100</td>
<td>50</td>
<td>20</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accelerometer range, g</th>
<th>2</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>KA</td>
<td>10000</td>
<td>5000</td>
<td>1000</td>
</tr>
</tbody>
</table>

2. Angular rates, linear accelerations and magnetic fields are in the carrier object axes (X is lateral axis, Y is longitudinal axis, Z is vertical axis). The AHRS-II orientation relative to the carrier object axes is set by alignment angles (see Appendix E. Variants of the Inertial Labs™ AHRS-II mounting relative to the object axes).

3. USW is unit status word (see Appendix D. The Unit Status Word definition, for details).
4. Temper is averaged temperature in 3 accelerometers.
5. Choice of altitude or heave for output depends on switch “Barometric altitude” (see section 10.2 for details).
6. The low byte is transmitted by first.

At the «AHRS-II NMEA» output data format the AHRS data are transmitted in the form of sentences with printable ASCII characters like the NMEA 0183 format. Each sentence starts with a "$$" sign and ends with <CR><LF> (carriage return 0xD and line feed 0xA symbols). All data fields are separated by commas. The general form of the «AHRS-II NMEA» sentence is the next

$PAPR,AAAA.aa,B,RRRR.rr,PPP.pp,HHH.hh,TTT.t,V.vv,SSSS*CC<CR><LF>

where PAPR is identifier and other fields are listed in the Table C.5.

Table C.5. The AHRS-II message in NMEA format

<table>
<thead>
<tr>
<th>Field</th>
<th>AAAA.aa</th>
<th>B</th>
<th>RRRR.rr</th>
<th>PPP.pp</th>
<th>HHH.hh</th>
<th>TTT.t</th>
<th>V.vv</th>
<th>SSSS</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Altitude</td>
<td>a</td>
<td>Roll</td>
<td>Pitch</td>
<td>Heading</td>
<td>Temper-</td>
<td>Vinp</td>
<td>USW</td>
<td>Check sum</td>
</tr>
<tr>
<td></td>
<td>or</td>
<td>b</td>
<td></td>
<td></td>
<td></td>
<td>ture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heave</td>
<td>h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes
1. "B" field denotes kind of height data that is defined by switch “Barometric altitude” (see section 10.2 for details):
   ‘a’ – absolute barometric altitude at the pressure 101325 Pa at sea level;
   ‘b’ – barometric altitude at known initial value;
   ‘h’ – heave.
2. USW is unit status word (see Appendix D. The Unit Status Word definition, for details).
3. Temperature is averaged value for 3 accelerometers.
4. Vinp is input voltage of the AHRS-II.
5. Check sum consists of a "*" and two hex digits representing XOR of all characters between, but not including "$" and "*".

At the “TSS1” output data format the AHRS-II provides accelerations, heave, pitch, and roll message in the commonly used TSS1 message format. The TSS1 data string consists of five data fields and contains 27 printable ASCII characters. The acceleration fields contain ASCII-coded
hexadecimal values. Motion measurements include ASCII-coded decimal values.

The general form of the TSS1 sentence is the next:

:\XXAAAASMHHHHQMRRRRSMPPPP<CR><LF>

<table>
<thead>
<tr>
<th>Message component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\XX</td>
<td>Horizontal acceleration (hex value), in 3.83 cm/s², with a range of zero to 9.81 m/s²</td>
</tr>
<tr>
<td>AAAA</td>
<td>Vertical acceleration (hex value - 2’s complement), in 0.0625 cm/s², with a range of –20.48 to +20.48 m/s²</td>
</tr>
<tr>
<td>S</td>
<td>Space character</td>
</tr>
<tr>
<td>M</td>
<td>Space if positive; minus if negative</td>
</tr>
<tr>
<td>HHHH</td>
<td>Heave, in centimeters, with a range of –99.99 to +99.99 meters</td>
</tr>
<tr>
<td>Q</td>
<td>Status flag</td>
</tr>
<tr>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>G</td>
<td>INS Ready Mode with valid GPS input</td>
</tr>
<tr>
<td>H</td>
<td>AHRS Ready Mode without GPS input</td>
</tr>
<tr>
<td>M</td>
<td>Space if positive; minus if negative</td>
</tr>
<tr>
<td>RRRR</td>
<td>Roll, in units of 0.01 degrees (ex: 1000 = 10°), with a range of –99.99° to +99.99°</td>
</tr>
<tr>
<td>S</td>
<td>Space character</td>
</tr>
<tr>
<td>M</td>
<td>Space if positive; minus if negative</td>
</tr>
<tr>
<td>PPPP</td>
<td>Pitch, in units of 0.01 degrees (ex: 1000 = 10°), with a range of –99.99° to +99.99°</td>
</tr>
<tr>
<td>&lt;CR&gt;</td>
<td>Carriage return</td>
</tr>
<tr>
<td>&lt;LF&gt;</td>
<td>Line feed</td>
</tr>
</tbody>
</table>
C.2. Text presentation of output data formats

User can choose one of the formats to view and save AHRS-II data depending on the necessary information (see Fig.4.1). In the beginning of each file, after the text «Test report», serial number of the tested AHRS-IIs is specified, and next are the AHRS-II firmware version, date and time of file saving. Below are examples of the saved data in each of available data formats.

**AHRS-II Full Output Data**

<table>
<thead>
<tr>
<th>Measurement rate, Hz</th>
<th>Dec = 10.55</th>
<th>Latitude= 39.02851</th>
<th>Longitude= -77.587</th>
<th>Altitude= 88.00</th>
<th>Date= 2015.4249</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial alignment</td>
<td>Heading = 243.018</td>
<td>Roll = -0.803</td>
<td>Pitch = -0.278</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heading Pitch Roll Gyro_X Gyro_Y Gyro_Z Acc_X Acc_Y Acc_Z Magn_X Magn_Y Magn_Z Reserv1 Reserv2 Temperature Vdd</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>243.01 -0.28 0.05 8 29 19 26 102 4108 -4846 -1473 -7606 0 0 8332 12.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>243.01 -0.28 0.05 11 20 19 29 104 4109 -4846 -1472 -7606 0 0 8332 12.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*(continuation)*

<table>
<thead>
<tr>
<th>USW (LH)</th>
<th>Heave</th>
<th>Surge</th>
<th>Sway</th>
<th>V_Heave</th>
<th>V_Surge</th>
<th>V_Sway</th>
<th>UP</th>
<th>UT</th>
</tr>
</thead>
<tbody>
<tr>
<td>00000000 00000000</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>42179</td>
<td>28855</td>
</tr>
<tr>
<td>00000000 00000000</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>42162</td>
<td>28655</td>
</tr>
</tbody>
</table>

**Note:** saved data units

| Heading Pitch Roll Gyro_X Gyro_Y Gyro_Z Acc_X Acc_Y Acc_Z Magn_X Magn_Y Magn_Z Reserv1 Reserv2 Temperature Vdd |
|-----------------|-------|-------|------|---------|---------|-------|-----|-----|
| deg deg deg ADC code | ADC code | ADC code | ADC code | ADC code | ADC code | ADC code | ADC code |
| (continuation) |

<table>
<thead>
<tr>
<th>USW (LH)</th>
<th>Heave</th>
<th>Surge</th>
<th>Sway</th>
<th>V_Heave</th>
<th>V_Surge</th>
<th>V_Sway</th>
<th>UP</th>
<th>UT</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m/s</td>
<td>m/s</td>
<td>m/s</td>
<td>ADC code</td>
<td>ADC code</td>
</tr>
</tbody>
</table>

In the Temperature column ADC codes are recorded sequentially from 7 temperature sensors of the gyros, accelerometers, magnetometers. In the Vdd column the AHRS-II input voltage and stabilized voltage supplied to the AHRS-II sensors are recorded sequentially. USW (Unit Status Word) is in binary form with low and high bytes listed in the last two columns. Status of each bit of the USW is specified in the Appendix C.
AHRS-II Calibrated Data

<table>
<thead>
<tr>
<th>Heading</th>
<th>Pitch</th>
<th>Roll</th>
<th>Rate_X</th>
<th>Rate_Y</th>
<th>Rate_Z</th>
<th>AccX</th>
<th>AccY</th>
<th>AccZ</th>
<th>Magn_X</th>
<th>Magn_Y</th>
<th>Magn_Z</th>
<th>Reserv1</th>
<th>Reserv2</th>
<th>Temperature</th>
<th>Vdd</th>
</tr>
</thead>
<tbody>
<tr>
<td>240.41</td>
<td>0.15</td>
<td>0.87</td>
<td>24.04</td>
<td>0.6</td>
<td>13.42</td>
<td>-0.014</td>
<td>-0.11</td>
<td>0.97</td>
<td>19490</td>
<td>-13800</td>
<td>37860</td>
<td>0</td>
<td>0</td>
<td>33.6</td>
<td>12.3</td>
</tr>
<tr>
<td>240.27</td>
<td>0.06</td>
<td>0.88</td>
<td>20.60</td>
<td>0.1</td>
<td>12.94</td>
<td>-0.034</td>
<td>-0.14</td>
<td>0.98</td>
<td>19440</td>
<td>-14130</td>
<td>37840</td>
<td>0</td>
<td>0</td>
<td>33.6</td>
<td>12.3</td>
</tr>
</tbody>
</table>

(continuation)

<table>
<thead>
<tr>
<th>USW (LH)</th>
<th>Heave</th>
<th>Surge</th>
<th>Sway</th>
<th>V_Heave</th>
<th>V_Surge</th>
<th>V_Sway</th>
<th>P_Bar</th>
<th>H_Bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000000 00000000</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>10306</td>
<td>87.9</td>
</tr>
<tr>
<td>0000000 00000000</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>101306</td>
<td>88.2</td>
</tr>
</tbody>
</table>

Note: saved data units

<table>
<thead>
<tr>
<th>Heading</th>
<th>Pitch</th>
<th>Roll</th>
<th>Rate_X</th>
<th>Rate_Y</th>
<th>Rate_Z</th>
<th>AccX</th>
<th>AccY</th>
<th>AccZ</th>
<th>Magn_X</th>
<th>Magn_Y</th>
<th>Magn_Z</th>
<th>Reserv1</th>
<th>Reserv2</th>
<th>Temperature</th>
<th>Vdd</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>deg/s</td>
<td>deg/s</td>
<td>deg/s</td>
<td>deg/s²</td>
<td>deg/s²</td>
<td>deg/s²</td>
<td>T</td>
<td>T</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

(continuation)

<table>
<thead>
<tr>
<th>USW (LH)</th>
<th>Heave</th>
<th>Surge</th>
<th>Sway</th>
<th>V_Heave</th>
<th>V_Surge</th>
<th>V_Sway</th>
<th>P_Bar</th>
<th>H_Bar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m/s</td>
<td>m/s</td>
<td>m/s</td>
<td>Pa</td>
<td>m</td>
</tr>
</tbody>
</table>

In the Vdd column the AHRS-II input voltage and stabilized voltage supplied to the AHRS-II sensors are recorded sequentially.

USW (Unit Status Word) is in binary form with low and high bytes listed in the last two columns.

Status of each bit of the USW is specified in the Appendix C.
### AHRS-II Quaternion Data

<table>
<thead>
<tr>
<th>Lk0</th>
<th>Lk1</th>
<th>Lk2</th>
<th>Lk3</th>
<th>Rate_X</th>
<th>Rate_Y</th>
<th>Rate_Z</th>
<th>AccX</th>
<th>AccY</th>
<th>AccZ</th>
<th>Magn_X</th>
<th>Magn_Y</th>
<th>Magn_Z</th>
<th>Reserv</th>
<th>Reserv</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4130</td>
<td>0.0012</td>
<td>-0.104</td>
<td>-0.9107</td>
<td>24.04</td>
<td>-5</td>
<td>13.42</td>
<td>-0.014</td>
<td>-0.11</td>
<td>0.97</td>
<td>19490</td>
<td>-13900</td>
<td>37860</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.4131</td>
<td>0.0012</td>
<td>-0.105</td>
<td>-0.9107</td>
<td>20.60</td>
<td>0.1</td>
<td>12.94</td>
<td>-0.034</td>
<td>-0.14</td>
<td>0.98</td>
<td>19440</td>
<td>-14130</td>
<td>37840</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(continuation)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Vdd</th>
<th>USW (L/H)</th>
<th>Heave</th>
<th>Surge</th>
<th>Sway</th>
<th>V_Heave</th>
<th>V_Surge</th>
<th>V_Sway</th>
<th>P_Bar</th>
<th>H_Bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>33.6</td>
<td>12.3</td>
<td>00000000</td>
<td>00000000</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>10308</td>
</tr>
<tr>
<td>33.6</td>
<td>12.3</td>
<td>00000000</td>
<td>00000000</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>101306</td>
</tr>
</tbody>
</table>

Note: saved data units

- - deg/s deg/s deg/s deg/s² deg/s² deg/s² T T T T

(continuation)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Vdd</th>
<th>USW (L/H)</th>
<th>Heave</th>
<th>Surge</th>
<th>Sway</th>
<th>V_Heave</th>
<th>V_Surge</th>
<th>V_Sway</th>
<th>P_Bar</th>
<th>H_Bar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>deg C</td>
<td>VDC</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m/s</td>
<td>m/s</td>
<td>m/s</td>
<td>Pa</td>
<td>m</td>
</tr>
</tbody>
</table>

In the Vdd column the AHRS-II input voltage and stabilized voltage supplied to the AHRS-II sensors are recorded sequentially. USW (Unit Status Word) is in binary form with low and high bytes listed in the last two columns. Status of each bit of the USW is specified in the Appendix C.
## AHRS-II Minimal Data

<table>
<thead>
<tr>
<th>Heading</th>
<th>Pitch</th>
<th>Roll</th>
<th>Rate_X</th>
<th>Rate_Y</th>
<th>Rate_Z</th>
<th>AccX</th>
<th>AccY</th>
<th>AccZ</th>
<th>Magn_X</th>
<th>Magn_Y</th>
<th>Magn_Z</th>
<th>Height</th>
<th>Temperature</th>
<th>Vinp</th>
<th>USW (L/H)</th>
</tr>
</thead>
<tbody>
<tr>
<td>231.06</td>
<td>0.00</td>
<td>-0.64</td>
<td>51.02</td>
<td>-16.06</td>
<td>16.62</td>
<td>0.022</td>
<td>0.142</td>
<td>0.915</td>
<td>16770</td>
<td>-17420</td>
<td>37710</td>
<td>0</td>
<td>34.1</td>
<td>12.3</td>
<td>0000000</td>
</tr>
<tr>
<td>230.93</td>
<td>0.00</td>
<td>-1.05</td>
<td>50.10</td>
<td>-22.64</td>
<td>9.96</td>
<td>0.0058</td>
<td>0.128</td>
<td>0.908</td>
<td>16550</td>
<td>-17900</td>
<td>37570</td>
<td>0</td>
<td>34.1</td>
<td>12.3</td>
<td>0000000</td>
</tr>
</tbody>
</table>

**Note:** saved data units

Heading: deg
Pitch: deg
Roll: deg
Rate_X: deg/s
Rate_Y: deg/s
Rate_Z: deg/s
AccX: deg/s²
AccY: deg/s²
AccZ: deg/s²
Magn_X: deg/s²
Magn_Y: deg/s²
Magn_Z: deg/s²
Height: m
Temperature: deg C
Vinp: T
USW (L/H): T

In the Vinp column the AHRS-II input voltage and stabilized voltage supplied to the AHRS-II sensors are recorded sequentially.

USW (Unit Status Word) is in binary form with low and high bytes listed in the last two columns.

Status of each bit of the USW is specified in the Appendix C.
AHRS-II NMEA

Example of the AHRS-II message in NMEA format:

$PAFR.0000 00 h:00 0.51,00 04.226.08,034 1,12.2,0000*42
$PAFR.0000 00 h:00 0.40,00 44.226.15,034 1,12.2,0000*57

See APPENDIX B, Description of data files for details of the AHRS-II message in NMEA format.

NMEA data messages can be converted to more convenient text form using «Report of experiment» item from the «Convert» menu. Example of converted NMEA messages to *.txt file is shown below.

Example of the text form of NMEA format:

P18    Test report Date/Time 03.07.2015 11:54:41, GPS reference week number 0
Integrated device s/n: F1550002 firmware version: A2SM v1 0.1.5 01.07.15
*IMU: AHRS s/n C1510338 firmware version: A1SM v6.0.1.2NS 15.06.15
*GNSS receiver, model: s/n: firmware version: maximum data rate: 20Hz
*Pressure sensor: present

Measurement rate, Hz 100
Magnetic declination Mdec = -10.55  Latitude = 39.0851  Longitude = -77.5387  Altitude = 88.00  Date= 2015.4249

Initial alignment
Heating = 226.018  Roll = -0.599  Pitch = -0.405

<table>
<thead>
<tr>
<th>Height</th>
<th>B</th>
<th>Heading</th>
<th>Pitch</th>
<th>Roll</th>
<th>Temperature</th>
<th>Vinp</th>
<th>USW (L/H)</th>
</tr>
</thead>
<tbody>
<tr>
<td>88.12</td>
<td>2</td>
<td>226.08</td>
<td>-0.04</td>
<td>-0.51</td>
<td>34.1</td>
<td>12.19</td>
<td>00000000  00000000</td>
</tr>
<tr>
<td>88.12</td>
<td>2</td>
<td>226.15</td>
<td>0.44</td>
<td>-0.40</td>
<td>34.1</td>
<td>12.19</td>
<td>00000000  00000000</td>
</tr>
</tbody>
</table>

Note: saved data units

<table>
<thead>
<tr>
<th>Height</th>
<th>B</th>
<th>Heading</th>
<th>Pitch</th>
<th>Roll</th>
<th>Temperature</th>
<th>Vinp</th>
<th>USW (L/H)</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>deg</td>
<td>deg</td>
<td>deg</td>
<td>deg</td>
<td>deg C</td>
<td>VDC</td>
<td>--</td>
</tr>
</tbody>
</table>
### Example of the INS message in TSS1 format:

```plaintext
:0300E3 -0025H 1372 -2435
:030100 -0025H 1372 -2436
```

See **APPENDIX B. Description of data files** for details of the INS message in TSS1 format.

**TSS1** data messages can be converted to more convenient text form using «Report of experiment» item from the “Convert” menu. Example of converted TSS1 messages to *.txt file is shown below.

### Example of the text form of TSS1 format:

<table>
<thead>
<tr>
<th>P19</th>
<th>Test report Date\Time 15.07.2015 11:55:24, GPS reference week number 1853</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Integrated device s/n: F1550000 firmware version: A2SM v1.0.1.6 14.07.15</td>
</tr>
<tr>
<td></td>
<td>*IMU: AHRS s/n C1510341 firmware version: A1SM v6.0.1.2NS 15.06.15</td>
</tr>
<tr>
<td></td>
<td>*GNSS receiver: OEM615-2.00 model: G1S00G0T0 s/n: BJYA15100546Y firmware version: OEM060600RN0000 maximum data rate: 20Hz</td>
</tr>
<tr>
<td>Measurement rate, Hz</td>
<td>60</td>
</tr>
<tr>
<td>Magnetic declination, Mdec</td>
<td>-10.5</td>
</tr>
<tr>
<td>Latitude</td>
<td>39.04</td>
</tr>
<tr>
<td>Longitude</td>
<td>-77.39</td>
</tr>
<tr>
<td>Altitude</td>
<td>120.00</td>
</tr>
<tr>
<td>Date</td>
<td>2015.4128</td>
</tr>
<tr>
<td>Initial alignment</td>
<td>Heading = 277.975 Roll = 13.510 Pitch = -24.357</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>H_Acc</th>
<th>V_Acc</th>
<th>Heave</th>
<th>Roll</th>
<th>Pitch</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.11</td>
<td>0.01419</td>
<td>-25</td>
<td>13.72</td>
<td>-24.35</td>
</tr>
<tr>
<td>0.11</td>
<td>0.01600</td>
<td>-25</td>
<td>13.72</td>
<td>-24.36</td>
</tr>
</tbody>
</table>

**Note:** saved data units

<table>
<thead>
<tr>
<th>H_Acc</th>
<th>V_Acc</th>
<th>Heave</th>
<th>Roll</th>
<th>Pitch</th>
</tr>
</thead>
<tbody>
<tr>
<td>m/s²</td>
<td>m/s²</td>
<td>cm</td>
<td>deg</td>
<td>deg</td>
</tr>
</tbody>
</table>
## APPENDIX D.
The Unit Status Word definition

<table>
<thead>
<tr>
<th>Bit</th>
<th>Parameter</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Initial Alignment</td>
<td>0 – Successful initial alignment&lt;br&gt;1 – Unsuccessful initial alignment due to&lt;br&gt;AHRS-II moving or large changing of outer magnetic field</td>
</tr>
<tr>
<td>1</td>
<td>AHRS-II Parameters</td>
<td>0 – Parameters are correct&lt;br&gt;1 – Parameters are incorrect</td>
</tr>
<tr>
<td>2</td>
<td>Gyroscope Unit</td>
<td>0 – No failure&lt;br&gt;1 – Failure is detected</td>
</tr>
<tr>
<td>3</td>
<td>Accelerometer Unit</td>
<td>0 – No failure&lt;br&gt;1 – Failure is detected</td>
</tr>
<tr>
<td>4</td>
<td>Magnetometer Unit</td>
<td>0 – No failure&lt;br&gt;1 – Failure is detected</td>
</tr>
<tr>
<td>5</td>
<td>Electronics</td>
<td>0 – No failure&lt;br&gt;1 – Failure is detected</td>
</tr>
<tr>
<td>6</td>
<td>Software</td>
<td>0 – No failure&lt;br&gt;1 – Failure is detected</td>
</tr>
<tr>
<td>7</td>
<td>AHRS-II mode</td>
<td>See the Table below</td>
</tr>
<tr>
<td>8</td>
<td>Incorrect Power Supply</td>
<td>0 – Supply voltage is not less than minimum level&lt;br&gt;1 – Low supply voltage is detected</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>0 – Supply voltage is not higher than maximum level&lt;br&gt;1 – High supply voltage is detected</td>
</tr>
<tr>
<td>10</td>
<td>Angular Rate Exceeding Detect</td>
<td>0 – X-angular rate is within the range&lt;br&gt;1 – X-angular rate is outrange</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>0 – Y-angular rate is within the range&lt;br&gt;1 – Y-angular rate is outrange</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>0 – Z-angular rate is within the range&lt;br&gt;1 – Z-angular rate is outrange</td>
</tr>
<tr>
<td>13</td>
<td>Large Magnetic Field Detect</td>
<td>0 – Total magnetic field within the normal range&lt;br&gt;1 – Total magnetic field limit is exceeded</td>
</tr>
<tr>
<td>14</td>
<td>Environmental Temperature</td>
<td>0 – Temperature is within the operating range&lt;br&gt;1 – Temperature is out of the operating range</td>
</tr>
<tr>
<td>15</td>
<td>AHRS-II mode</td>
<td>See the Table below</td>
</tr>
</tbody>
</table>
The AHRS-II indicates its current mode of operation in the bits 7 and 15 as the next table shows.

**Indication of the AHRS-II current operational mode**

<table>
<thead>
<tr>
<th>USW bits</th>
<th>AHRS-II mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit #7</td>
<td>Bit #15</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
APPENDIX E.
Variants of the Inertial Labs™ AHRS-II mounting relative to object axes

The Inertial Labs™ AHRS-II has axes orientation shown on Fig.E.1. With usual installation of the AHRS-II on carrier object the AHRS-II X, Y Z axes should be parallel to the object lateral, longitudinal and vertical axes.

But the Inertial Labs AHRS-II can be mounted on the object in any known position (up to upside-down, upright etc.) relative to the object axes. Such mounting doesn’t change right calculation of the object orientation if angles of the AHRS-II mounting are correctly stored in the AHRS-II nonvolatile memory.

To set these angles select item «Device option …» from the «Options» menu. In opened window Fig.4.2 angles of the AHRS-II mounting are in the “Alignment angles” section.
The AHRS-II alignment angles are set in the next order (like azimuth, pitch and roll setting):

- first alignment angle sets position of the AHRS-II longitudinal axis Y relative to longitudinal axes of the object measured in the horizontal plane of the object. Clockwise rotation is positive;
- second alignment angle is equal to angle of inclination of the AHRS-II longitudinal axis Y relative to the horizontal plane of the object. Positive direction is up;
- third alignment angle is equal to inclination angle of the AHRS-II lateral axis X measured around AHRS-II’s longitudinal axis. Positive rotation is X axis moving down.

All angles are set in degrees.

Some examples of the Inertial Labs AHRS-II mounting relative the object are shown on Fig.E.2.

To check correctness of the alignment angles please run the AHRS-II using the Inertial Labs AHRS-II Demo program.
Fig.E.2. Examples of the Inertial Labs™ AHRS-II mounting on the carrier object

- **a** – alignment angles are $0, 0, 0$ (degrees);
- **b** – alignment angles are $0, 0, 180$ (degrees);
- **c** – alignment angles are $90, 0, 0$ (degrees);
- **d** – alignment angles are $180, -90, 0$ (degrees).