# Single- & Dual-Antenna GPS-Aided Inertial Navigation Systems INS

# USER MANUAL

| | | | | | |
|---|---|---|---|---|---|
| **Models** | **INS-B**<br>**INS-B-OEM** | **INS-P**<br>**INS-P-OEM** | **INS-D**<br>**INS-D-OEM** | **INS-DL**<br>**INS-DL-OEM** | **INS-DU**<br>**INS-DU-OEM** |
| **Revision** | **2.48** | | | | |

# Revision History

| Revision | Date | Author | Description |
|---|---|---|---|
| 1.0 | Jul.15, 2015 | AK | Released version. |
| 1.2 | Sep.03, 2015 | ON | 1. Implemented auto start option with choice of desirable variant of output data format after device power on (since INS firmware version 1.0.2.0). See section 10.5.<br>2. Added option “Use SBAS” to “GNSS receiver” tab in the “Devices options” menu.<br>3. Corrected mistake in Tables B.2, B.5, B.6, B.12 in Appendix B.1: ms_pos is replaced by ms_gps<br>4. Updated description of the “INS NMEA Output” data format in Appendix B.2 (timestamp is added).<br>5. Added description of the “INS Sensors NMEA output” data format in Appendix B.2. |
| 1.3 | Nov.02, 2015 | ON, AK | For INS Demo version 2.0.13.48 and higher.<br>1. Updated section “4.2.2. GNSS receiver “tab” (affected since INS firmware version 2.0.1.2)<br>2. Added section “4.5. Magnetometers calibration options”.<br>3. Updated section “10.3. Features of Altitude and Heave calculation”.<br>4. Parameters of adaptive algorithm of heave calculation are added to “Correction options” window (Fig.4.7) and described in section “10.3.1. Adjustment of the algorithm of heave calculation” (affected since INS firmware version 2.0.1.2).<br>5. Added section “10.2. Control of the GNSS receiver”.<br>6. Added section “12. INS and GNSS data post-processing”. |
| 1.4 | Nov.26, 2015 | AK | 1. Added “The most important notes” section.<br>2. Corrected TSS1 data format description in “Appendix B.2. Text presentation of output data formats”. |
| 1.5 | Feb.05, 2016 | AK | For INS Demo version 2.0.15.62 from 01/15/2016 and higher.<br>1. Added possibility of automatic creation of new data folder for each run, see section 4.1.<br>2. Added description of new features in “7.4. Preset parameters” section.<br>3. Added possibility of COM-port baud rate change for output raw GNSS data (see “4.2.2. “GNSS receiver” tab” section).<br>4. Updated section “12.1 Recording of raw GNSS data” due to item 3.<br>5. Added description of new “Additional” tab in the “Correction options” menu. |
| 1.6 | Feb.17, 2016 | AK | 1. Corrected INS message payload at the “INS OPVT” data format in Appendix B, Table B.2.<br>2. Added new output data format “INS QPVT” (Quaternion of orientation, Position, Velocity, Time) and its description – for INS Demo version 2.0.17.69 from 02/17/2016 and higher. |

| | | | |
|---|---|---|---|
| 1.7. | Apr.21, 2016 | ON | 1. Updated “The most important notes” section, “At the first use” subject.<br>2. Added sections “4.2.4. Change of the main COM-port baud rate” and “4.2.5. Limitation of the INS maximum measurement rate” – for INS Demo version 2.0.20.80 from 03/25/2016 and higher.<br>3. Added “Appendix B. Installation of the MOXA Serial-to-USB converter drivers (for INS with RS-422 interface)”.<br>4. Added Note 2 to Table C.5 about correct relationship between orientation angles and quaternion presentation.<br>5. Added magnetic declination field to “INS Full Output Data” format instead of reserved field (see Table C.6) – since INS firmware version 2.2.0.2. |
| 1.8 | Jul.29, 2016 | ON | For INS Demo version 2.0.22.84 from 04/22/2016 and higher.<br>1. Updated “The most important notes” section.<br>2. Changed “IMU” and “GNSS receiver” tabs in “Devices options” and their description.<br>3. Added section “12.3. INS sensors error model for INS + GNSS data post-processing”.<br>4. Added section “13. Synchronization of INS data with LiDAR and other devices”.<br>5. Added possibility to change PPS configuration and processing of mark input signal (since INS firmware version 2.2.0.3) – see sections 13.1 and 13.2.<br>6. In Appendix C: Changed GNSS information in output data formats INS OPVT; INS QPVT; INS Full Output Data; INS Minimal Data (Tables C.2 – C.6, C.13). |
| 2.0 | Aug.09, 2016 | ON | For INS Demo version 2.0.28.107 from 08/05/2016 and higher that supports new line of Inertial Labs™ INS units: INS-B, INS-P, INS-D.<br>1. Added two output data formats – INS OPVT2A, INS OPVT2Ahr to “Test Options” (see section 4.1).<br>2. Changed “Correction options” window and available settings there (see section 4.3).<br>3. Features of INS algorithm and possibilities of their adjustment are described in section “4.3.1. “Settings” tab of “Correction options…” window”.<br>4. Removed “Marine device parameters” and “Track angle for INS correction” from “Preset parameters” item in “Parameters” menu (see section 7.4). |
| 2.1 | Aug.23, 2016 | ON | 1. Added ±450°/s gyro range for KG values (see notes to Tables C.2, C.5, C.6, in Appendix C.1).<br>2. Added examples of text presentation of “INS OPVT2A” and “INS OPVT2Ahr” output data formats in Appendix C.2 |
| 2.2 | Sep.05, 2016 | ON | For INS Demo version 2.0.29.110 from 2016-09-02 and higher.<br>1. Allowed change of the GNSS data rate in the “GNSS receiver” tab of “Devices options…” window (see section 4.2.2).<br>2. Added indication of GNSS receiver failure in the Unit Status Word – since INS firmware version 2.5.0.2 (see Appendix D).<br>3. INS Demo program stops the INS unit if failure of gyro, accelerometer or GNSS receiver is detected (see section 11). |

| | | | |
|---|---|---|---|
| 2.3 | Sep.19, 2016 | AK | For INS Demo version 2.0.31.112 from 2016-09-15 and higher.<br>1. Added output data format – OPVT2AW to “Test Options” (see section 4.1).<br>2. Added examples of text presentation of “INS OPVT2AW” output data format in Appendix C.2 |
| 2.4 | Dec.12, 2016 | ON, AK | 1. Added “Extended Initial alignment” checkbox (see Fig. 4.2) and its description.<br>2. Changed GNSS COM-port 2 parameters and their description (see Section 4.2.2).<br>3. Changed Pressure sensor tab (see Section 4.2.3)<br>4. Added new INS settings – for catapult start (Figs 4.16) and combined heading correction (Figs 4.17), see section 4.3.<br>5. Corrected note to description of 3D calibration run (see Section 10.4.1, Step 8).<br>6. Changed description of USW bits #7,15 (Appendix B)<br>7. Corrected KA scale factor for ±8g accelerometer range and scale factor for supply voltage (see Tables C.2, C.5 to C.8 and notes to them in Appendix C.1). |
| 2.5 | Jun.24, 2017 | ON, AK | 1. Changed “IMU” tab of the “Devices options” menu: since INS Demo version 2.0.40.196 from 2017-06-23 it supports arbitrary (but known) installation of INS-D two antennas on carrier object, for INS-D firmware since version 2.9.1.7.<br>2. Added “Appendix F. Installation of GNSS Antennas”.<br>3. Added scale factor values to Table 12.2. Binary Structure of raw IMU data (see Section 12.2). |
| 2.6 | Nov.15, 2017 | AK | 1. Updated “The most important notes”.<br>2. Deleted “INS Full Output” and “TSS1” output formats.<br>3. Added “INS OPVTAD” output data format.<br>4. Deleted Heave related information.<br>5. Changed “GNSS receiver”, “Pressure sensor” tabs of the “Devices options” window (see sections 4.2.2, 4.2.3).<br>6. Added “External sensors” and “Triggers” tabs to the “Devices options” window and their description (see sections 4.2.4, 4.2.5).<br>7. Changed “Preset Parameters” menu and its description (see section 7.4).<br>8. Added description of the VG3D calibration (see section 10.4.1).<br>9. Added on-the-fly VG3D calibration and its description (see section 10.4.4).<br>10. Added possibility to enter GPS Time shift at generation of raw IMU data (see section 12.2).<br>11. Changed description of USW bits #7,15 that are used for indication of stages of on-the- fly VG3D calibration (see Appendix D).<br>12. Deleted section 14. “Compatibility between the INS firmware and INS Demo versions”.<br>13. Added g value to notes to Tables C.2, C.5 – C.9 with description of output data formats (Appendix C.1).<br>14. Added “Appendix G. Use of the STRSVR tool”. |

| | | | |
|---|---|---|---|
| 2.7 | Jan.23, 2018 | ON | For INS Demo version 2.0.45.250 from 2018-01-12 and higher.<br>1.Added possibility to set coordinates of any measuring point for calculation of INS position and velocity (see section 4.2.1).<br>2. Changed “External sensors” tab in the “Devices options” window to include parameters of encoder-based odometer (see section 4.2.4).<br>3. Added description of COM4 port functions (to receive external data from a device with RS232 interface or to output GPRMC messages), see sections 4.2.2, 4.2.4.<br>4. Removed “Time stamp correction” switch from “Correction options” window (see section 4.3). Time stamp correction is always active.<br>5. Added section “10.7. INS operation with encoder-based odometer (wheel speed sensor)”.<br>6. Added two output data formats “INS OPVT & Raw IMU Data” and “SPAN rawimu”.<br>7. Changed recommendations for “Advanced Settings for COMN” window in “USB serial port (COMN) Properties” (see Appendix A, Fig.A.10).<br>8. Increased header of the text presentation of saved INS output data to include values of all INS parameters which change is allowed to user (see Appendix C.2).<br>9. Added “Appendix H. Using Ethernet port for communication with the Inertial Labs™ INS”. |
| 2.8 | Jun.14, 2018 | ON | For INS Demo version 2.0.46.272 from 2018-05-15 and higher.<br>1. Added “INS OPVT GNSSext” and “User Defined Data” output data formats in “Test options” menu item.<br>2. Added “User Defined Data” menu item to the “Options” menu and its description in section 4.6.<br>3. Added “Round time stamp” switch in “Correction options” window (see section 4.3).<br>4. Added possibility to restore INS parameters from prm file where serial number differs from serial number of INS unit which is currently connected, see section 7.2.<br>5. Added section “10.8. Operations with CAN data”.<br>6. Added “Pressure sensor noise STD” parameter to “Pressure sensor” tab of the “Devices options” window (see section 4.2.3).<br>7. Added “Round time stamp” check-box to “Correction options…” window (see section 4.3).<br>8. Added description of the extended block of the initial alignment data in Appendix C.1, Table C.2.<br>9. Changed type of “Air Speed” field in aiding data from word to sword (signed short), see Table C.11.<br>10. Added KA scale factors for ±4g, ±10g, ±15g and ±40g accelerometer ranges (see notes to Tables C.3, C.7, C.8, C.9, C.26 in Appendix C.1).<br>11. Added Table C.6. New_GPS indicator of new update of GNSS data, in Appendix C.1.<br>12. Added INS-DL to the list of models of INS products (see Introduction). |

| | | | |
|---|---|---|---|
| | | | 13. Added note about raw GNSS data logs for INS-DL (see notes below the Table 12.1) |
| 2.9 | Jul.31, 2018 | ON | For INS Demo version 2.0.46.279 from 2018-07-26 and higher.<br>1. Added “COM4” tab to “Devices options” window to combine settings of all variants of COM4 port using. Added appropriate section 4.2.5. “COM4” tab of “Devices options…” window.<br>2. Changed name and structure of section “10.7. INS operation with odometer”. Added section “10.7.1. INS operation with OBDII odometer”.<br>3. Added “Heading” measurement type to aiding data (see Table C.12) and appropriate data type to “User Defined Data” output format (see Table 4.2, Table C.27).<br>4. Added “Dilution of precision” data type to “User Defined Data” output format (see Table 4.2, Table C.27).<br>5. Added more detailed description of INS Demo operation with Inertial Labs™ CAN2.0-to-RS232 adapter (see section 10.8.1).<br>6. Added description of profile creation for INS data post-processing in Waypoint Inertial Explorer (see section 12.3).<br>7. Added choice of “Min Raw GNSS” (minimal set of raw GNSS data logs, see Table 12.2 in section 12.1) in COM2, COM3 port settings in the “GNSS receiver” tab of “Devices options…” window. It is supported in INS firmware since version 3.2.5.8.<br>8. Added description of “Get BIT” item in “Run” menu (see section 5.7).<br>9. Corrected position of the accelerometer mass-center in Inertial Labs™ INS unit (see Fig.F.1 in Appendix F.1). |
| 2.10 | Aug.30, 2018 | ON | For INS Demo version 2.0.46.281 from 2018-08-23 and higher.<br>1. Added “UTC” data type to “Time data” group, “GNSS Position and Speed accuracy” data type to “GNSS data” group in “User Defined Data” output format (see Table 4.2, Table C.27).<br>2. Updated “User defined data…” dialog window (see Fig.4.28, Fig.4.29 in section 4.6). |
| 2.11 | Oct.03, 2018 | ON | 1. Added Inertial Labs™ INS-B-OEM and INS-D/DL-OEM units (see Introduction).<br>2. Added position of the accelerometer mass-center in Inertial Labs™ INS-OEM unit (see Fig.F.2 in Appendix F.1).<br>3. Changed measurement units of accelerations AccX, AccY, AccZ from m/s2 to ‘g’ in “INS OPVT GNSSext” data format (see Table C.25).<br>4. Added “GDOP, PDOP” and “GNSS Track over ground” data types to “User Defined Data” output format (see Table 4.2, Table C.27).<br>5. Renamed “UTC” data types in “User Defined Data” output format (see Table C.27).<br>6. Added “Device self test” menu item to the “Run” menu and its description in section 5.7.<br>7. Added explanation of INS average data rate that appears in the left part of the status bar (see section 5.1).<br>8. Added explanation of “UTC Decimal Seconds” in “User Defined Data” output format (see Note 4 to Table C.27 in Appendix C.1). |

| | | | |
|---|---|---|---|
| 2.12 | Feb.04, 2019 | DB, ON | 1. “GPIO” line of electrical interface is renamed to “MARK IN”.<br>2. Added “Cobham UAV 200 Satcom” output data format in “Test options” menu item. |
| 2.13 | Feb.26, 2019 | DB, ON | For INS GUI version 2.0.47.309 from 2019-02-25 and higher.<br>1. Added “Averaged output data” checkbox to “IMU” tabs of “Devices options” window to switch between averaged and instant data at output data at rate less than 200Hz.<br>2. Changed “External sensors” tab of “Devices options” window and its description in section 4.2.4.<br>3. “COM4” tab of “Devices options” window is renamed to “CAN / COM4” tab, see its description in section 4.2.5.<br>4. Updated section “10.7. INS operation with odometer”.<br>5. Added support and configuration of both CAN 2.0A and CAN 2.0B messages (see sections 4.2.5.1, 10.8).<br>6. Updated section “10.8. Operations with CAN data”.<br>7. Removed section “10.8.1. Using Inertial Labs™ CAN2.0-to-RS232 adapter for evaluation”.<br>8. Added “Magnetometers axes alignment” menu item to the “Plugins” menu and its description in section 8.4, and section “10.9. INS and OS3D-FG SAMC axes alignment”<br>9. Added section “12.2.1. Embedding raw IMU data into GNSS stream” |
| 2.14 | Apr.02, 2019 | DB, ON | 1. Added “Wheel circumference (m)” and “Tics per revolution” parameters of encoder to “External sensors tab” of “Devices options” window (see sections 4.2.4, 10.7.2).<br>2. Added possibility to include TIMEDWHEELDATA logs with raw encoder data to combined file with raw IMU and raw GNSS data for post-processing (see section 12.2.1).<br>3. Added support of output HEHDT messages through COM4 port, see section 4.2.5.<br>4. Added “Sensors options” item at the “Options” menu, see section 4.4.<br>5. Removed obsolete ranges of gyros and accelerometers and appropriate values of KG, KA factors for gyro and accelerometer scaled data in “Appendix C.1. Description of data files”. |
| 2.15 | Apr.08, 2019 | DB,JZ | 1. Added support of an external GNSS receiver in “External Sensors” tab. |
| 2.16 | Apr.11, 2019 | ON, DB, JZ | 1. Added “External velocity” aiding data (see Table 4.2, Table C.12, Table C.27).<br>2. Added “Ext.Vel. reference frame” choice to “External sensors” tab of “Devices options” window.<br>3. Added “GNSS receiver clock info” data type to “User Defined Data” output format (see Table 4.2, Table C.27, Table C.29).<br>4. Changed IMU Status description (see Table C.24). |
| 2.17 | May.03, 2019 | ON, DB, JZ | 1. Implemented a possibility to utilize “User Defined Data” output format with converter “Combine RAWIMUB and GPS data” (see essential notes in section 12.2.1). |

| | | | |
|---|---|---|---|
| 2.18 | May.24, 2019 | DB, JZ | 1. Added possibility to output “COM1 duplicated data” through port COM4, see section 4.2.5.2.<br>2. Added “Velocity constraints” option to “Correction options” window (see Fig. 4.26).<br>3. Added “KF position covariance HR” data To “INS service data” group of “User Defined Data” output format (see Table 4.2). |
| 2.19 | Jun.20, 2019 | DB | 1. Added important note about connection of encoder-based odometer to INS, see section 4.2.4.1.<br>2. Removed “Extended info” checkbox from “GNSS receivers” tab of “Devices options” window (see section 4.2.2).<br>3. Added new parameters to configure ZUPT mode, see section 4.3. |
| 2.20 | Jul.03, 2019 | DB | 1. Added possibility to choose GNSS receiver’s COM2, COM3 port type, see section 4.2.2.<br>2. Added new section “8.5. World Magnetic Model updating”.<br>3. Added TerraStar based correction to “GNSS receiver” tab of “Devices options” window (see section 4.2.2). |
| 2.21 | Jul.24, 2019 | DB | 1. Added new section “10.2.3. Accelerated start of the NovAtel GNSS receiver with TerraStar service at known position”.<br>2. Corrected information related to INS initial alignment process throughout the whole document.<br>3. Added note 3 to section “4.2.4.3 Using external magnetic compass” about necessity power off / on the INS unit so changes get applied.<br>4. Replaced BDSEPHEMA and GALEPHEMA logs with BD2EPHEM and GALEPHEMERIS logs respectively (see Table 12.2). |
| 2.22 | Jul.30, 2019 | DB, WD | 1. Added “Appendix I. Using the Internal Datalogger”. |
| 2.23 | Aug,19, 2019 | ON, DB | 1. In section “4.2.4.2. Using the main COM1 port to receive external aiding data” added note that “Odometer offset” specifies the reference point position for external velocity data relative to the INS unit.<br>2. Added “NAV440” output data format in “Test options” menu item.<br>3. Corrected information about rotation angles in section 10.4 and Appendix E.<br>4. Corrected information in Appendix I. “Using the Internal Datalogger”.<br>5. Added Appendix J. INS Preventive Maintenance. |
| 2.24 | Sep.25, 2019 | DB, ON | 1. Added note in section 4.2.4.3 that external magnetic compass SAMC can be installed with any orientation relative to INS unit, but their axes alignment is necessary.<br>2. Specified acceptable change of pitch and roll angles in different positions for procedure of INS and SAMC axes alignment, see section 10.9.<br>3. Corrected description to the GNSS correction “AUTO” type, see section 10.2.1.<br>4. Added additional description of internal datalogger features (see Appendix I).<br>5. Added “ZUPT threshold” parameter to “External sensors” tab of “Devices options…” window which is velocity threshold for stop detection at operation with encoder, see section 4.2.4.1.<br>6. “Velocity constraints” option is updated to “Tunnel guide” feature |

| | | | |
|---|---|---|---|
| | | | (see section 4.3).<br>7. Added values to “INS solution status”: applied ZUPT, INS invalid solution, see Appendix C, Table C.29.<br>8. Changed USW bit #1 indication to “Software status”, see Appendix D. |
| 2.25 | Oct.02, 2019 | DB | 1. Added “Firmware and parameters update…” menu item to the “Plugins” menu and its description in section 8.6, and section “14. The procedure of INS firmware and parameters updating”. |
| 2.26 | Oct.10, 2019 | DB | 1. Implemented a possibility to configure INS to use CAN BUS based odometer (see sections 4.2.5.2 and 10.7.2). |
| 2.27 | Oct.16, 2019 | AS | 1. Revised Appendix I. “Using the Internal Datalogger”. Revised web interface, added automatic logging and recycling description. |
| 2.28 | Nov.06, 2019 | DB, ON | 1. Parameter “Ext.Vel. reference frame” is renamed to “DVL reference frame” in “External sensors” tab of “Devices options” window (see sections 4.2.4). Also changed name of external aiding data type “External velocity” to “DVL data” (see sections 4.7).<br>2. Added explanation of Factor and Offset parameters in CAN message description for CAN BUS based odometer (see section 10.7.2). |
| 2.29 | Dec.02, 2019 | DB | 1. Added new section “Appendix I.6 Setting up a DHCP server to use the internal datalogger”.<br>2. Revised information window about successful axis alignment procedure between SAMC and INS unit (see Fig. 10.40).<br>3. Added note about how *.hrm file can be created within post-processing in the NovAtel Inertial Explorer (see section 9).<br>4. Changed configuration parameters for signal 3 of CAN BUS based odometer (see section 10.7.2). |
| 2.30 | Dec.27, 2019 | DB | 1. Added note about the inability to combine the internal dataloger and support Ethernet for data/command transfer in one INS unit (see preface to Appendix H).<br>2. Revised Appendix I. “Using the Internal Datalogger”. Added description to new web interface. |
| 2.31 | Jan.09, 2020 | DB | 1. Added “Save last position” checkbox to “IMU” tab of “Devices options” window (see sections 4.2.1). |
| 2.32 | Jan.23, 2020 | ON | 1. Added automatic 3D calibration of magnetometers and its description (see section 10.4.5).<br>2. Added section “10.4.6. Choice of set of INS calibration parameters”. |
| 2.33 | Feb.03, 2020 | DB | 1. Added section “10.8.3. Modifying the DBC file to interpret the CAN messages”.<br>2. Implemented a possibility to output CAN messages through second CAN BUS (see sections 4.2.5.1). |
| 2.34 | Feb.10, 2020 | DB | 1. Added automatic 2D calibration of magnetometers and its description (see section 10.4.5). |
| 2.35 | Feb.24, 2020 | ON | 1. Added “Emulate” item to “File” menu for emulation if INS operation using saved data (see section 6.2).<br>2. Added switching off / on the GNSS receiver data input to the INS algorithm (see section 10.10). |
| 2.36 | Feb.26, 2020 | DB | 1. Added section “Appendix I.7 The procedure of the Datalogger updating”. |

| | | | |
|---|---|---|---|
| 2.37 | Mar.30, 2020 | ON | 1. Added new parameters “Freeze position and velocity” and Gyro_3 threshold to configuration of ZUPT mode in “Correction options…” window (see section 4.3).<br>2. Added possibility to enable PDP filter in the NovAtel receiver in “GNSS receiver” tab of “Devices options” windows. |
| 2.38 | May.28, 2020 | DB | 1. Specified that for operation with second CAN port device should be factory configured by user request (see section 4.2.5).<br>2. Added possibility to disable SBAS and Terrastar corrections (see section 10.2.1).<br>3. Added possibility to adjust the INS unit for input external PPS signal (see description in section 13.1).<br>4. Specified if the external GNSS receiver is used then it is highly recommended to feed its PPS signal to INS input (see section 4.2.4.4). Also, added the possibility to choose INS port type (COM or Ethernet) to input data from an external GNSS receiver. |
| 2.39 | Jun.24, 2020 | DB | 1. Added STD_k field to the “External sensors” tab of “Devices options…” window, which allows setting noise STD of external heading data (see section 4.2.4.2).<br>2. Revised and corrected section “4.2.8. Limitation of the INS maximum output data rate”.<br>3. Added “Velocities HR” data type to “Navigation data” group of “User Defined Data” output format (see section 4.7, Table 4.2, Table C.28).<br>4. Added “GNSS antennas position” data type to “External aiding data” group of “User Defined Data” output format (see section 4.7, Table 4.2, Table C.28). Also, information about “GNSS antennas position” is included to “New aiding data” indicator (see Table C.13, bit #9).<br>5. Added examples of signals in little- and big-endian formats in CAN messages from CAN BUS (see section 10.7.2, Fig.10.30 and Fig.10.31).<br>6. Removed notes that the VG3D calibration is at the testing stage. |
| 2.40 | Jul.17, 2020 | TL, DB | 1. Grammar revisions and readability.<br>2. Added note that during 2D-2T calibration it is recommended to change the Pitch angle in every run on maximum possible value (at least on 15 degrees) (see section 10.4.1). |
| 2.41 | Aug.20, 2020 | WD | Complete revision of Internal Datalogger Section (Appendix I) |
| 2.42 | Sep.30, 2020 | DB | 1. Removed “Load Block Parameters” and “Read Block Parameters” items from the “Parameters” menu as an obsolete functionality. Additionally, removed section 7.1 with their description.<br>2. Removed “Fixed” checkbox from “IMU” tab of “Devices options” window (see section 4.2.1). Currently, the INS data rate is limited by factors of 200 Hz automatically, no user action need.<br>3. Revised section “8.3. Angles accuracy”.<br>4. Added “Calculation time” data type to “User Defined Data” output format (see Table 4.2, Table C.28).<br>5. To “GNSS position type” added the following options to shows what data was used by the GNSS receiver in navigation solution for position calculation: PPP conv., PPP, PPP basic conv., PPP basic (see section 5.1). |

| | | | |
|---|---|---|---|
| | | | 6. Renamed the “TerraStar” drop-down list to “PPP” in “GNSS receiver” tab of “Devices options” window, and to the list added the new option “Oceanix” (see section 4.2.2 and 10.2.1).<br>7. Added Oceanix correction type to Table C.5 and Table C.16.<br>8. Added miniAHRS type to “Use external magnetic compass” drop-down list in the “External sensors” tab of the “Devices options” window. Additionally, there added possibility to set manually the SAMC alignment angles if the procedure of axes alignment between INS and SAMC cannot be performed (see section 4.2.4.3). |
| 2.43 | Nov.09, 2020 | DB | 1. Revised and corrected Table C.16 (pos_type) with notes below.<br>2. Added note if hardware error occurred, then all USW bits become equal to 1 (see Appendix D).<br>3. Added information about new INS type – INS-DU. |
| 2.44 | Nov.17, 2020 | DB | 1. Added “Ambient Air Data” to the new aiding data indicator (see Table C.13) and added appropriate data type to “User Defined Data” output (see Table 4.2 and Table C.28).<br>2. Specified that the usage of the “Ambient Air Data” can increase the accuracy of barometric altitude calculation (see section 10.3).<br>3. Added note that the North wind and East wind data are northward and eastward components of the ground speed of air mass motion (see notes below to Table C.12 and Table C.28). |
| 2.45 | Mar.12, 2021 | DB | 1. Improved readability of INS axes name in Fig. F.4.<br>2. Added “Altitude external” to the new aiding data indicator (see Table C.13) and added appropriate data type to “User Defined Data” output format (see Table 4.2 and Table C.28).<br>3. Updated text and links through Appendix H. Also, there added new subsections “H.6. Communication OVER the Ethernet in TCP/IP MODE” and “H.7. Communication OVER the Ethernet in Auto Start Mode”.<br>4. Updated Fig. 12.5, Fig. 12.6, and Fig. 12.12 and description to them within section 12 due to the new appearance in the last Inertial Explorer software version.<br>5. Added “Freeze orientation” parameter to ZUPT mode that allows freezing of the INS orientation when immobility is detected (see section 4.3).<br>6. Added “GyroF_Bandwidth” parameter to “Correction options” window to configure bandwidth of filtered gyro data (see section 4.3). “Gyro data filtered” is added to “User Defined Data” output format (see Table 4.2 and Table C.28). |
| 2.46 | Mar.26, 2021 | DB | 1. Specified the default value for GyroF_Bandwidth parameter is 0 Hz, see section 4.3.<br>2. Added “Table 4.2. The default value of ZUPT parameters” to section 4.3.<br>3. Added “Convert to IMR data” and “Convert to DMR data” options to Convert main menu (see section 9).<br>4. Added “Wind speed” data type to “User Defined Data” output format (see Table 4.2 and Table C.28).<br>5. Added R_w parameter for adjusting Kalman Filter for wind speed estimation, see section 4.2.4.2. |

| | | | |
|---|---|---|---|
| 2.47 | Apr.29, 2021 | DB | 1. Renamed the “Odometer offset relative to the IMU” parameter to “External data offset relative to the IMU” in the “External sensors” tab of “Devices options” (see section 4.2.4).<br>2. Revised and corrected description to “Convert log data to bin file” converter (see section 9.5).<br>3. Added KF_restart_delay parameter to correction options window to configure delay of INS Kalman Filter restart at available GNSS data when KF measurement residual exceeds the set threshold. It allows adjusting INS robustness at multi-path and other GNSS data corruption. See section 4.3.<br>4. Added “HG4930 IMU status” data type to “User Defined Data” output format (see Table 4.2 and Table C.28). The status description provided in Table C.29. |
| 2.48 | May.17, 2021 | DB | 1. Corrected information regarding INS-DL within Table 12.1, Table 12.2, and Table 12.3.<br>2. Corrected 7$^{th}$ bit in Table C.29 from 1 to 0. |

# Table of Contents

Introduction ..... 19
The Most Important Notes ..... 21
1. General Information ..... 22
2. Installation of Drivers and Configuration of PC Parameters ..... 23
3. Main Menu of the Program ..... 24
4. Options Menus ..... 26
4.1. Test Options ..... 26
4.2. Devices Options ..... 28
4.2.1. “IMU” Tab of “Devices Options” Window ..... 29
4.2.2. “GNSS Receiver” Tab of “Devices Options” Window ..... 32
4.2.3. “Pressure Sensor” Tab of “Devices Options” Window ..... 36
4.2.4. “External Sensors” Tab of “Devices Options” Window ..... 37
4.2.4.1. Parameters of Encoder-Based Odometer ..... 37
4.2.4.2. Using the Main COM1 Port to Receive External Aiding Data ..... 38
4.2.4.3. Using External Magnetic Compass ..... 39
4.2.4.4. Using External GNSS Receiver ..... 40
4.2.5. “CAN / COM4” Tab of “Devices Options” Window ..... 41
4.2.5.1. Configuration of CAN Messages Output ..... 41
4.2.5.2. Configuration of CAN Messages Input (for CAN BUS Based Odometer) ..... 42
4.2.5.3. Configuration of COM4 Port ..... 43
4.2.5.4. Parameters of OBDII Odometer ..... 43
4.2.6. “Triggers” Tab of “Devices Options” Window ..... 44
4.2.7. Change of the Main COM-Port Baud Rate ..... 45
4.2.8. Limitation of the INS Maximum Output Data Rate ..... 47
4.3. Correction Options ..... 48
4.4. Sensors Options ..... 52
4.5. Swaying Compensation ..... 53
4.6. Magnetometers Calibration Options ..... 54
4.7. User Defined Data ..... 55
4.7.1. Review and Editing of the Existing Configuration of the “User Defined Data” Format in INS Unit ..... 59
4.7.2. “User Defined Data” Format Configuration File (*.udd) ..... 60
4.7.3. INS Start with “User defined data” Output Format ..... 60
5. Run Menu ..... 61
5.1. INS 3D ..... 61
5.2. Cockpit Style of Visualization ..... 67
5.3. On-the-Fly Accuracy Style of Visualization ..... 67
5.4. Data Graphs Style of Visualization ..... 68
5.5. Visualization of INS Relative Position ..... 69
5.6. Peculiarities of Data Displayed at the “INS Sensors Data” Format ..... 70
5.7. Other Items of the “Run” Menu ..... 71
6. File Menu ..... 72
6.1. “Open” Item ..... 72
6.2. “Emulate” Item ..... 73
6.3. “Save As” Item ..... 73

7. Parameters Menu ..... 74
7.1. Restore Parameters ..... 74
7.2. Save Parameters ..... 75
7.3. Preset Parameters ..... 75
8. Plugins Menu ..... 77
8.1. Embedded ..... 77
8.2. Magnetometers Field Calibration ..... 79
8.3. Angles Accuracy ..... 80
8.4. Magnetometers Axes Alignment ..... 81
8.5. World Magnetic Model Updating ..... 82
8.6. Firmware and Parameters Update ..... 83
9. Convert Menu ..... 84
9.1. Report of experiment ..... 84
9.2. Convert to Raw IMU data ..... 84
9.3. Convert to IMR data ..... 85
9.4. Convert to DMR data ..... 85
9.5. Convert log data to bin file ..... 85
9.6. Combine RAWIMUB and GPS data ..... 85
10. The INS Operation ..... 86
10.1. The Main Operation Modes of the INS ..... 86
10.2. Control of the GNSS Receiver ..... 90
10.2.1. GNSS Corrections ..... 90
10.2.2. Control of GNSS Receiver Model ..... 93
10.2.2.1. Adding New Model to the GNSS Receiver ..... 93
10.2.2.2. Choosing One of Saved Models for the GNSS Receiver ..... 94
10.2.2.3. Removing Model from the GNSS Receiver ..... 95
10.2.3. Accelerated Start of the NovAtel GNSS Receiver with TerraStar or Oceanix Service at Known Position ..... 95
10.3. Features of Altitude Calculation in the INS ..... 96
10.4. Calibration of the INS Magnetometers ..... 97
10.4.1. Description of the 2D, 2D-2T, 3D, and VG3D Calibration Procedures ..... 100
10.4.2. Clearing of the Soft and Hard Iron Calibration Parameters ..... 106
10.4.3. Conditions of Successful Calibration of the INS ..... 106
10.4.4. On-the-Fly VG3D Calibration ..... 107
10.4.5. Automatic 2D and 3D Calibration ..... 109
10.4.6. Choice of Set of INS Calibration Parameters ..... 110
10.5. Orientation Accuracy Test of the INS ..... 111
10.5.1. Separate Accuracy Test for Each Reference Angle ..... 112
10.5.2. On-the-Fly Accuracy Test ..... 114
10.6. INS Automatic Start ..... 118
10.7. INS Operation with Odometer ..... 119
10.7.1. INS Operation with OBDII Odometer ..... 120
10.7.2. INS Operation with CAN BUS Based Odometer ..... 121
10.7.3. INS Operation with Encoder-Based Odometer (Wheel Speed Sensor) ..... 122
10.7.3.1. Encoder-Based Odometer Calibration ..... 124
10.8. Operations with CAN Data ..... 126

10.8.1. Review and Editing of the Existing Configuration of the "CAN Message Set" Format in INS Unit ....129
10.8.2. "CAN Message Set" Format Configuration File (*.ucan) ....130
10.8.3. Modifying the DBC File to Interpret the CAN Messages ....130
10.9. INS and SAMC Axes Alignment ....132
10.9.1. Description of the Axes Alignment Procedures ....132
10.9.2. Clearing Axes Alignment Parameters ....134
10.10. Switching Off / On the GNSS Receiver Data Input ....135
11. Continuous Self-Monitoring of the INS Health ....137
12. INS and GNSS Data Post-Processing ....138
12.1. Recording of Raw GNSS Data ....138
12.2. Raw IMU Data Generation ....142
12.3. Generation of IMR Data File with IMU Data and Time ....143
12.3.1. INS GUI Embedded Convertor ....144
12.3.2. NovAtel Converter ....144
12.4. Generation of DMR Data File with Odometer Data and Time ....146
12.5. Embedding Raw IMU and Odometer Data into GNSS Stream ....146
12.6. INS Sensors Error Model for INS + GNSS Data Post-Processing ....149
13. Synchronization of INS Data with LiDAR and Other Devices ....151
13.1. Control of PPS Output Signal ....151
13.2. Processing of Mark Input Signal ....153
13.3. INS Operation with LiDAR ....153
13.3.1. Configuration of INS Main Data ....154
13.3.2. Configuration of COM2 Port for Output of GNSS Raw Data ....154
13.3.3. Configuration of COM3 Port for Output of $GPRMC Messages ....154
13.3.4. Configuration of PPS Signal ....155
13.3.5. Configuration of Mark Input Signal ....155
14. The Procedure of INS Firmware and Parameters Updating ....156
14.1. Using INS GUI for Firmware and Parameters Update ....156
14.2. Direct Run of Firmware and Parameters Update Utility ....158
15. Choice of 3D Model for Visualization of the INS Orientation ....159
16. Troubleshooting ....160
16.1. What to do at Strange Behavior of the INS ....160
16.2. How to Repair the INS Parameters ....161
16.3. What to do if Messages "Cannot read parameters!", "Cannot load parameters!", or "Cannot start INS" Appear ....162
APPENDIX A. Installation of the COM-to-USB Converter Drivers and Configuration of PC Parameters ....163
APPENDIX B. Installation of the MOXA Serial-to-USB Converter Drivers (for INS with RS-422 Interface) ....168
APPENDIX C. Description of Data Files ....172
C.1. Structure of Binary File ....172
APPENDIX D. The Unit Status Word Definition ....224
APPENDIX E. Variants of the Inertial Labs™ INS Mounting Relative to Object Axes ....225
APPENDIX F. Installation of the GNSS Antennas ....227
F.1. Installation of Single GNSS Antenna ....227
F.2. Installation of Two GNSS Antennas for INS-D Operation ....229

APPENDIX G. Use of the STRSVR Tool .....231
APPENDIX H. Using Ethernet Port for Communication with the Inertial Labs™ INS .....233
H.1. Connection Overview .....233
H.2. Connection Steps.....234
H.3. Networking Details .....234
H.4. Checking the Connection to the Network .....235
H.5. Communication VIA Ethernet USING a Virtual Serial Port .....236
H.6. Communication OVER the Ethernet in TCP/IP MODE.....236
H.7. Communication OVER the Ethernet in Auto Start Mode .....240
UDP messages logging/monitoring .....242
APPENDIX I. Using the Internal Datalogger .....244
I.1 Preparing INS for Operation with Datalogger .....244
I.2 Description of Web Based Internal Datalogger Interface .....244
I.3 Automatic Logging and Recycling .....249
I.4 Converting Outputted Data to *.txt File .....250
I.5 Notes on Applications of Internal Datalogger .....251
I.6 Setting up a DHCP Server to Use the Internal Datalogger .....252
I.7 The Procedure of the Datalogger Updating.....255
For Logger Versions Prior to 3.0.0 .....255
For Logger Versions After 3.0.0 .....257
APPENDIX J INS Preventive Maintenance.....259
J.1. Introduction .....259
J.2. General Care.....260
J.2.1. Surface Cleaning .....260
J.2.2. Protection for Magnetic Interference .....260
J.2.3. Safe Mounting Practices.....261
J.3. Calibrations .....261
J.3.1. Correct Calibration Methods .....261
J.3.2. Calibration Frequency .....261
J.3.3. Degaussing for Magnetometer Calibration.....262
J.4. Transportation .....262
J.4.1. Carrying Case .....262
J.5. Connector Care .....263
J.5.1. Data Cable Handling .....263
J.5.2. Data Rates for Given Cable Lengths .....264
J.6. Electrical Protection.....265
J.6.1. Surge Protector.....265
J.6.2. Powering Off.....265
J.6.3. Temperature Control .....266
J.7. Software and Firmware Protection.....266
J.7.1. Frequency of Updates .....266
J.7.2. Backing Up Data .....266
J.7.3. Monitoring Storage.....266
J.7.4. Datalogger Security.....267
J.8. Repair and Replacement.....267
J.8.1. Warranty Information.....267

# List of Tables

Table 4.1. INS maximum measurement rate for different output data formats ..... 47
Table 4.2. The default value of ZUPT parameters ..... 51
Table 4.3. Groups and data types of the "User Defined Data" ..... 56
Table 10.1. Available variants of SBAS data ..... 91
Table 10.2. Example of a *.csv file created at accuracy test ..... 117
Table 10.3. List of supported CAN messages ..... 127
Table 10.4. Example of rotation angles ..... 132
Table 12.1. Logs for raw GNSS data ..... 139
Table 12.2. Minimal set of raw GNSS data logs ..... 139
Table 12.3. Logs of raw GNSS data supported by INS-DL and INS-DU units ..... 140
Table 12.4. Binary Structure of raw IMU data ..... 143
Table C.1. Structure of the first 50 bytes of *.bin file (short block of initial alignment data) 172
Table C.2. Structure of the first 128 bytes of *.bin file at extended block of initial alignment data ..... 173
Table C.3. The INS message payload at the "INS OPVT" (Orientation, Position, Velocity, Time) data format ..... 174
Table C.4. Values of KG, KA factors for gyro and accelerometer scaled data ..... 175
Table C.5. GNSS_info1 – information about GNSS data ..... 175
Table C.6. GNSS_info2 – information about GNSS data ..... 176
Table C.7. New_GPS indicator of new update of GNSS data ..... 176
Table C.8. The INS message payload at the "INS QPVT" (Quaternion of orientation, position, velocity, time) data format ..... 176
Table C.9. The INS message payload at the "INS OPVT2A" (Orientation, Position, Velocity, Time, Dual-antenna receiver data) format ..... 178
Table C.10. The INS message payload at the "INS OPVT2AW" (Orientation, Position, Velocity, Time, Dual-antenna receiver data, GPS Week) format ..... 180
Table C.11. The INS message payload at the "INS OPVT2AHR" (Orientation, Position, Velocity, Time, Dual-antenna receiver data, with high resolution) data format ..... 182
Table C.12. The INS message payload at the "INS OPVTAD" data format ..... 183
Table C.13. New aiding data indicator ..... 186
Table C.14. The message payload at the "INS Sensors Data" format ..... 187
Table C.15. sol_stat – GNSS solution status ..... 188
Table C.16. pos_type – GNSS position or velocity type ..... 189
Table C.17. ext_sol_stat – GNSS extended solution status ..... 189
Table C.18. GPS and GLONASS signal-used mask ..... 190
Table C.19. Galileo and BeiDou signal-used mask ..... 190
Table C.20. The message payload at the "INS Minimal Data" format ..... 190
Table C.21. The message payload at the "INS OPVT & Raw IMU Data" format ..... 191
Table C.22. The "SPAN rawimu" message structure ..... 192
Table C.23. GPS Reference Time Status ..... 193
Table C.24. GNSS Receiver Status ..... 193
Table C.25. IMU Status ..... 194
Table C.26. The INS message payload at the "INS OPVT GNSSext" data format ..... 194
Table C.27. Payload of the "User Defined Data" ..... 197
Table C.28. Detailed description of "User Defined Data" structure ..... 197

Table C.29. The Honeywell HG4930 IMU status description ..... 203
Table C.30. INS solution status (data type # 0x54) ..... 203
Table C.31. Structure of the “Cobham UAV 200 Satcom” sentence ..... 206
Table C.32. The “NAV440” message structure ..... 207
Table C.33. NAV440 Default BIT Status Definitions ..... 208
Table D.1. The Unit Status Word description ..... 224
Table J.1. Data rate for cable lengths using the CAN Bus cable ..... 264
Table J.2. Data rate for cable lengths using the RS-232 cable ..... 265
Table J.3. Data rate for cable lengths using the RS-422 cable ..... 265

# Introduction

This manual is designed to study and use software for all modifications of the Inertial Labs™ GPS-Aided Inertial Navigation System (INS) for its designed purposes.

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

Inertial Labs™ provides the following models of INS products (see Fig. 0.1 to Fig. 0.6):

- INS-B and INS-B-OEM (Basic model) – use high-grade IMU and high-grade single-antenna GNSS receiver;
- INS-P (Professional model) – uses high-grade Fluxgate magnetometers, high-grade IMU, and high-grade single-antenna GNSS receiver; and
- INS-D, INS-DL, INS-DU (dal-antenna models), and appropriate OEM versions – use high-grade IMU and dual-antenna GNSS receiver and measures static and dynamic heading, independent of magnetic field disturbance.

**Important notes:**

1. In this document, all information related to the INS-D is correct for the INS-DL and INS-DU, unless otherwise specified.
2. In this document, all information related to the INS-B, INS-P, and INS-D is correct for the INS-B-OEM, INS-P-OEM and INS-D-OEM respectively, unless otherwise specified.
3. Any model of INS can be factory configured to contain an internal datalogger to record data, but only upon request by a customer (see Appendix I. Using the Internal Datalogger”).

**Fig. 0.1. Inertial Labs™ INS-B and INS-P**

**Fig. 0.2. Inertial Labs™ INS-D and INS-DL**

**Fig. 0.3. Inertial Labs™ INS-DU**

**Fig. 0.4. Inertial Labs™ INS-B-OEM and INS-P-OEM**

**Fig. 0.5. Inertial Labs™ INS-D-OEM and INS-DL-OEM**

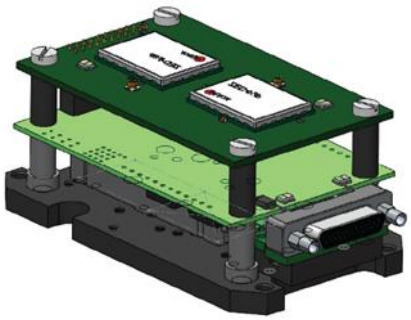


**Fig. 0.6. Inertial Labs™ INS-DU-OEM**

# The Most Important Notes

| Subject | Note |
|---|---|
| To view and edit INS parameters | INS must be connected to a computer and powered.<br>The serial port number to which the INS is connected and its baud rate should be chosen in the “Test options” menu (see section 4.1). |
| INS readiness for operations | INS is ready to receive commands and to output data after initialization time is completed (not more than 25 sec after power on) and the LED indicator has switched color from yellow to red. |
| At the first use | 1. Please enter approximately true Latitude, Longitude, Altitude, and Date in the “Device options”, “IMU” tab (see section 4.2.1). This allows correct INS start even without visible GNSS satellites.<br>2. Next, set correct value of the magnetic declination. This parameter is necessary to calculate true heading using measured magnetic heading. Since INS firmware version 2.2.0.2, the magnetic declination can be calculated in the INS continuously. Check “Auto” in the “Device options” menu to activate this option. |
| After INS and GNSS antenna(s) installation | Measure the GNSS antenna position relative to the IMU (in m). For INS-D, also measure the secondary antenna position relative to the IMU (in m). Then enter these coordinates in the appropriate fields in “IMU” tab of the “Devices options” menu (see section 4.2.1). |
| Data rate (update rate) | This can be changed in the “Devices options” menu, but it must not exceed the maximum value shown in Table 4.1 (see section 4.2.8). |
| Object hard and soft iron compensation | Do not forget to calibrate INS-P on hard and soft iron after mounting on the carrier object (see section 10.4). However, if the “Use_mags” switch is disabled in the “Settings” tab of “Correction options”, then such calibration is not necessary. |
| Pressure sensor | If the INS has no access to the ambient external pressure (for example, if it is installed inside a pressurized cabin) or if the INS pressure sensor can be exposed to speed air streams, please set the Baro-altimeter to “Disabled” in the “Pressure sensor” tab of the “Devices options” menu to switch the INS vertical correction to the GNSS altitude only. |
| Automatic start | INS has the ability to start operation automatically after power on, with continuous output data in desirable output data format (see section 10.6). |
| Changing parameters of GNSS receiver or CAN, COM4 settings | After changing parameters in the “GNSS receiver” or “CAN / COM4” tab of the “Devices options” menu, it is necessary to power off/power on the INS unit to either restart onboard GNSS receiver or to re-initialize COM4 port. |
| INS algorithm adjustment | Features of the INS algorithm and possibilities of their adjustment are described in section “4.3. Correction Options”. |

# 1. General Information

## Operating system

This version of the GUI software is fully compatible with the operating system MS Windows XP, MS Windows Vista, MS Windows 7, and MS Windows 10.

## Working with the software

The "Inertial Labs™ INS GUI" software is a windows-based Win32 application, and standard means used in Windows (mouse and keyboard) are needed to operate it. Directory structure necessary for data storage is created by user. All necessary configurations and calibration coefficients are stored in the INS nonvolatile memory, and they are automatically loaded into the INS microprocessor. Calibration coefficients are set by INS developers; they can be changed, but only under guidance of the INS developer. Upon termination, the "Inertial Labs™ INS GUI" software creates a default.prm file for its operation, in which the most recently used parameters of the microprocessor and shell are stored. During work with the INS, files with extensions of .txt, .rtf, .prm, .dat, and .bin can be created. Files with extensions .txt and .rtf can be created by operator, and files with extensions .prm, .dat and .bin are created automatically by the software when it saves text or graphical data.

## Requirements to the system resources

The software requires 6 Mbytes of RAM for proper operation. Hard disk capacity required for proper operation is determined by the size of the GUI software files (approximately 12 MBytes) and by the files saved during operation (no more than 100 Mbytes). Recommended screen resolution is 1280x1024 pixels. The INS is connected to a computer through a standard COM-port. The INS can also be connected to a PC through a USB-port with a COM-to-USB converter. In this case, reliability of signal reception/transmission between a PC and the INS can greatly depend on the quality of the COM-to-USB converter and on correct configuration of its driver. The INS manufacturer guarantees reliable operation of the INS if it is connected directly to the COM-port. Appendix A describes installation and configuration of drivers for one of the possible COM-to-USB converters.

## Requirements to operators

The INS GUI software uses a standard Windows operating system. To use the GUI software, operators should know the basic principles of PC operation and should be able to use the MS Windows operating system.

# 2. Installation of Drivers and Configuration of PC Parameters

The "Inertial Labs™ INS GUI" software does not require any installation. Simply copy the software folder INS_GUI_* to the working directory.

When you connect the INS with RS-232 interface to a standard computer COM-port, drivers are not needed. If the INS is connected to a USB-port with a COM-to-USB converter, in some cases a driver may be required (see "Appendix A. Installation of the COM-to-USB Converter Drivers and Configuration of PC parameters" for more details).

If you use the INS with RS-422 interface, you must install an RS422-to-USB converter driver (see "Appendix B. Installation of the MOXA Serial-to-USB Converter Drivers (for INS with RS-422 interface)").

To find the numbers of the PC COM-ports, go to the "**Device Manager**" window (Control Panel/System and Security/System/Device Manager). In the opened "Device Manager" window (Fig. 2.1), 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 the OS.

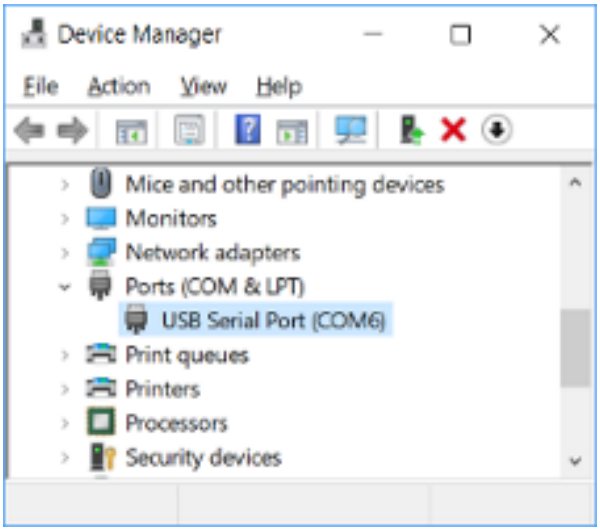



**Fig. 2.1.**

# 3. Main Menu of the Program

The main menu of the "Inertial Labs™ INS GUI" software contains the following items (Fig. 3.1).

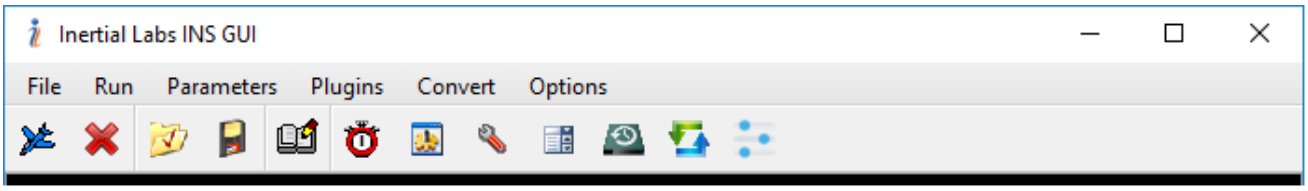



**Fig. 3.1.**

**File** menu contains operations with saved data of INS runs (Fig. 3.2).

**Run** menu contains the INS control commands (Fig. 3.3).

**Parameters** menu contains operations with INS parameters (Fig. 3.4).

**Plugins** menu contains the INS GUI plugins (Fig. 3.5).

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

**Options** menu contains the INS configuration commands (Fig. 3.7).

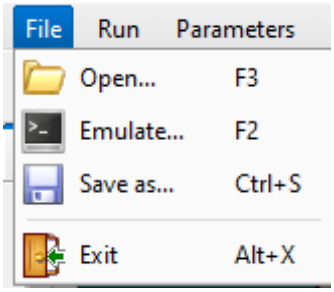



**Fig. 3.2.**

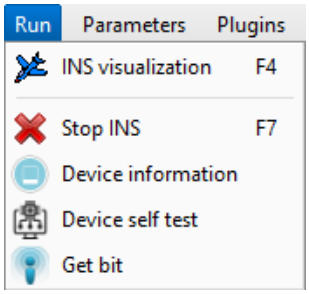



**Fig. 3.3.**

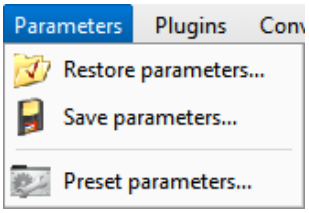



**Fig. 3.4.**

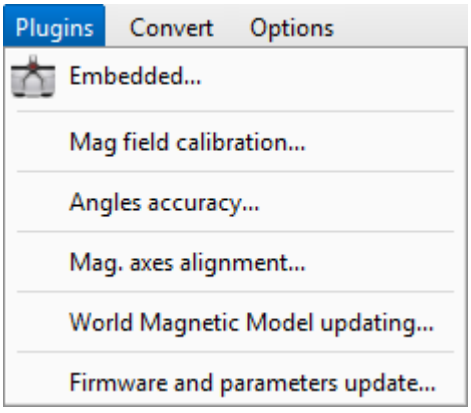



**Fig. 3.5.**

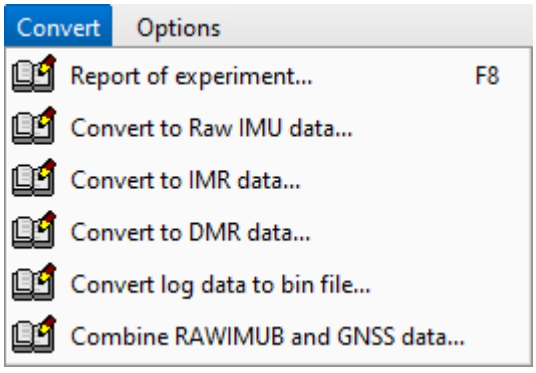



**Fig. 3.6.**

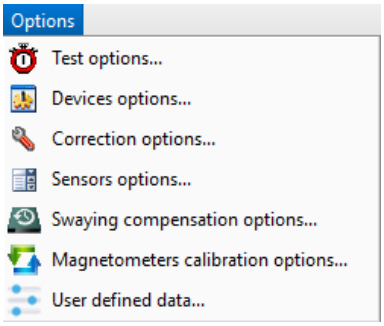



**Fig. 3.7.**

Icons for the most often used commands are placed on the horizontal toolbar.

**Run:**

INS visualization, F4

Stop INS

**Parameters:**

Restore parameters

Save parameters

**Convert:**

Report of experiment, F8

**Options:**

Test options

Swaying compensation options

Devices options

Magnetometers calibration options

Correction options

User defined data

Sensor options

# 4. Options Menus

## 4.1. Test Options

To set operation parameters of the INS, COM-port, format of output data, select **"Test options"** (Fig. 3.7) from the **"Options"** menu (or click icon). A **"Test Options"** dialog box (Fig. 4.1) will open.

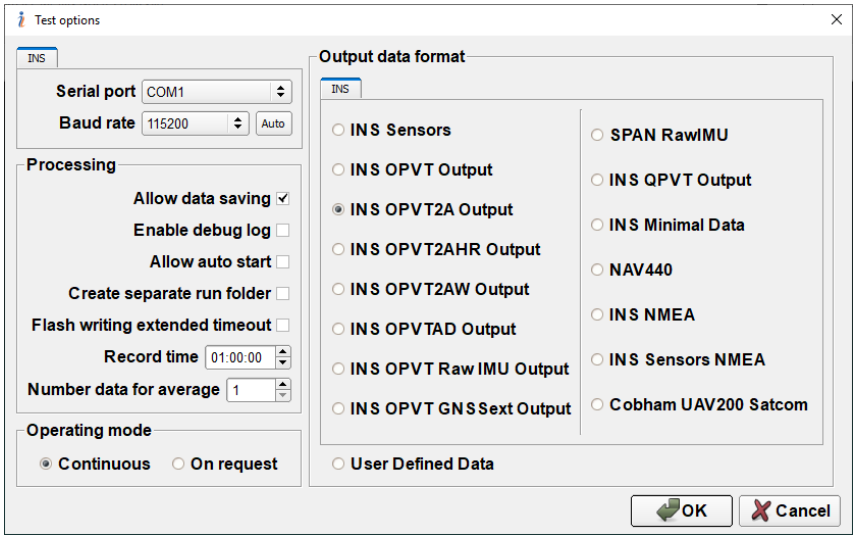



**Fig. 4.1.**

You can set the following parameters in the **"Test Options"** window:

- **Serial port** – number of the COM-port to which the main port of the INS is connected.
- **Baud rate** – set rate of the computer COM-port for connection of the INS unit. (See section 4.2.7 for details.) The default value of the baud rate is 115200 bps.
- **Allow data saving** – allows recording of the test data to file. If it is unchecked, no file will be created. If it is checked, a file will be created and the message "Data are writing in file" will be displayed.
- **Enable debug log** – allows recording of the log file of a test run. In case of an INS GUI crash, this file can be used to debug errors. Log file contains information about commands that were sent by the INS GUI and appeared errors. In case of errors, this file should be sent to the Inertial Labs™ with a brief description of user actions.
- **Allow auto start** – allows operation with INS that was already started before run of the INS GUI software. (See section 10.6 for details.)
- **Create separate run folder** – allows automatic creation of separate data folder for each run. On default this option is disabled.

- **Flash writing extended timeout** – when checked, the software waits for an answer from the INS for up to 20 seconds after the command for parameters loading to IMU was sent. This parameter should be set if recommended by developers for special INS firmware. By default, "Flash writing extended timeout" 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, and seconds can be changed using 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 is changed with the arrows to ±1 or by entering the required value from a keyboard. The default value is 1.
- **Operating mode** – defines the INS's output method, Continuous or On Request. The default method is Continuous.
- **Output data format** – sets the format of INS output data. User can select one of the following formats:
    - INS Sensors (contains data from the devices inside INS – IMU (as AHRS), GNSS receiver, pressure sensor)
    - INS OPVT Output (orientation, position, velocity, time)
    - INS OPVT2A (orientation, position, velocity, time, dual-antenna receiver data)
    - INS OPVT2AW (orientation, position, velocity, time, dual-antenna receiver data, GPS week)
    - INS OPVT2AHR (orientation, position, velocity, time, dual-antenna receiver data, with high resolution)
    - INS OPVTAD (orientation, position, velocity, time, external aiding data)
    - INS QPVT Output (quaternion of orientation, position, velocity, time)
    - INS Minimal Data (minimal configuration of orientation, position, velocity and time data)
    - INS OPVT & Raw IMU Data (orientation, position, velocity, time and raw IMU data)
    - SPAN rawimu (raw IMU data in NovAtel SPAN rawimub format)
    - INS OPVT GNSSext (orientation, position, velocity, and extended information about time and the GNSS data
    - INS NMEA
    - INS Sensors NMEA

- Cobham UAV 200 Satcom
- NAV440
- User Defined Data (see section 4.7 for details)

The default data format is “INS OPVT Output”. For more information on the output data formats, see Appendix C.

## 4.2. Devices Options

To set and control INS operation parameters, select **“Devices options”** from the **“Options”** menu (Fig. 3.7), or click icon (Fig. 3.1). A **“Devices options”** (Fig. 4.2) dialog box will open. There are six tabs: IMU, GNSS receiver, Pressure sensor, External sensors, CAN / COM4, and Triggers.

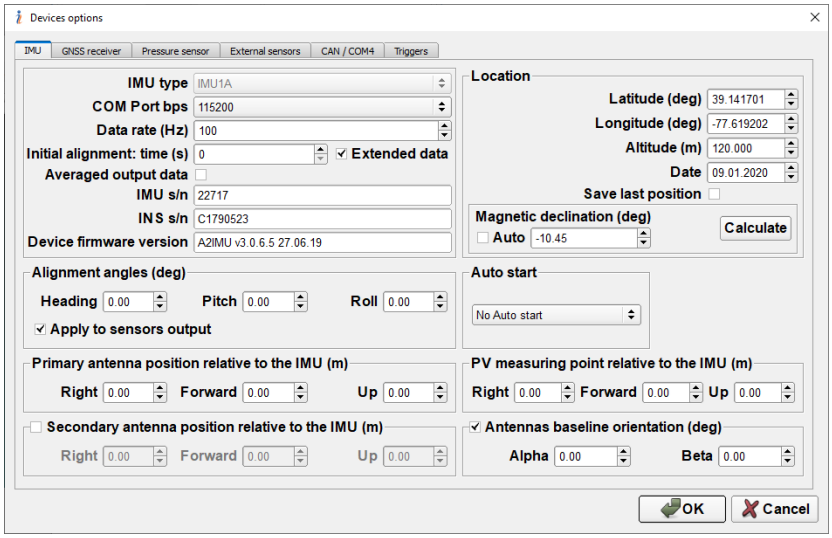



**Fig. 4.2.**

A **“Devices option”** item is available <u>only if</u>:

- The INS is powered,
- the INS is connected to a computer,
- the COM port number and its baud rate are chosen properly, and
- INS initialization time (about 25 seconds after power on) is completed and LED indicator lights red.

If all of these features are not in place, the error window with message “**Cannot read parameters!**” appears over the above window (see Fig. 4.3). Click “OK”, and choose the correct COM-port number (see section “4.1. Test Options”).

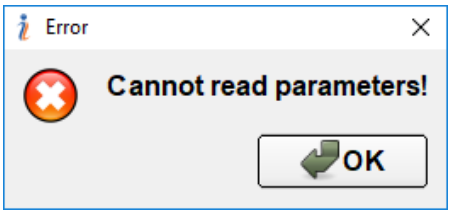



**Fig. 4.3.**

### 4.2.1. "IMU" Tab of "Devices Options" Window

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 (see Fig. 4.2):

- **IMU type** – shows type of IMU inside the INS unit. This parameter cannot be changed.
- **COM Port bps** – sets baud rate of the main INS COM-port (see section "4.2.7. Change of the Main COM-Port Baud Rate" for details). Default value is set to 115200 bps.
- **Data rate (Hz)** – sets output data rate in Hertz. Minimum value of the parameter is 1; maximum value is 200. This rate 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 data rate is limited by the chosen baud rate of the COM-port that the INS unit is connected to, and it also depends on the chosen output data format (see Fig. 4.1) because of different numbers of transferred bytes. See section "4.2.8. Limitation of the INS Maximum Output Data Rate" for details.

- **Initial alignment time (sec)** – sets the initial alignment time in seconds. The INS output data will be displayed in respective windows only after the time set in this parameter is over. During initial alignment, <u>the INS must be absolutely unmovable</u> relative to the Earth. Minimum value of the parameter is 0, and it can be changed to ±1 with the arrows or by entering the necessary value from a keyboard. Default value is set to 30 seconds.

**Note:** If the device starts while moving or for some other reason it is impossible to achieve absolutely stationarity standing at the start, you should set the initial alignment time to 0 seconds to skip initial alignment. But, in such a case, INS dynamic accuracy may be decreased.

- **Extended data** checkbox specifies the format of the initial alignment block. If this checkbox is set, then INS outputs extended initial alignment block after initial alignment is completed. Otherwise INS outputs short block of the initial alignment data (see Appendix C.1 for details).
- **Averaged output data** checkbox – when checked, averaged data are output at rate less than 200Hz. Otherwise instant data are output.
- **IMU s/n** – specifies the serial number of the IMU inside the INS unit. This parameter cannot be changed.
- **INS s/n** – specifies the serial number of the INS in use. This parameter cannot be changed.

- **Device firmware version** – the firmware version of the INS in use, which consists firmware type, firmware version, and date of this version separated by blanks. This parameter cannot be changed.
- **Latitude (deg)** – initial latitude of the INS operational location.
- **Longitude (deg)** – initial longitude of the INS operational location.
- **Altitude (m)** – initial altitude above sea level of the INS operational location.
- **Date** – day, month, and year when the INS is used.
- **Save last position** – checkbox that allows saving the last calculated position and date to the INS flash memory after INS stop. Thus, at the next INS operation, updated data will appear in above Latitude, Longitude, Altitude and Date fields.

**Notes:**

1. It is highly recommended to set current latitude, longitude, and altitude for setting the initial position in case the GNSS data is not available at the INS start.
2. It is necessary to set current latitude, longitude, altitude, and date before hard and soft iron calibration of the INS magnetometers (see section 8.2).

- **Magnetic declination (deg)** – sets magnetic declination at the location where the INS operates. The parameter value is changed by entering the required value from a keyboard or by automatic calculation, which can be determined by clicking on the "Calculate" button and entering Latitude, Longitude, Altitude, and Date values. Default value of the magnetic declination is set to 0.

  Since INS firmware version 2.2.0.2, the magnetic declination can be calculated in the INS continuously using calculated current position and time. Check **"Auto"** check-box (see Fig. 4.2) to activate this option.

**Notes:**

1. It is important to set the magnetic declination correctly for the INS operation because it requires knowing the true heading, which is calculated by adding the magnetic declination to the measured magnetic heading.
2. Magnetic declination is calculated using the World Magnetic Model, produced by the U.S. National Centers for Environmental Information and the British Geological Survey, see http://www.ngdc.noaa.gov/geomag/WMM/DoDWMM.shtml. (See section 8.5 for updating the World Magnetic Model.)

- **Alignment angles (deg)** – angles between the INS axes and the carrier object. These are set after INS mounting (see "Appendix E. Variants of the

Inertial Labs™ INS Mounting Relative to Object Axes"). Default values are set to 0 degrees.

- **Apply to sensors output** checkbox. If this box is checked, then sensors data are output in the carrier object axes, the orientation of which, relative to the INS axes, is set by "Alignment angles". This is the default option. Otherwise sensors data are output in INS axes.
- **PV measuring point relative to the IMU (m)** – sets coordinates of measuring point for position and velocity calculation. Set coordinates of the measuring point relative to the accelerometer mass-center of the INS unit (see Appendix F, Fig. F.1) in the object axes – right, forward, and up directions, in meters.
- **Auto start** – enables or disables automatic start of the INS and data output after power on without any command from the host computer. See section 10.6 for details.
- **Primary antenna position relative to the IMU (m)** – sets the primary GNSS antenna mounting lever relative to the INS unit, in meters. After the INS unit and GNSS antenna installation on the carrier object it is necessary to measure the center of antenna position relative to the accelerometer mass-center of the INS unit, in the object axes – right, forward, and up directions (see Appendix F). Then it is necessary to enter these coordinates in the appropriate fields in the IMU tab (Fig. 4.2) and click "OK" to apply these coordinates and store them in the INS nonvolatile memory.
- **Secondary antenna position relative to the IMU (m)** – sets the secondary GNSS antenna mounting lever relative to the INS unit, in meters. This option is supported for INS-D with firmware version since 2.9.1.7 and allows the secondary antenna installation in an arbitrary (but known) position relative to the INS-D unit and primary antenna.

**Note:** Earlier two antennas should be installed parallel to the longitudinal axis of the carrier object.

The secondary antenna position can be set in two ways. The first way is to measure the center of the antenna position in meters relative to the accelerometer mass-center of the INS unit, in the object axes – the right, forward, and up directions (see Appendix F), and then enter these coordinates in the "Secondary antenna position relative to the IMU (m)" field (see Fig. 4.2). Click "OK" to apply these coordinates and store them in the INS nonvolatile memory.

- **Antennas baseline orientation (deg)** – provides the second (alternate) way to set the secondary antenna position – as orientation of the baseline between two antennas relative to the carrier object axes (see Appendix F

for details). In this field, two angles (Alpha and Beta) should be measured and entered (see Fig. 4.2). Then click “OK” to apply these angles and store them in the INS nonvolatile memory. This setting is supported for INS-D with firmware version since 2.9.1.7.

**Notes:**

1. If, after mounting the INS, its axes X, Y, and Z are parallel to the carrier object lateral, longitudinal, and vertical axes, then the antenna coordinates should be measured in the directions of the INS X, Y, and Z axes.
2. On the other hand, the INS unit can be mounted on the object in any known position (up to upside-down, upright, etc. See “Appendix E. Variants of the Inertial Labs™ INS Mounting Relative to the Object Axes). In such a case, please set the GNSS antenna coordinates measured only in the object axes (on the right, forward, and up directions), but not in the INS axes.

### 4.2.2. “GNSS Receiver” Tab of “Devices Options” Window

Settings and parameters related to onboard GNSS receiver are located in the “GNSS receiver” tab of “Devices options” window (see Fig. 4.4).

**Note:** If the INS unit comes without onboard GNSS receiver, then this tab has no value. To setup an external GNSS receiver, please refer to section “4.2.4.4 Using External GNSS Receiver” of this document.

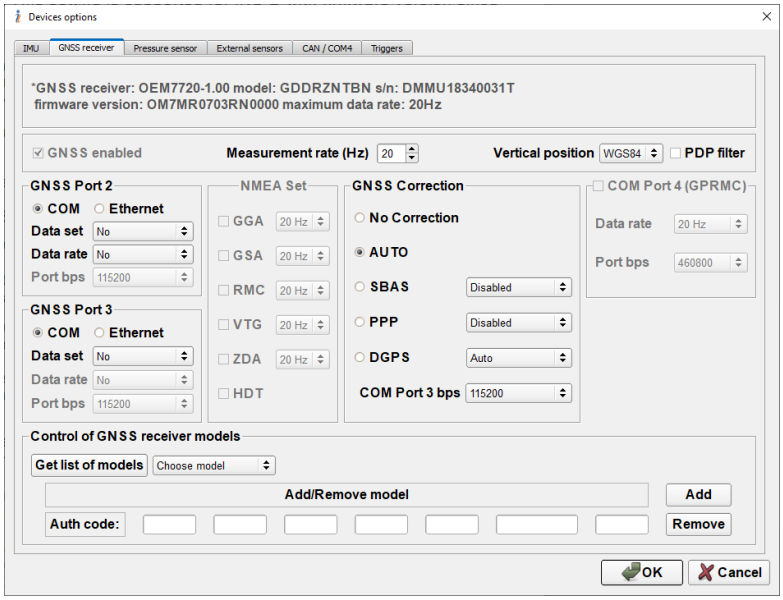



**Fig. 4.4.**

The first two rows of the “GNSS receiver” tab show the following information: GNSS receiver name, model, serial number, firmware version, and maximum data rate.

The following settings available for operation with the GNSS receiver:

- **GNSS enabled** – enables use of the GNSS data. This parameter cannot be changed.
- **Set measurement rate (Hz)** – rate of the GNSS data update in Hertz. It is highly recommended to set this rate to the maximum value supported by the actual model of the GNSS receiver. Note the INS unit controls the entered rate of the GNSS data and does not allow setting the rate to a larger than supported value by the current GNSS receiver model.
- **Vertical position** – enables choice of variant of output altitude – above mean sea level (MSL) or above WGS84 ellipsoid.
- **PDP filter** – allows enabling of the Pseudorange/Delta-Phase (PDP) filter in the NovAtel receiver to smooth a jumpy GNSS position and to bridge outages in satellite coverage. Note that an enabled PDP filter can make the GNSS position less accurate.
- **GNSS Port 2** – these fields configure the GNSS receiver port 2 setting for output of GNSS raw data or NMEA data set through **COM** or **Ethernet** port type:
    - **Data set** – allows choice of the desirable set of GNSS receiver data for output through port 2. In the drop-down list, the user can choose GNSS raw data (full or minimal set) or NMEA set output (see Fig. 4.5). When “No” is selected, no GNSS data are output. Default setting is “No”.
    - **Data rate** – sets the frequency of raw GNSS data output through port 2. When Data set is set to “Raw GNSS” or “Min Raw GNSS” (see Fig. 4.5), the user can choose the frequency of data output in the Data rate drop-down list (see Fig. 4.6). See section “12.1. Recording of Raw GNSS Data” for more details.

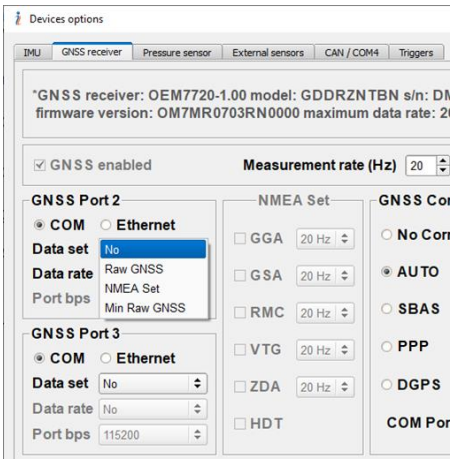



**Fig. 4.5.**

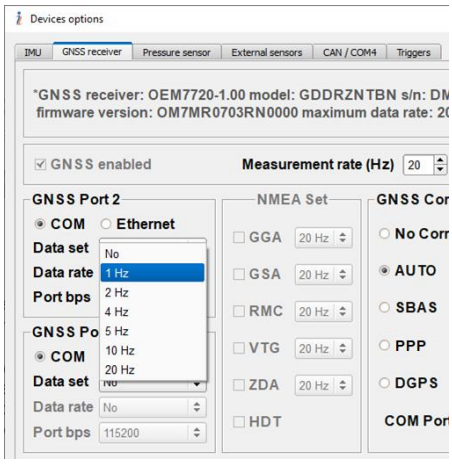



**Fig. 4.6.**

- **Port bps** – allows the user to set the baud rate of the port 2 for output GNSS data. The user can select the needed port baud rate in the drop-down list (see Fig. 4.7). Default value is “115200”. If GNSS raw data are chosen for port 2 output, then it is necessary to set the same COM-port baud rate in the GNSS_Reader program for raw GPS data recording (see section “12.1. Recording of Raw GNSS Data” for more details).

**Note:** The standard COM-port baud rate of 115200 bps can provide GPS L1 raw data frequency up to 5 Hz. Raw data with higher frequency, using GPS + GLONASS, L1/L2 frequencies, may contain gaps, so it is necessary to use a USB-port on the host computer and to increase COM-port baud rate. To provide the maximum 20 Hz GNSS raw data output, set a 921600 bps baud rate. Please contact Inertial Labs™ for details.

- **NMEA Set** – allows setting desired NMEA messages for output through GNSS port 2 when NMEA Set is chosen in Data Set (see Fig. 4.8). By default, INS outputs GPGGA, GPVTG and GPZDA if no checkboxes in NMEA Set are chosen.

It is possible to set a desirable frequency for each chosen NMEA message. The user can choose frequency of data output in the drop-down list next to the NMEA message name.

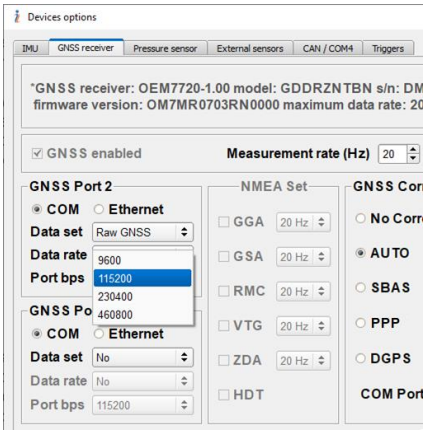



**Fig. 4.7.**

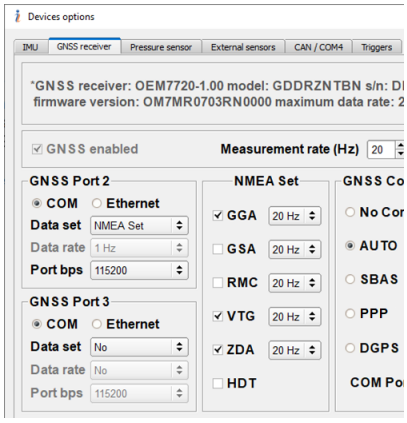



**Fig. 4.8.**

- **GNSS Port 3** – these fields configure the GNSS receiver port 3 setting for output GNSS raw data or GPRMC messages (used only for INS data synchronization with LiDAR) through **COM** or **Ethernet** port type:
  - **Data set** – allows choice of the desirable set of GNSS receiver data for output through port 3. in the drop-down list, the user can choose GNSS raw data (full or minimal set) or GPRMC message (see Fig. 4.9). When “No” is chosen, no GNSS data are output. Default setting is “No”.

- **Data rate** – sets the frequency of GNSS port 3 data output. When Data set is set other than “No”, user can choose frequency of data output (Data rate) in the drop-down list (see Fig. 4.10).
- **Port bps** – allows the user to set the baud rate of GNSS port 3. The user can select the needed port baud rate in the drop-down list: 9600, 19200, 38400, 57600, 115200, 230400, or 460800 bps. Default value is 115200 bps.

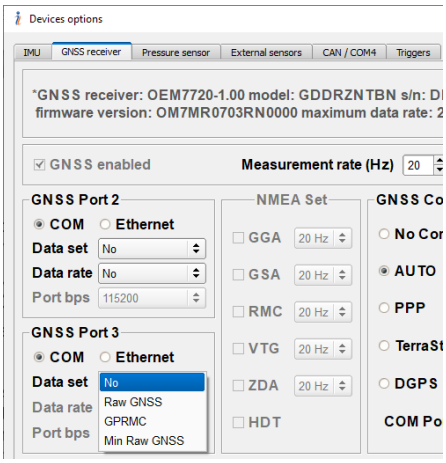



**Fig. 4.9.**

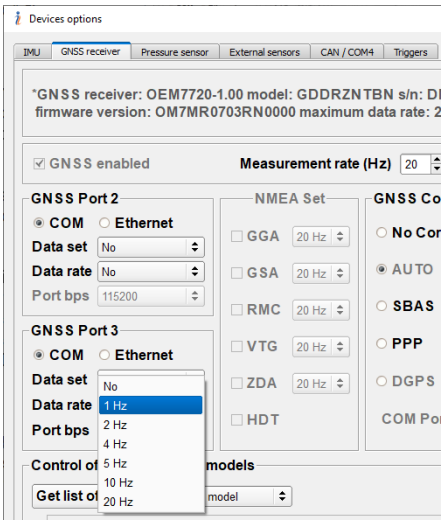



**Fig. 4.10.**

- **GNSS Correction** – these fields adjust correction of GNSS receiver data to improve position accuracy. The type of GNSS correction is chosen by radio button (see Fig. 4.4). Default value is “AUTO”. See section “10.2.1. GNSS Correction” for details.

**Note:** COM3 port can be used for input of the GNSS corrections only if the Data Set parameter in the GNSS COM-Port 3 field is set to “No”.

- **Control of GNSS receiver models** – this field allows addition, change, and removal of GNSS receiver model (see Fig. 4.4). For details see section 10.2.2 “Control of GNSS Receiver Model”.
- **COM Port 4 (GPRMC)** – these fields show current configuration of COM4 port for output of GPRMC messages, which is set in “CAN / COM4” tab (see section 4.2.5.3).
  - **Data rate** – frequency of COM4 port data output
  - **Port bps** – baud rate of the COM4 port

**Notes:**

1. Not all Inertial Labs™ INS units have four COM-ports. Please contact Inertial Labs™ about INS configuration.

2. Since INS GUI version 2.0.46.279 from 2018-07-26, the COM4 port configuration is transferred to the “CAN / COM4” tab of “Devices options” window (see section 4.2.5) to combine settings of all variants of COM4 port use.

**Important note:** After applying any changes in the “GNSS receiver” tab by clicking the “OK” button, it is necessary to switch off and then switch back on the INS unit to restart the onboard GNSS receiver.

### 4.2.3. “Pressure Sensor” Tab of “Devices Options” Window

This tab makes it possible for the user to choose the pressure sensor that is necessary for the INS altitude correction (see Fig. 4.11).

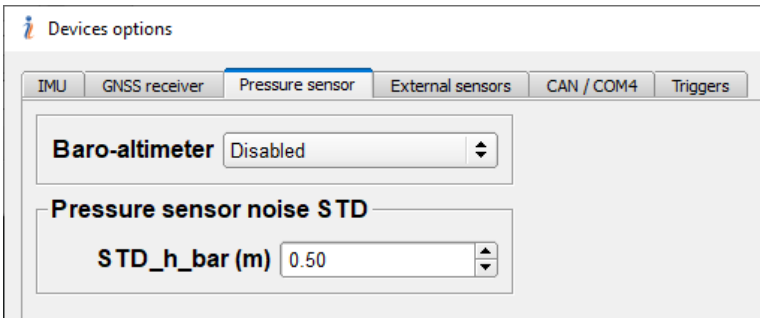



**Fig. 4.11.**

- **Baro-altimeter** – this drop-down list contains variants of the pressure sensor using for INS altitude correction:
  - disabled (default setting)
  - primary altitude sensor
  - secondary altitude sensor
- **Pressure sensor noise STD** – sets value of standard deviation of the pressure sensor noise.

See section “10.3. Features of Altitude Calculation in the INS” for a more detailed explanation of operations of the pressure sensor.

### 4.2.4. "External Sensors" Tab of "Devices Options" Window

Using external sensors data can greatly improve INS position, velocity, and orientation calculation during long-time GNSS outage. INS GUI allows configuration of INS operation with different types of external sensors. Choice of available external sensors and settings of their parameters can be performed in the "External sensors" tab of the "Devices options" window (see Fig. 4.12).

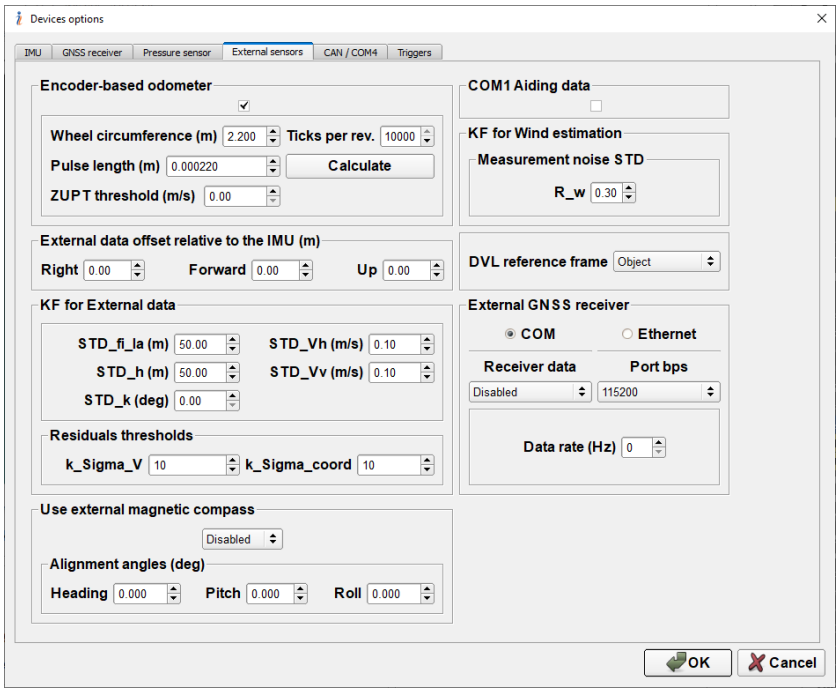



**Fig. 4.12.**

#### 4.2.4.1. Parameters of Encoder-Based Odometer

**Important note:** The INS unit should be factory configured to receive pulse/bi-phase signals from the encoder.

For using the encoder-based odometer, it is necessary to check the **"Encoder-based odometer"** checkbox (see Fig. 4.12) and configure the following parameters:

- **Wheel circumference (m)** – the parameter of the wheel where encoder is installed.
- **Tics per rev.** – refers to the encoder parameter (number of tics per revolution).
- **Pulse length (m)** – the distance in meters between low to high transitions of the encoder signal. This parameter value is changed by entering the required value from a keyboard or can be calculated by clicking on the "Calculate" button and using "Wheel circumference (m)" and "Tics per revolution" values.
- **ZUPT threshold (m/s)** – the threshold for horizontal speed measured with odometer for stop detection in the odometer ZUPT algorithm.

- **External data offset relative to the IMU** – the lever arm measured from the accelerometer mass-center (see Fig. F.1) of the INS unit to external data source (like odometer or DVL) in the vehicle coordinate frame – in the right, forward, and vertical directions.
- **STD_Vh (m/s)** – the standard deviation of the odometer noise. Usually its value is 0.10 m/s, but it depends on the encoder.
- **k_Sigma_V** – residual threshold. Its default value is 10.

**Notes:**

1. For INS operation with encoder-based odometer, it is enough to enter the "Pulse length (m)" value and leave zeros in the "Wheel circumference (m)" and "Tics per revolution" fields.
2. Value of "Pulse length (m)" can be calculated by using formula (see formula 10.1 placed section 10.7.3) or can be calculated automatically after odometer calibration (see section 10.7.3.1).
3. For creation of TIMEDWHEELDATA logs (if encoder-based odometer data are going to be used at INS data post-processing), it is necessary to enter both "Tics per revolution" and "Pulse length (m)" values.
4. Default value of the "ZUPT threshold (m/s)" is 0.05 m/s. However, at low resolution of the encoder (high value of the "Pulse length (m)"), it is necessary to increase ZUPT threshold to decrease time of car stop detection. For example, at "Pulse length" = 0.6 m and "ZUPT threshold" = 0.05 m/s, the car stop will be detected only after 0.6 / 0.05 = 12 seconds.

Please contact Inertial Labs™ to get recommendations for odometer parameters values.

See section "10.7.3. INS Operation with Encoder-Based Odometer (Wheel Speed Sensor)" for more details.

#### 4.2.4.2. Using the Main COM1 Port to Receive External Aiding Data

The Inertial Labs™ INS uses the main COM1 port for commands and data transfer between the Inertial Labs™ INS and the host computer.

Since INS firmware version 2.8.2.0, it is possible to send external aiding data to the INS unit using the main COM1 port during INS ordinary operation when INS outputs data through the COM1 port.

Check the **"COM1 Aiding data"** checkbox (see Fig. 4.12) to allow aiding data input. By default, aiding data input is disabled.

- **DVL reference frame** – specifies the coordinate frame in which DVL data are defined – vehicle axes (in the right, forward, and up directions) or in navigational frame (East, North, and Up).
- **External data offset relative to the IMU** – the lever arm measured from the accelerometer mass-center (see Fig. F.1) of the INS unit to external data source (like odometer or DVL) in the vehicle coordinate frame – in the right, forward, and vertical directions.

Check/set the following parameters for Kalman Filter, in the next fields:

- **STD_fi_la (m)**, **STD_h (m)** – noise of external horizontal and vertical position aiding data.
- **STD_k (deg)** – noise STD of external heading data.
- **STD_Vh (m/s)**, **STD_Vv (m/s)** – noise of horizontal and vertical speed data.
- **k_Sigma_V**, **k_Sigma_coord** – Kalman filter residuals thresholds.

Please contact Inertial Labs™ to get recommendations for above parameters values.

If INS receives air speed adding data, then Kalman filter is used for estimation of wind speed and direction. The following parameter can be used to adjust this Kalman Filter:

- **R_w** – noise STD of air speed (in m/s). The default value is 0.3 m/s.

See INS ICD, section "6.6.4. Aiding Data Input Through the Main COM-Port" for details.

#### 4.2.4.3. Using External Magnetic Compass

The INS can be factory configured to use the external Stand Alone Magnetic Compass (SAMC) to measure components of the Earth magnetic field. The SAMC can be installed in any part of carrier object with a good magnetic environment.

To use the SAMC, chose the sensor type from **"Use external magnetic compass"** drop-down list (see Fig. 4.12):

- OS3D-FG.
- MiniAHRS.

If the INS unit contains onboard magnetometers, the SAMC will be used instead them.

**Notes:**

1. The SAMC can be installed with any orientation relative to the INS unit.
2. Before use of the external SAMC, it is necessary to align the SAMC axes to INS axes (see section 10.9 for details). However, If the procedure of axes alignment cannot be performed, it is possible to set the angles manually in the **Alignment angles** area (see Fig. 4.12).
3. If external SAMC is used, then hard/soft iron calibration of its magnetometers should be performed in the same way as for INS magnetometers (see section 10.4 for details).
4. Any change of the "Use external magnetic compass" setting is applied only after unit power off / on.

#### 4.2.4.4. Using External GNSS Receiver

The option to use an external GNSS receiver has been implemented since firmware version 3.2.8.6. Settings to configure the external GNSS receiver are located on the right side of **"External sensors"** tab of **"Devices options"** window (see Fig. 4.12).

Description of the "External GNSS receiver" fields:

- **COM** and **Ethernet** checkboxes – allow the user to set INS port type to input data from the external GNSS receiver.
- **Receiver data** – allows user to choose appropriate output format of external GNSS receiver data from the drop-down list (see Fig. 4.13). Once a desired format is chosen, the "GNSS receiver" tab of "Devices options" window disables immediately (see Fig. 4.14). To stop using the external GNSS receiver, simply choose "Disabled" from the drop-down of "Receiver Data" field.
- **Port bps** – COM-port baud rate, which should be set the same as for the receiver's COM-port. Default value is set to 115200 bps.
- **Data rate (Hz)** – rate of the receiver data.

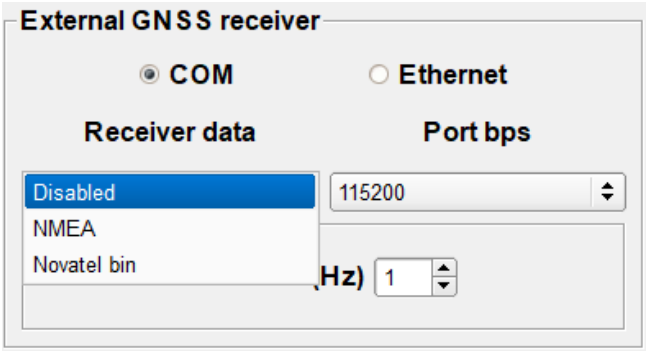



Fig. 4.13.

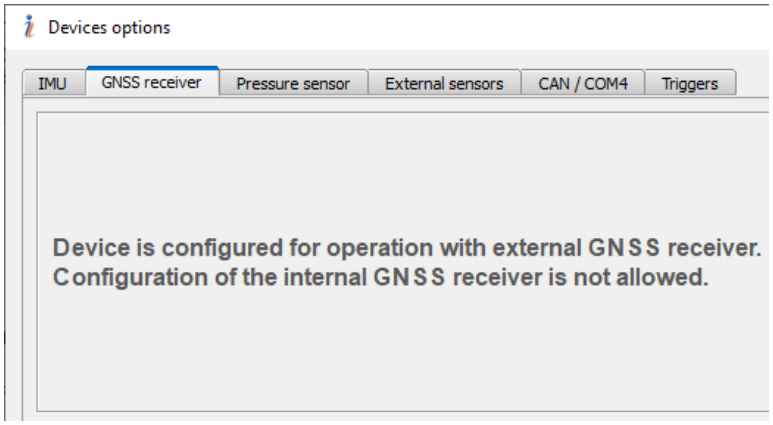



Fig. 4.14.

**Note:** Be aware that if the external GNSS receiver is used, it is highly recommended to feed its PPS signal to INS input to improve operation. Ensure that the INS is configured for PPS input. See section 13.1 for more details about PPS signal.

## 4.2.5. "CAN / COM4" Tab of "Devices Options" Window

The "CAN / COM4" tab (see Fig. 4.15) combines configurations for CAN port and COM4 port, to prevent a simultaneous usage of them.

Since INS GUI version 2.0.50.360, configuration parameters for the second CAN port have also been located here. Note that the device should be factory configured to have onboard second CAN BUS (this option is only available upon request).

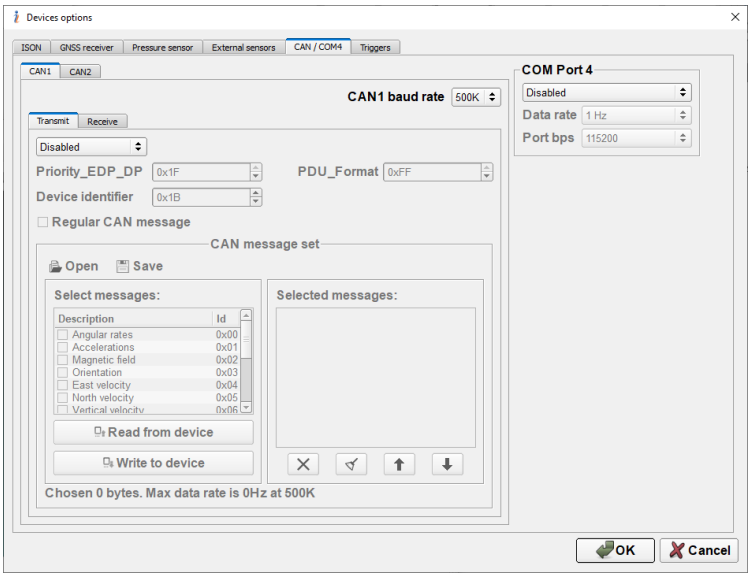



Fig. 4.15.

### 4.2.5.1. Configuration of CAN Messages Output

The INS allows output of CAN messages through one or two CAN ports. To allow INS output of CAN messages, go to **"CAN1"** or **"CAN2"** tab (see Fig. 4.15) and then to the "Transmit" tab within. It is necessary to then choose the variant of the CAN data (CAN2.0A or CAN2.0B) in the drop-down list and to configure (if default settings are inapplicable) active parameters:

- **CAN baud rate**.
- Components of the CAN identifier – **Priority_EDP_DP**, **PDU_Format**, **Device identifier**.
- **CAN message set**.

See section “10.8. Operations with CAN Data ” for all details.

**Notes:**

1. The second CAN port can be added to the INS unit only upon request. It allows simultaneous output of CAN messages through first and second CAN ports.
2. To re-initialize the CAN port, it is necessary to power off / on the INS after changing any parameters in the “CAN / COM4” tab.
3. INS GUI software checks compatibility of chosen options in the “CAN / COM4” tab. So if CAN output is set, then COM4 cannot be used for operations.

### 4.2.5.2. Configuration of CAN Messages Input (for CAN BUS Based Odometer)

Once the user has access to the vehicle’s CAN BUS and knows which CAN messages indicate the velocity of the car, it is possible to connect the CAN BUS to the INS unit as an odometer.

Only the first CAN port allows receiving CAN messages. To configure this port go to the “CAN1” tab and then to the “Receive” tab (see Fig. 4.16). Full configuration of CAN settings is provided by INS GUI since version 2.0.50.349.

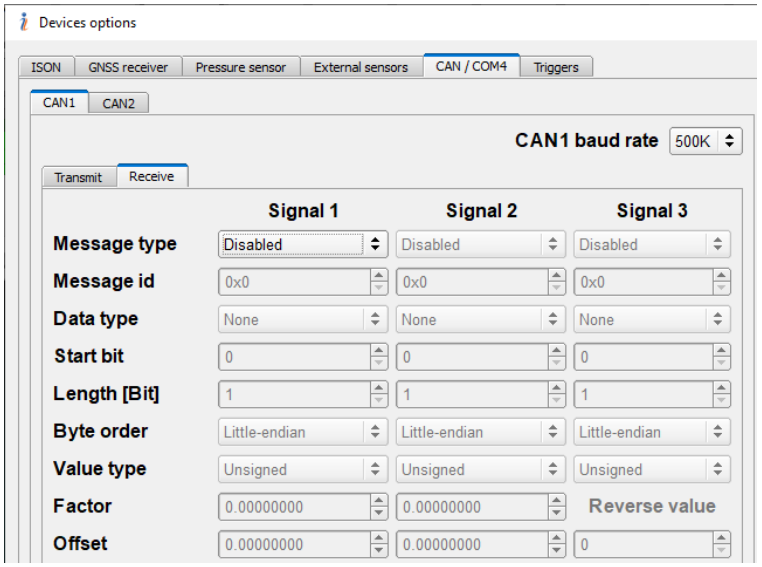



**Fig. 4.16.**

See section “10.7.2. INS Operation with CAN BUS Based Odometer” for more details.

**Important note:** To re-initialize the CAN port, it is necessary to power off / on the INS after changing any parameters in the “CAN1” or “CAN2” tab.

### 4.2.5.3. Configuration of COM4 Port

**"COM Port 4"** fields (see Fig. 4.15) allow the user to choose the variant of COM4 port being used, as Fig. 4.17 shows:

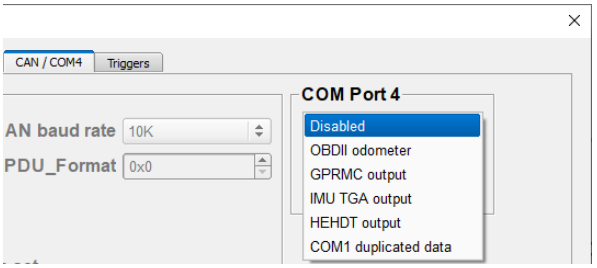



**Fig. 4.17.**

- **Disabled**.
- **OBDII odometer** – to use COM4 for connection of an OBDII odometer with interface converted to RS-232.
- **GPRMC output** – to output NMEA GPRMC messages through COM4 port.
- **IMU TGA output** – to output high frequency IMU data (time, gyros, and accelerometers) through COM4 port.
- **HEHDT output** – to output NMEA HEHDT messages through COM4 port.
- **COM1 duplicated data** – to output through COM4 port the same data that are transmitted via COM1 port. COM4 port bps and data rate parameters duplicate values of COM1 port automatically, without the possibility of changing them.

Also, the user should configure the following parameters in the "COM Port 4" field:

- **Data rate** – for data input / output through COM4 port.
- **Port bps** – COM4 port baud rate.

**Notes:**

1. To re-initialize the COM4 port, it is necessary to power off / on the INS after changing any parameters in the "COM Port 4" field.
2. INS GUI software checks compatibility of chosen options in the "CAN / COM4" tab. So if any variant other than "Disabled" is chosen in the "COM Port 4" field, CAN messages cannot be output.

### 4.2.5.4. Parameters of OBDII Odometer

For using **OBDII odometer,** it is necessary to choose the appropriate variant in the "COM Port 4" field (see Fig. 4.15, Fig. 4.17).

It is then necessary to set the following parameters of the COM4 port (see Fig. 4.15):

- **Data rate** – specifies the frequency of the odometer data input in Hertz. Minimum value of the parameter is 1 Hz, and it can be changed with arrows

or by entering the necessary value from a keyboard. The default value is set to 5Hz.

- **Port bps** – sets the baud rate of COM4 that provides input of the odometer data. User can choose the needed COM4 port baud rate in the drop-down list: 4800, 9600, 14400, 19200, 38400, 57600, 115200, 230400, or 460800 bps. Default value is 115200 bps.

Also, it is necessary to configure the INS Kalman Filter parameters for odometer in the **"External sensors"** tab of the **"Devices options"** window (see Fig. 4.12):

- **STD_Vh (m/s)** – standard deviation of the odometer noise. Usually its value is 0.28 m/s.
- **k_Sigma_V** – residual threshold. Its default value is 10.

See section "10.7.1. INS Operation with OBDII Odometer" for more details.

**Important note:** To re-initialize COM4 port, it is necessary to power off / on the INS after changing any parameters in the "COM Port 4" field.

### 4.2.6. "Triggers" Tab of "Devices Options" Window

In the "Triggers" tab, the user can set the following parameters (see Fig. 4.18):

- **Mark inputs control** – allows adjusting of the mark input signal that can be used to trigger specific GNSS raw receiver data. See section "13.2. Processing of Mark Input Signal" for details.
- **PPS control** – adjusts the pulse-per-second (PPS) signal generated by the GNSS receiver for data synchronization with other devices. See section "13.1. Control of PPS Output Signal" for details.

**Important note:** To restart the onboard GNSS receiver after any changes in the "Triggers" tab (after clicking the "OK" button), it is necessary to switch off / on INS unit.

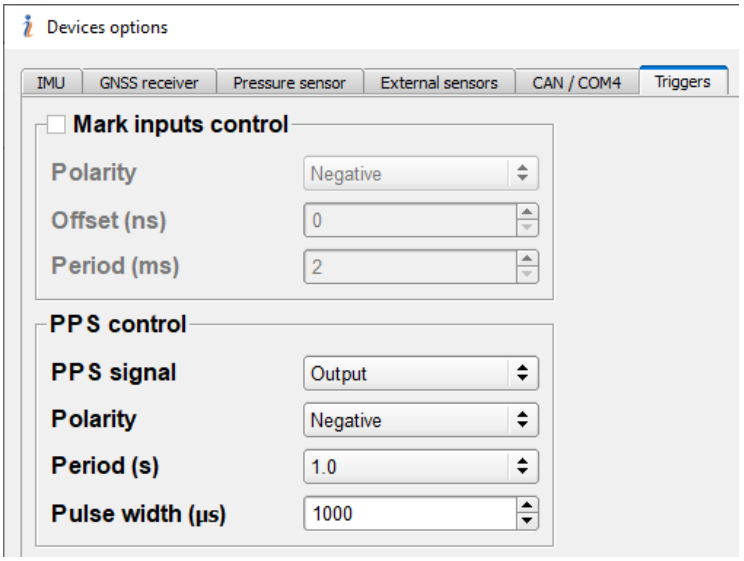



**Fig. 4.18.**

## 4.2.7. Change of the Main COM-Port Baud Rate

The main COM-port is used for the INS connection to the host computer for receipt of commands and output of INS data. The default baud rate for the main COM-port is set to 115200 bps (maximum for the standard COM-port). If the host computer requires another baud rate for the INS connection, the user can choose one from the options: 4800, 9600, 14400, 19200, 38400, 57600, 115200, 230400, or 460800 bps. The same baud rate must be set in the "**Test Options**" field of the INS GUI.

**Notes:**

1. Baud rate change is implemented in the INS firmware version since 2.2.0.0 and is supported by INS GUI since version 2.0.19.78.
2. To allow baud rate change, the INS unit must be connected to a computer and powered.
3. The standard COM-port of a host computer (PC) does not support baud rate greater than 115200 bps. Therefore, a Serial-to-USB adapter should be used for INS connection to the host computer.
4. Baud rate must be set the same both for INS unit and the INS GUI to allow this software to control the INS unit.

At first use, set the correct COM-port baud rate in the "**Test Options**" tab (see Fig. 4.1). The value must be the same as it is set in the INS unit. If COM-port baud rate in the INS unit is unknown, then click "**Auto**" button. After several seconds, a window with the caption "Serial port baud rate XXXXXX was successfully determined" will appear (see Fig. 4.19) and the determined baud rate will appear in the **"Test Options"** window.

To change the COM-port baud rate in the INS unit, go to the "**Devices Options**", **"IMU"** tab (see Fig. 4.2) and choose the necessary baud rate from the list (as Fig. 4.20 shows).

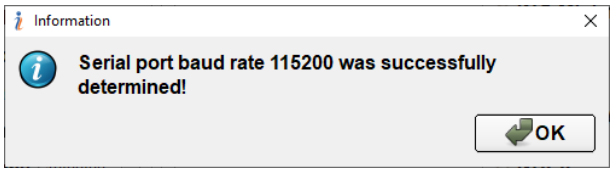



**Fig. 4.19.**

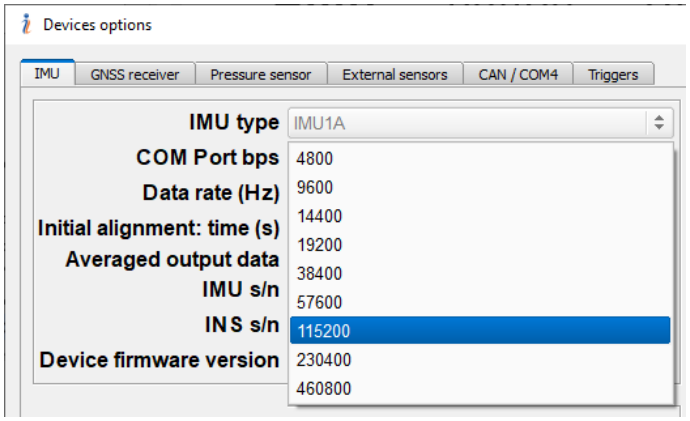



**Fig. 4.20.**

After the baud rate is chosen, click the "**OK**" button to load the changed parameters to the INS nonvolatile memory. Then the information windows shown in Fig. 4.21 and Fig. 4.22 will appear. Click the "**OK**" button to close these windows. Note that the COM-port baud rate in the "**Test Options**" window will change to the chosen value, too, to maintain accurate communication between the INS GUI software and the INS unit.

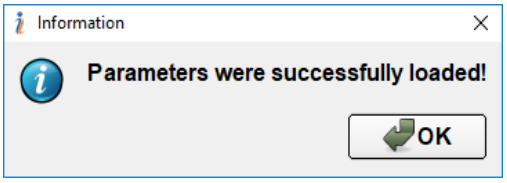



**Fig. 4.21.**

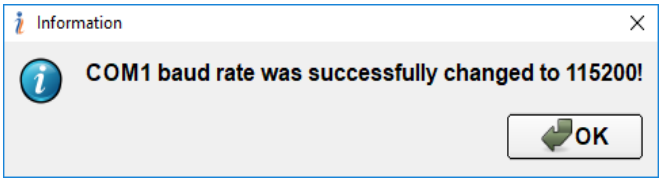



**Fig. 4.22.**

### 4.2.8. Limitation of the INS Maximum Output Data Rate

When setting of the data rate for the INS 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 data rate (in Hz) can be calculated using the baud rate and data package length:

$$\text{max_meas_rate} = \frac{\text{COM_baud_rate}}{\text{bits_per_byte} * \text{package_length}} \tag{4.1}$$

where COM_baud_rate is COM port baud rate (bits/s); bits_per_byte = 11 bits per one transferred byte of data; package_length is payload length of chosen output data format (for binary data package_length = payload length plus 8 bytes of overhead).

**Note:** The maximum data rate of INS data is limited by 200 Hz.

Since firmware version 3.2.0.0, the INS can only output at data rates that are factors of 200 (1, 2, 4, 5, 8, 10, 20, 25, 40, 50, 100, and 200 Hz). Calculated maximum data rates using equation (4.1) must be rounded down to the nearest factor of 200 that is listed above. The actual values of the maximum data rates calculated in this way for each output data format shown in Table 4.1.

**Table 4.1. INS maximum measurement rate for different output data formats**

| Output data format | Data package length, bytes | COM-port baud rate, bps | | | | | |
|---|---|---|---|---|---|---|---|
| | | 9600 | 19200 | 38400 | 115200 | 230400 | 460800 |
| | | Maximum measurement rate, Hz | | | | | |
| INS Sensors Data | 84+8 | 8 | 10 | 25 | 100 | 200 | 200 |
| INS OPVT | 92+8 | 8 | 10 | 25 | 100 | 200 | 200 |
| INS QPVT | 94+8 | 8 | 10 | 25 | 100 | 200 | 200 |
| INS OPVT2A | 101+8 | 8 | 10 | 25 | 50 | 100 | 200 |
| INS OPVT2AW | 103+8 | 5 | 10 | 25 | 50 | 100 | 200 |
| INS OPVT2AHR | 129+8 | 5 | 10 | 20 | 50 | 100 | 200 |
| INS OPVTAD | 177+8 | 4 | 8 | 10 | 50 | 100 | 200 |
| INS Minimal Data | 50 | 10 | 25 | 50 | 200 | 200 | 200 |
| INS OPVT GNSSext | 186+8 | 4 | 8 | 10 | 50 | 100 | 200 |
| INS_OPVT_rawIMUdata | 90+8 | 5 | 10 | 40 | 100 | 200 | 200 |
| SPAN_rawimu | 72 | 20 | 25 | 50 | 100 | 200 | 200 |
| INS NMEA | 93 | 8 | 10 | 25 | 100 | 200 | 200 |
| INS Sensors NMEA | 141 | 5 | 10 | 20 | 50 | 100 | 200 |
| Cobham UAV 200 Satcom | 128 | 5 | 10 | 25 | 50 | 100 | 200 |
| NAV440 | 39 | 20 | 40 | 50 | 200 | 200 | 200 |

INS GUI controls correctness of the measurement rate setting. If the user sets a measurement rate in the "**Devices Options**" window (see Fig. 4.2) that exceeds limits shown in Table 4.1, then a warning window (Fig. 4.23) appears. Click "Yes" to correct the entered measurement rate or "No" to ignore this warning. "No" should be selected

if the user wants to choose another output data format in the "**Test Options**" with less length of data package. In either case, the INS controls acceptable measurement rate onboard at the start of operation to not allow excess of maximum value. If the user chooses an output data format in the "**Test Options**" window that does not match set measurement rate, then a second warning window (Fig. 4.24) appears.

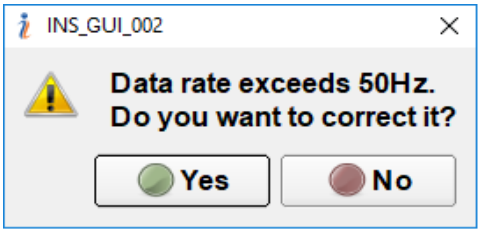



**Fig. 4.23.**

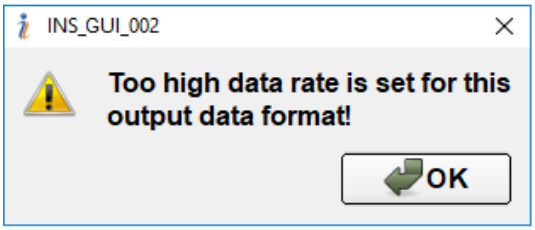



**Fig. 4.24.**

## 4.3. Correction Options

The user can adjust some parameters of the INS algorithm. To do so, select **"Correction options"** from the **"Options"** menu (Fig. 3.7), or click the icon (Fig. 3.1). A **"Settings"** tab of the "Correction options" window will be opened (see Fig. 4.25).

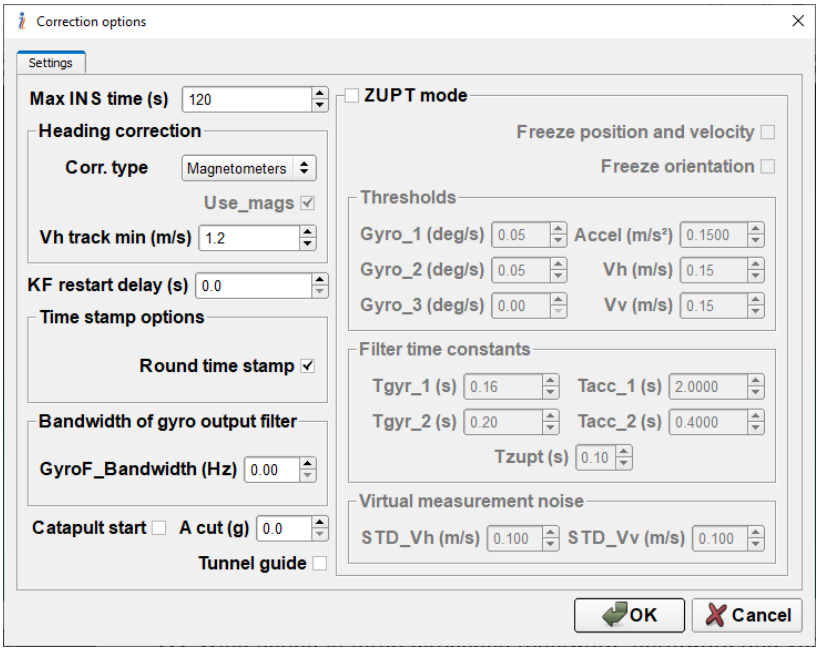



**Fig. 4.25.**

The following are settings for adjustment of the INS algorithm:

- **Max INS time** – the maximum time (in seconds) of autonomous INS operation at absence of GNSS data (GNSS outage). INS orientation and position data are calculated using integration of gyros and accelerometers data; therefore, at absence of GNSS data the INS errors in orientation and position calculation are accumulated and increase significantly with time. At long-time GNSS outage, after "Max INS time" is reached, INS pauses

calculation of position and velocity data but continues calculation of orientation (heading, pitch, and roll) using the algorithm of Attitude and Heading Reference System (AHRS). Minimum value of the "Max INS time" is 1 sec, and it can be changed to ±1 sec with the arrows or by entering the necessary value from a keyboard. Default value is set to 120 seconds.

- **Corr.type** – specifies data used for INS heading correction. There are six variants in the drop-down list (see Fig. 4.26):
  - **Magnetometers** – uses magnetic heading as reference.
  - **AHRS** – uses gyro-magnetic heading calculated using AHRS algorithm.
  - **GNSS track** – uses GNSS track angle as the heading reference for INS correction. This improves INS heading accuracy in bad magnetic environments for some applications like car, fixed-wing aircraft, and other vehicles that do not move sideways.

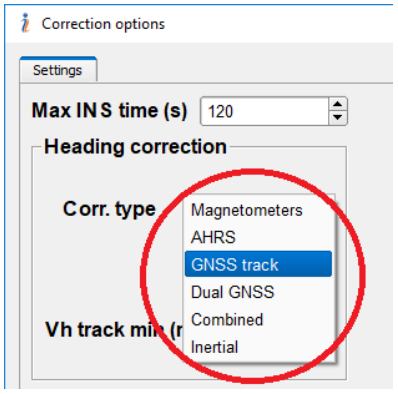


**Fig. 4.26.**

The INS starts using the GNSS track angle for heading correction after the carrier object moves with horizontal speed at least two times more than the "Vh track min" threshold. At the next stops of the object, the INS cancels correction from the GNSS track angle if horizontal speed is less than the "Vh track min" threshold (when object stop is detected). Heading is then calculated with correction from magnetometers (if "Use_mags" is switched on) or using gyros data only (if "Use_mags" is off). If "Use_mags" is switched off, then initial heading is zero.

  - **Dual GNSS** – default is **INS-D** correction using heading calculated by dual-antenna GNSS receiver inside the INS-D unit. This is the most accurate heading reference for INS correction when GNSS data are available and narrow-integer RTK solution is achieved for GNSS heading calculation.
  - **Combined** –uses switching between GNSS track angle and magnetometers for heading reference, with changes in INS algorithm. Combined correction is designed for special applications like unmanned aerial vehicles (UAV). Please contact Inertial Labs™ about the possibility of using this variant of INS correction in your application.
  - **Inertial** – does not use external heading information for INS correction. Instead, it fuses accelerometers and gyros data together with GNSS position and velocity to estimate INS heading. This type of correction can be used for carrier objects that move with noticeable speed even at lateral motion.

- **Use_mags** – enables or disables using of magnetometers for INS heading correction. If “Corr.type” is set to “Magnetometers” then “Use_mags” switch is ON and cannot be changed.

**Notes:**

1. INS does not require calibration of its magnetometers on hard/soft iron if the “Use_mags” switch is disabled.
2. If “Corr.type” is set to “GNSS track” or “Inertial”, and “Use_mags” switch is disabled, then initial heading is zero. It becomes true after the carrier object moves with horizontal speed at least twice of “Vh track min” threshold.
3. If “Corr.type” is not set to “Magnetometers”, then at GNSS data lost the magnetometers can be used (at “Use_mags” enabled) to continue heading calculation. At “Use_mags” disabled, the INS heading is calculated by integration of gyros when GNSS data are lost.

- **Vh track min (m/s)** – the threshold for horizontal speed of carrier object to allow using of the GNSS track angle for INS correction (if it is chosen in “Corr.type” field). Default value is 1.2 m/s.
- **KF restart delay (s)** – delay of INS Kalman Filter restart at available GNSS data when KF measurement residual exceeds the set threshold. It allows adjusting INS robustness at multi-path and other GNSS data corruption. Default value is 2 seconds.
- **Round time stamp** – sets round time stamps (if checked) or accurate time stamps (if unchecked) for all INS output data. See INS ICD rev.2.10 and newer, section “6.16. Time Stamps in INS Messages” for more details. Default setting is checked.
- **GyroF_Bandwidth** – sets bandwidth of filtered gyro data. “Gyro data filtered” can be output, if necessary, through “User Defined Data” format (see Table 4.3). Default value of GyroF_Bandwidth is zero (additional filter is not applied to gyro data).
- **Catapult start** – allows use of the special INS algorithm for the UAV with catapult launching. On default the “Catapult start” is disabled.
- **Note:** Catapult start is at the testing stage. Please contact Inertial Labs™ about the possibility of using the Catapult start.
- **A cut (g)** – the threshold of acceleration at catapult launching. The INS uses specific correction from GNSS data during times in which acceleration exceeds this threshold.
- **Tunnel guide** – when enabled, this feature allows the INS to reduce its accumulated errors during long-time GNSS outage. Use this feature when external aiding data are unavailable.

To ensure proper Kalman Filter calculation when the "Tunnel guide" feature is chosen, set noise of horizontal speed data "STD_Vh (m/s)" to 1.5 and vertical speed data "STD_Vv (m/s)" to 0.3 in the **"External sensors"** tab of **"Devices options"** window (see Fig. 4.12).

**Note:** "Tunnel guide" feature only fits fixed-axle land vehicles, such as a car.

- **ZUPT** – enables or disables "Zero Velocity Update" (ZUPT) mode. When enabled, ZUPT allows the INS to reduce its accumulated orientation and position errors once a carrier object stops.

Note for certain applications when a complete motionless state is not achievable, such as marine or airborne applications, ZUPT option should be disabled. Default setting of ZUPT is disabled.

- **Freeze position and velocity** – enables or disables freezing of INS position and zeroing INS velocity output at stop detected in ZUPT mode. On default the setting is disabled.
- **Freeze orientation** – enables or disables freezing of INS orientation at stop detected in ZUPT mode. On default the setting is disabled.
- **Thresholds** group – represents thresholds for filtered gyros signal (**Gyro_1, Gyro_2, Gyro_3**), accelerometers signal (**Accel**), and horizontal and vertical speeds (**Vh** and **Vv,** respectively) that are used to detect stop of a carrier object in ZUPT mode. The default value of every parameter is shown in Table 4.2.
- **Filter time constants** group – represents time constants (in seconds) of filters for gyroscopes (**Tgyr_1, Tgyr_2**), accelerometers (**Tacc_1, Tacc_2**), horizontal and vertical speeds (**Tzupt**) that are used to detect stops of a carrier object. The default value of every parameter is shown in Table 4.2.
- **STD_Vh, STD_Vv (m/s)** – noise standard deviation of virtual velocity measurements that are used in ZUPT mode. The default value of every parameter is shown in Table 4.2.

**Table 4.2. The default value of ZUPT parameters**

| Parameter | Default value |
|---|---|
| **Thresholds** | |
| Gyro_1 | 0.05 deg/s |
| Gyro_2 | 0.05 deg/s |
| Gyro_3 | 0.05 deg/s |
| Accel | 0.15 m/s$^2$ |
| Vh | 0.15 m/s |
| Vv | 0.15 m/s |
| **Filter time constants** | |
| Tgyr_1 | 0.16 s |

| | |
|---|---|
| Tgyr_2 | 0.20 s |
| Tacc_1 | 2.0 s |
| Tacc_2 | 0.4 s |
| Tzupt | 0.1 s |
| **Virtual measurement noise** | |
| STD_Vh | 0.1 m/s |
| STD_Vv | 0.1 m/s |
| **Switch for freezing INS output at stop** | |
| Freeze position and velocity | false |
| Freeze orientation | false |

**Important note:** Due to the variety of carrier objects, the values of ZUPT parameters can be adjusted by the user. But because these values have a drastic effect on the final results, contact Inertial Labs™ for advice on how to identify the appropriate values if needed.

## 4.4. Sensors Options

To set and control INS sensors parameters, select **"Sensors options"** from the **"Options"** menu (Fig. 3.7), or click the icon (Fig. 3.1). A **"Sensors options"** (Fig. 4.27) window opens.

The following are settings for the INS gyros and accelerometers:

- **Range**
  - **Gyro** – shows the measurement range of gyros. This parameter cannot be changed.
  - **Acc** – shows the measurement range of accelerometers. This parameter cannot be changed.
- **Output variant** (see Fig. 4.28)
  - **Instant angular rate and acceleration** – the INS outputs the latest sample of sensors data in the data message.
  - **Average angular rate and acceleration** – the INS outputs the average of the internal 800 Hz or 2000Hz (depending on IMU version) samples between two data messages.
  - **Incremental Angle and Incremental Velocity** – the INS outputs integrals of sensors data calculated for 800 Hz or 2000Hz (depending on IMU version) samples divided by time stamp of data output. In fact, gyros and accelerometers data are presented here as angle increment and velocity increment (Delta Theta and Delta Velocity, respectively) between two data messages divided by time stamp of data output. Magnetometers data are the same as at average sensors data variant.

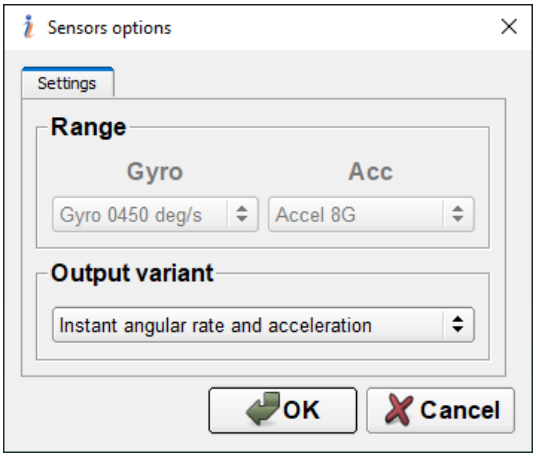



Fig. 4.27.

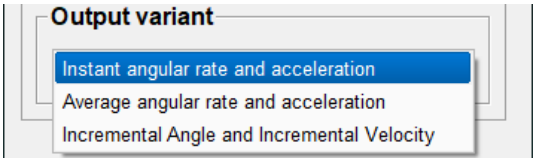



Fig. 4.28.

## 4.5. Swaying Compensation

It is possible to increase the INS orientation accuracy at object swaying if necessary to compensate linear acceleration at place of the INS mounting. For this purpose select "**Swaying compensation options**" from the **"Options"** menu (Fig. 3.7) or click the icon (Fig. 3.1). A "**Swaying compensation options**" dialog box (Fig. 4.29) will be opened that allows you to set the lever of the INS mounting relative to the center of the object Swaying (usually this is the object center of gravity).

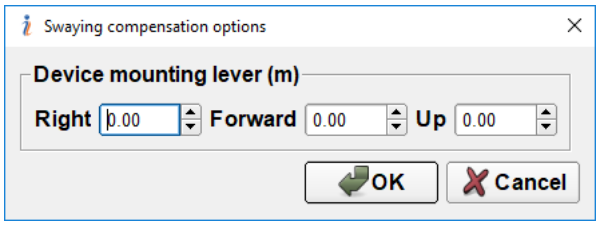



Fig. 4.29.

The lever must be set in the carrier object axes – on the right, forward, and up. If, after the INS mounting, its axes X, Y, and Z are parallel to the carrier object lateral, longitudinal, and vertical axes, then the INS position should be measured in the directions of the INS X, Y and Z axes. If the INS unit is mounted on the object in another known position (up to upside-down, upright, etc.; see Appendix E. Variants of the Inertial Labs™ INS Mounting Relative to the Object Axes), then set the INS position only in the object axes (on the right, forward, and up directions), but not in the INS axes.

## 4.6. Magnetometers Calibration Options

The Inertial Labs™ INS 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 INS magnetometers is provided. To configure parameters of this calibration select "**Magnetometers calibration options**" from the **"Options"** menu (Fig. 3.7) or click the icon (Fig. 3.1). The dialog window shown in Fig. 4.30 will open.

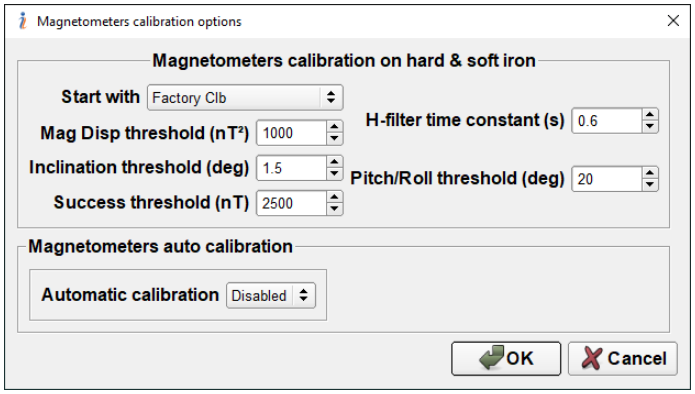



**Fig. 4.30.**

The following are the parameters for adjustment in the magnetometers calibration:

- **Automatic calibration** – allows user to switch on 2D or 3D automatic calibration of magnetometers during ordinary INS run. See section 10.4.5 for details.
- **Start with** – specifies which of four sets of calibration parameters the INS starts with: "Last INS Clb", "Factory Clb", "2D-2T, 3D, VG3D, 2D Clb", or "Previous Auto Clb". The "Start with" parameter is usually set automatically after the last calibration performed. See section 10.4.6 for more details.
- **Mag Disp threshold ($nT^2$)** – specifies calibration data that should be deleted from the calibration procedure because the INS was not moved at this procedure. Default value 1000 $nT^2$ is set by developers and can be changed only after agreement with them.
- **Inclination threshold (deg)** is valid for 2D and 2D-2T calibration types and determines acceptable pitch and roll deviation from their median in the calibration run. INS data over this threshold are not used at calculation of calibration parameters. Default value is 1.5 degrees. This parameter can be changed only after agreement with developers.
- **Success threshold (nT)** is acceptable value of magnetic field calibration error to have a successful result of the 3D calibration if its accuracy cannot

be estimated in degrees. Default value is 2500 nT. This parameter can be changed only after agreement with developers.

The following thresholds in the right-side section of the **"Magnetometers calibration on hard & soft iron"** section are used to estimate the calibration quality in terms of possible INS heading accuracy:

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

See section "10.4. Calibration of the INS" for a detailed description of the Magnetometers calibration procedure.

## 4.7. User Defined Data

Since INS firmware version 3.2.4.3, the user can choose desired INS data for output using **"User Defined Data"** output format. INS GUI since version 2.0.46.272 supports this data format and provides easy-to-use interface for its configuration. At first use, it is necessary to choose INS data for the output. Select **"User defined data"** from the **"Options"** menu (Fig. 3.7), or click the icon (Fig. 3.1). The configuration window **"**User defined data**"** will be opened (Fig. 4.31).

① – Drop-down list of available INS data
② – Selected data types
③ – To write or read the set of "User Defined Data" to / from INS flash memory;
④ – Operations with *.udd configuration files

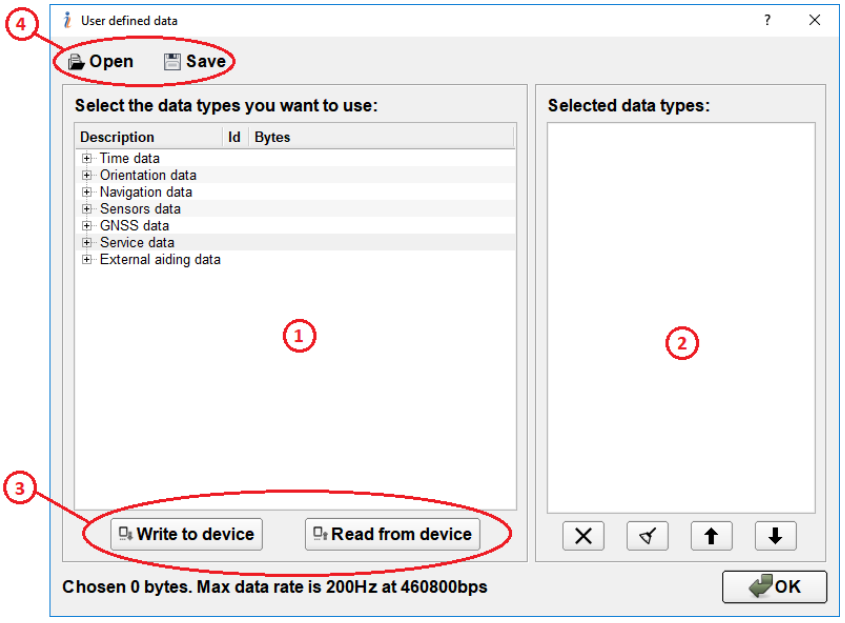



**Fig. 4.31. Configuration window for the "User defined data"**

The field **"Select the data types you want to use"** contains all INS data types that can be chosen for output. These data types are grouped appropriately: **Time data, Orientation data, Navigation data, Sensors data, GNSS data, INS service data,** and **External aiding data**. See Table 4.3 for a full list of available data types.

There are three columns in the **"Select the data types you want to use"** window:

- **Description** – contains the name of the data type.
- **Id** – contains the ID of the data packet.
- **Bytes** – contains the size of the data type.

**Table 4.3. Groups and data types of the "User Defined Data"**

| Data group | Data type | Description |
|---|---|---|
| Time data | 0x01 | GPS INS Time (round) |
| | 0x02 | GPS INS Time |
| | 0x03 | GPS IMU Time |
| | 0x04 | UTC |
| | 0x05 – 0x06 | Reserved |
| Orientation data | 0x07 | Orientation angles |
| | 0x08 | Orientation angles HR |
| | 0x09 | Quaternion of orientation |
| | 0x0A – 0x0F | Reserved |
| Navigation data | 0x10 | Position |
| | 0x11 | Position HR |
| | 0x12 | Velocities |
| | 0x13 – 0x1A | Data destined for other device |
| | 0x1B | Velocities HR |
| | 0x1C – 0x1F | Reserved |
| Sensors data | 0x20 | Gyro data |
| | 0x21 | Gyro data HR |
| | 0x22 | Accelerometer data |
| | 0x23 | Accelerometer data HR |
| | 0x24 | Magnetometer data |
| | 0x25 | Barometer data |
| | 0x26 | Sensors bias |
| | 0x27 | Accelerometer data in PV measuring point |
| | 0x29 | Gyro data filtered |
| | 0x2A | HG4930 IMU status |
| | 0x2B – 0x2F | Reserved |
| GNSS data | 0x30 | GNSS Position |
| | 0x31 | GNSS Position HR |
| | 0x32 | GNSS Velocity, Track over ground |
| | 0x33 | GNSS Heading, GNSS Pitch |
| | 0x34 | GNSS position STD |
| | 0x35 | GNSS Heading STD, GNSS Pitch STD |
| | 0x36 | GNSS info short |
| | 0x37 | Full satellites info |

| | | |
|---|---|---|
| | 0x38 | GNSS Solution status |
| | 0x39 | GNSS Position or Velocity type |
| | 0x3A | GNSS Angles position type |
| | 0x3B | Number of satellites used in solution |
| | 0x3C | GPS week |
| | 0x3D | GNSS Velocity Latency |
| | 0x3E | GNSS Position timestamp |
| | 0x3F | GNSS Velocity timestamp |
| | 0x40 | GNSS Heading timestamp |
| | 0x41 | New GPS |
| | 0x42 | Dilution of precision (DOP) |
| | 0x43 | GNSS Position and Speed accuracy |
| | 0x44 | GDOP, PDOP |
| | 0x45 | GNSS Track over ground |
| | 0x46 | Reserved |
| | 0x47 | GNSS diff age |
| | 0x48 | GNSS ECEF Velocity STD |
| | 0x49 | PPPSEED status |
| | 0x4A – 0x4F | Reserved |
| Service data | 0x50 | Supply voltage |
| | 0x51 | Stabilized voltage |
| | 0x52 | Temperature |
| | 0x53 | Unit status word (USW) |
| | 0x54 | Navigation solution status |
| | 0x55 | KF position covariance |
| | 0x56 | KF heading covariance |
| | 0x57 | KF position covariance HR |
| | 0x58 | KF velocity covariance |
| | 0x59 | Calculation time |
| | 0x5A – 0x5F | Reserved |
| External aiding data | 0x60 | Odometer |
| | 0x61 | Air speed |
| | 0x62 | Wind data |
| | 0x63 | External position |
| | 0x64 | Doppler shift from locator |
| | 0x65 | New aiding data |
| | 0x66 | Heading external |
| | 0x67 | DVL (Doppler Velocity Log) data |
| | 0x68 | Sensor bias external |
| | 0x69 | Pitch and Roll external |
| | 0x6A | GNSS antennas position |
| | 0x6B | Ambient Air Data |
| | 0x6C | Altitude external |
| | 0x6D – 0x89 | Reserved |
| Air speed | 0x8A | Wind Speed |
| | 0x8B – 0x8F | Reserved |

**Notes:**

1. It is highly recommended to choose unit status word (USW) to control INS unit state (see Appendix D for details).
2. If even one package from the "GNSS data" group is chosen, then it is highly recommended to select "New_GPS" data as well. This indicates a GNSS data update(see Appendix C.1, Table C.7 for details).
3. If even one package from "External aiding data" group is chosen, then it is highly recommended to choose "New aiding data" as well. This indicates an aiding data update (see Appendix C.1, Table C.13 for details).
4. For detailed descriptions of INS data types, see Appendix C.1, Table C.28.

Chosen data types appear in the **"Selected data types"** field (see Fig. 4.32). The following control icons are below the **"Selected data types"** field:

– to delete the selected data type

– to delete all selected data packets

– to move the selected data packet up in the list

– to move the selected data packet down in the list

The bottom string in the **"User defined data"** window (Fig. 4.32) contains the summary information about chosen data packets: total number of bytes and the maximum data rate for the current serial port baud rate (set in the **"Tests Options"**).

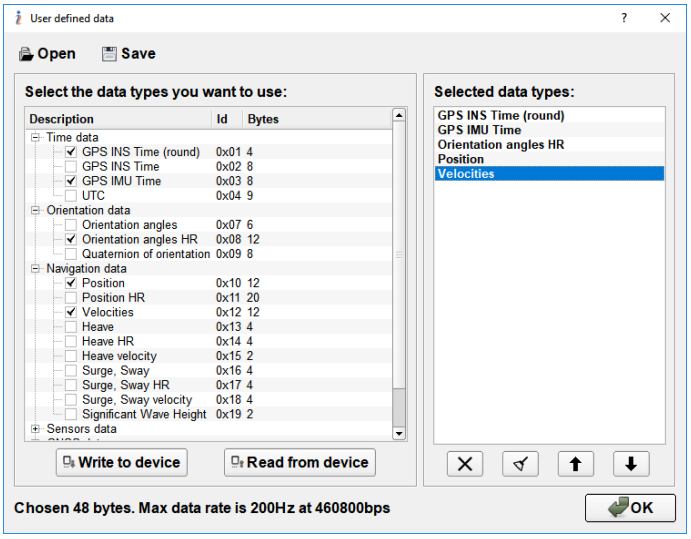



**Fig. 4.32.**

**Notes:**

1. Full size of the data message is larger than the total number of bytes of chosen packets. Full structure of the data message includes also header and other fields according to the message structure (see Appendix C.1, Table C.27, and INS ICD, Table 6.2).
2. Maximum data rate is calculated based on full size of the data message according to the formula (4.1) shown in section 4.2.8.

After choosing INS data types for output at the "User Defined Data" format, select the "**Write to device"** icon to write this configuration to the INS unit. If the operation is successful, the message in Fig. 4.33 appears. If the operation fails, the message in Fig. 4.34 appears.

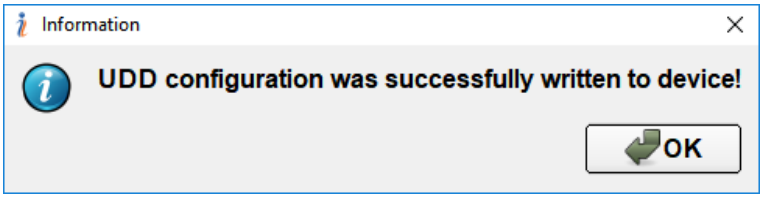



Fig. 4.33.

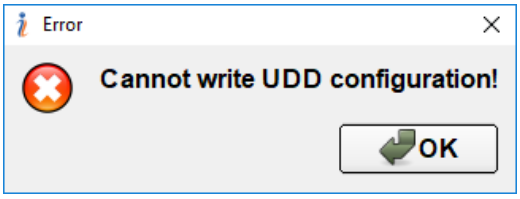



Fig. 4.34.

If the operation is unsuccessful, perform the following:

- Check settings of the device connection (serial port number and baud rate)
- Check INS firmware version – it should be no earlier than 3.2.4.0 to support the "User defined data" format.

### 4.7.1. Review and Editing of the Existing Configuration of the "User Defined Data" Format in INS Unit

Click "**Read from device"** (Fig. 4.31) to subtract the current configuration of the "User defined data" format from the INS unit. If the operation is successful, the message in Fig. 4.35 appears. If the operation fails, the message in Fig. 4.36 appears.

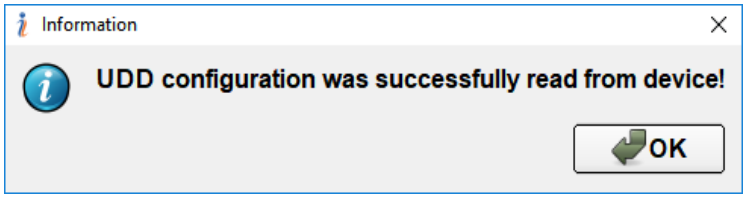



Fig. 4.35.

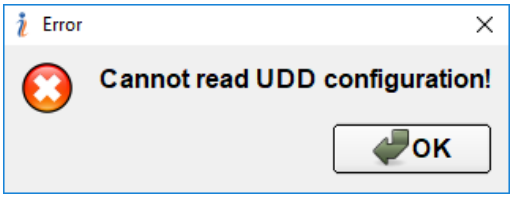



Fig. 4.36.

If the operation is unsuccessful, perform the following:

- Check settings of the device connection (serial port number and baud rate);
- Check INS firmware version – it should be no earlier than 3.2.4.0 to support the "User defined data" format.

The current INS configuration will be displayed in the "Select the data types you want to use" and "Selected data types" fields (see Fig. 4.32).

You can add or remove data packets. Also, using the control icons under "Selected data types" field, you can arrange the data types in the required order.

Press "Write" to write the configuration to the INS flash memory. If the operation is successful, the message in Fig. 4.33 will appear. If it is unsuccessful, the message in Fig. 4.34 will appear.

### 4.7.2. "User Defined Data" Format Configuration File (*.udd)

Created configuration of the "User defined data" format can be transferred to other INS units using binary file with the **.udd** extension.

To save the current configuration to file, please click the **"Save"** icon (Fig. 4.32), after which a standard MS Windows "Save as..." window is opened. The user can change the file name or keep its default name with a **.udd** extension. After saving, the message in Fig. 4.37 appears.

To load the **"User defined data"** configuration from the file, please click the **"Open"** icon (Fig. 4.31), after which a standard Windows "Open" window appears. In this window please select one of the previously saved files with a **.udd** extension. After opening the selected file, the message in Fig. 4.38 appears.

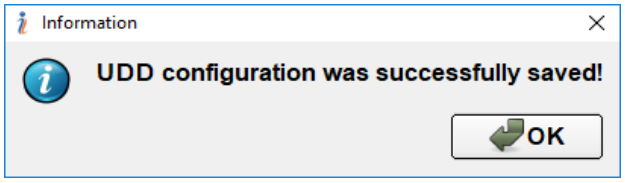



**Fig. 4.37.**

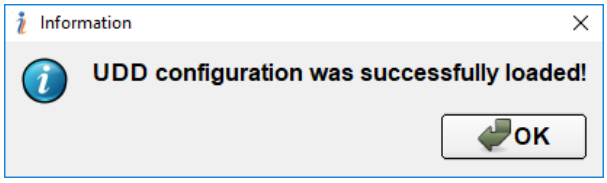



**Fig. 4.38.**

After loading configuration of the **"**User defined data**"** format, it is displayed in the **"Select the data types you want to use"** and **"Selected data types"** fields (see Fig. 4.32).

**Notes:**

1. It possible to edit this configuration as described above.
2. To apply configuration of the "User defined data" format to the INS unit, please click the "Write" icon.

### 4.7.3. INS Start with "User defined data" Output Format

To start the INS unit with the configured "User defined data" format, it is necessary to select the appropriate variant of INS output data format in "**Test Options**". Then click the **"Start"** icon on the vertical toolbar.

# 5. Run Menu

Control of the INS is done by the commands in the "**Run**" menu (Fig. 3.3). This menu contains the following items:

- **INS visualization** – opens the appropriate tab with different variants of visualization of the INS operation.
- **Stop INS** – stops the INS.
- **Device Information** – shows main information about the connected device.
- **Device self-test** – opens the tab containing the result of the INS self-test completed during INS initialization after power on.
- **Get BIT** – shows the INS unit Built-in-Test (BIT) status – temperature and the USW (see Appendix D. The Unit Status Word Definition).

There are five variants of visualization of the INS outputs:

- INS 3D
- Cockpit
- Snapshot (for the on-the-fly accuracy test)
- Data graphs
- INS relative position

## 5.1. INS 3D

"**INS 3D GUI"** is the default variant of the INS visualization in which current orientation angles of the INS are shown as spatial orientation of an airplane (see Fig. 5.1). To go to this visualization style, select **"INS visualization"** from the **"Run"** menu (Fig. 3.3), or select the icon on the toolbar, or press the **F4** button.

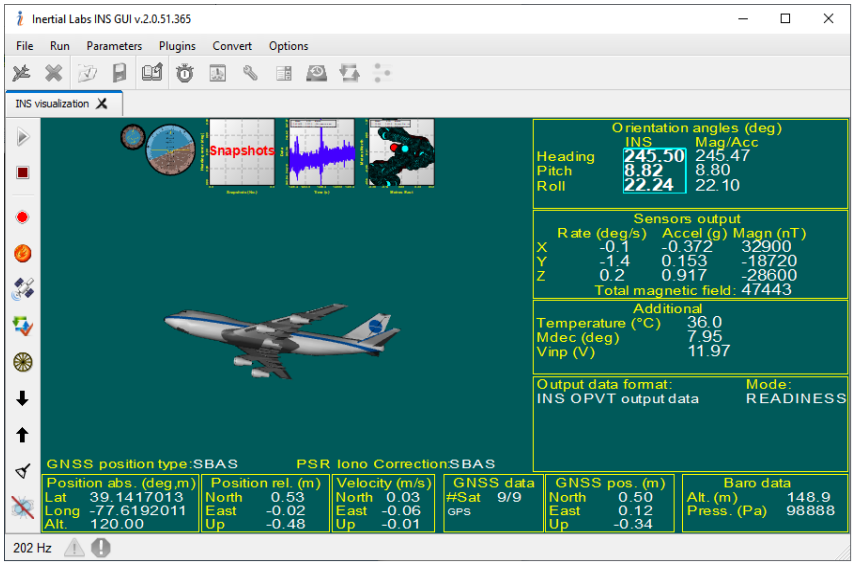



**Fig. 5.1.**

Some additional 3D models may be used for visualization of the INS orientation (see section “15. Choice of 3D Model for Visualization of the INS Orientation).

In the opened “INS visualization” tab, four control icons (active “Start” and “Write” , and inactive “Stop” , and “Snapshot” ) and service icons (“GNSS switch On/Off imitation” , “Start/Stop VG3D clb” , “Start/Stop Odometer Clb” , and “Stop MagAutoClb” ) appear in the left vertical toolbar. If in the **“Test Options”** menu the data output method “On Request“ is chosen, then the inactive icon “Request” appears.

Two icons appear in the status bar: “Warnings” and “Failures” .

Warning and failure messages are generated by the INS in its Unit Status Word (see Appendix D) and appear near and icons. You can close these messages by clicking on them.

Descriptions to the , , and icons are provided in section 10.2.3.

Additionally, the average data rate appears in the left part of the status bar about 10 seconds after INS started data output begins. Note this is the rate of data received by PC, not the INS data rate. Numbers in the status bar are therefore variable in contrast to the stable data rate of the INS unit. Showing the data rate is helpful if the INS unit started automatically, without command from INS GUI, in case the user is unaware of what data rate was set in INS unit.

The “INS visualization” tab consists of two vertical parts. Visualization panel of the INS outputs is situated on the left part of the tab. The right part displays text data from the INS plus additional information. Note that the right part is the same for all visualization styles.

The “**Start**” icon starts the INS with parameters saved in the INS microprocessor. Next, initial alignment of the INS is performed (with displayed message “Initial alignment. Please wait”). A progress bar of initial alignment will appear in the status line of the main window. During the initial alignment, <u>the INS must be unmovable relative to the Earth</u>. Once the initial alignment time is over, observe changes in numeric data and graphical evolutions of the object.

**Note:** For visual convenience of the INS position perception displayed on the monitor and the INS real position, it is recommended to place the INS 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**" icon is pressed, icons "Stop" , "Snapshot" , "Start/Stop VG3D clb" , and "Stop MagAutoClb" become active. If in the **"Test Options"** menu the data output method "On Request" is chosen, then the "Request" icon becomes active as well.

Upon clicking the "**Write**" icon , the measured data are saved, which is signified by the message "Data are writing in file!". Note that the data are saved in binary file and can be used in two ways:

- Visualization through opening the file in "**File**", **"Open"** menu item (see section "6.1. "Open" Item").
- Conversion to the text file using "**Report of experiment**" from "**Convert**" menu item (see section "9. Convert Menu").

"**Stop**" – stops data output to the screen and data saving procedure with no data losses.

**"Snapshot"** – used for fixing the current values of measured data during continuous run (see section "10.5.2. On-the-Fly Accuracy Test").

**"GNSS switch On/Off imitation"** button allows switching off/on the GNSS receiver input to the INS algorithm during the INS operation. This feature can be used to check INS operation at GNSS outage. Please note that the receiver is not physically disconnected, and the INS unit continues transferring GNSS data to output independent of whether the GNSS receiver input to the INS algorithm is switched on or off.

If GNSS receiver switched off the INS unit does not use GNSS data in its calculations only. The INS indicates this by setting the number of satellites used in navigation solution, #Sat, to zero in output data package. But GNSS_info2 field of INS output data package contains true information about GNSS data (see Table C.6). If the necessary number of GNSS satellites is available, then "Solution status" of the GNSS_info2 field indicates "GNSS solution is computed".

**"Start/Stop VG3D clb"** – used to start or stop the on-the-fly VG3D calibration process (see section 10.4.4 for more details).

**"Stop MagAutoClb"** – used to stop automatic calibration of magnetometers (see section 10.4.5 for more details).

If the data output method "On Request" is chosen in the menu "Test options", then getting data from the INS is performed by clicking the icon **"Request"**. In case of data saving (if the icon "Write" is pressed), the measured data are written in one file sequentially.

**"Start/Stop Odometer clb"** – used to start or stop the odometer calibration process (see section 10.7.3.1 for more details).

**Current orientation angles are displayed in the upper right part of the window (Fig. 5.1)**, while position and velocity data are displayed in the bottom part of this window. Additional displayed data depend on the selected output data format (see Appendix C for description of data formats). If default "INS OPVT Output" data format is chosen, then the following data are displayed in the right part of the window shown in Fig. 5.1:

- Orientation angles "Heading", "Pitch", and "Roll". In the "INS" column, angles calculated in the INS's microprocessor using the embedded main algorithm are output. The "Magn/Acc" column shows orientation angles calculated in the INS GUI 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:** It is important to set the magnetic declination correctly in the **"Devices Options"** menu (see Fig. 4.2) because the INS operation requires knowing the true heading, but not the magnetic one.

- Output signals of the INS 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 INS axes (X is lateral axis, Y is longitudinal axis, Z is vertical axis). Axes X, Y, and Z are object axes if non-zero alignment angles are set for INS mounting (see Appendix E. Variants of the Inertial Labs™ INS Mounting Relative to Object Axes).

- Total measured magnetic field value in nT ("Total magnetic field").
- Current temperature "Temperature (degC)": the temperature inside the INS.
- The set value of the magnetic declination ("Mdec (deg)").
- Input supply voltage of the INS in VDC ("Vinp (V)").
- Format of output data "Output Data Format": This format is set in the "**Test Option**" window (Fig. 4.1).
- Current mode of the INS operation (Readiness).

**Current position and velocity are displayed in the bottom part of window in Fig. 5.1:**

- In the "Position abs. (deg, m)" column the INS absolute position is displayed – Latitude (degrees), Longitude (degrees), and Height (meters), which are calculated in the INS.
- In the "Position rel. (m)" column the INS position relative to the start point is shown. Here, changes of latitude and longitude are recalculated to changes of linear coordinates in the North and East directions.
- In the "Velocity (m)" column, the North, East, and Vertical components of the INS velocity are displayed.
- The "GNSS data" column shows the following information about GNSS data:
  - #Sat – the number of satellites used in navigation solution.
  - GPS / GLO / Gal / Bei – shows what navigation systems are currently used (GPS, GLONASS, Galileo, BeiDou).
  - Ext.sol. – extended solution status of the GNSS data (available if "INS Sensors Data" format is chosen). See Appendix C, Table C.17 for details.
- The "GNSS pos (m)" column shows the GNSS position relative to the start point. Here, change for GNSS latitude and longitude are recalculated to change of linear coordinates in the North and East directions.
- The "Baro data" column shows data measured by the pressure sensor: "Temp.(decC)" – is temperature in °C; "Press.(Pa)" – is pressure in Pascals; "Alt.(m)" – is barometric altitude in meters.

**Detailed information about quality of GNSS solution placed above the position and velocity columns in the bottom part of window in Fig. 5.1:**

- GNSS position type – shows what data were used by the GNSS receiver in navigation solution for position calculation:
  - Single-point position
  - DGPS (pseudorange differential solution)

    - Solution calculated using corrections from SBAS
    - PPP solution
    - RTK (narrow-integer) solution
    - RTK (other) solution
    - PPP conv. (Converging TerraStar-C, TerraStar-C PRO, TerraStar-X, or Oceanix solution)
    - PPP (Converged TerraStar-C, TerraStar-C PRO, TerraStar-X, or Oceanix solution)
    - PPP basic conv. (Converging TerraStar-L solution)
    - PPP basic (Converged TerraStar-L solution)
    - Other
- PSR Iono Correction – shows what data were used for pseudorange ionosphere correction:
    - Default (unknown or default Klobuchar model)
    - Klobuchar Broadcast
    - SBAS Broadcast
    - Multi-frequency Computed
    - DGPS (pseudorange differential correction)
    - NovAtel Blended Iono Value

To stop data output from the INS, click the "**Stop**" icon .

To leave the INS visualization mode, click the icon in the title of the current tab.

For other styles of visualization of the INS outputs, there are clickable previews in the upper part of the "INS visualization" tab (Fig. 5.2). It is possible to switch between visualization styles at any time of INS operation by simply clicking on its preview.

a) b) c) d) e)

**Fig. 5.2.**

## 5.2. Cockpit Style of Visualization

The **"Cockpit"** window shows current attitude of the INS in "Cockpit display" style (see Fig. 5.3). To switch visualization to this mode, click on the preview shown in Fig. 5.2 (b) and the window shown in Fig. 5.3 will appear. A heading indicator is 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, while limb corresponds to roll.

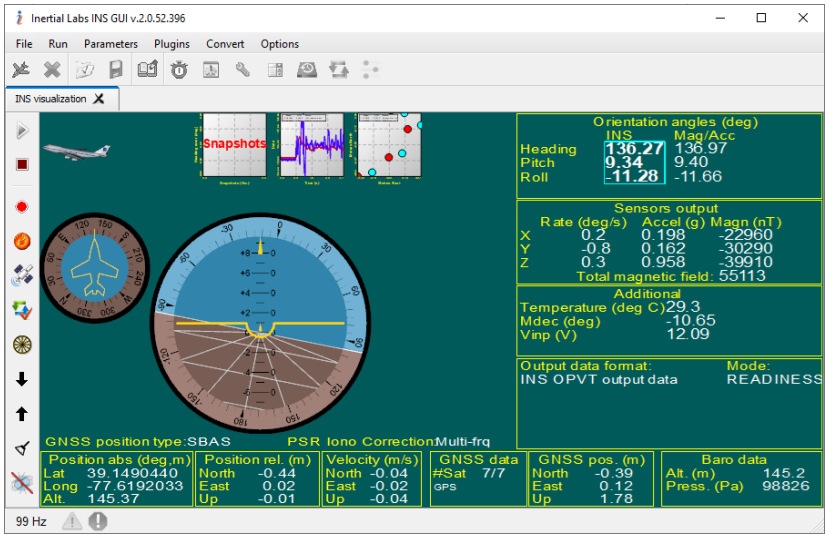



**Fig. 5.3.**

To switch to a visualization style other than "Cockpit", click on the appropriate preview in the upper part of the "INS visualization" tab (Fig. 5.3). To stop data output from the INS, click the "Stop" icon .

## 5.3. On-the-Fly Accuracy Style of Visualization

The **"On-the-fly accuracy"** feature is designed for checking the INS accuracy at its ordinary operation when the INS can be directed to points with known orientation.

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

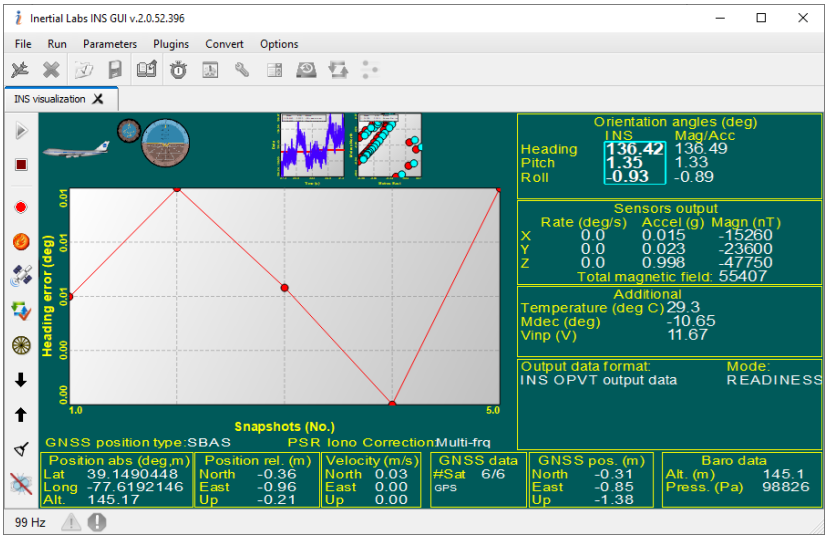



**Fig. 5.4.**

For more information about this type of visualization, see section "10.5.2. On-the-Fly Accuracy Test".

## 5.4. Data Graphs Style of Visualization

The **"Data graphs"** window shows graphs of current INS outputs (see Fig. 5.5). To switch visualization to this mode, click on the preview shown in Fig. 5.2 (d), and the window shown in Fig. 5.5 will appear.

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

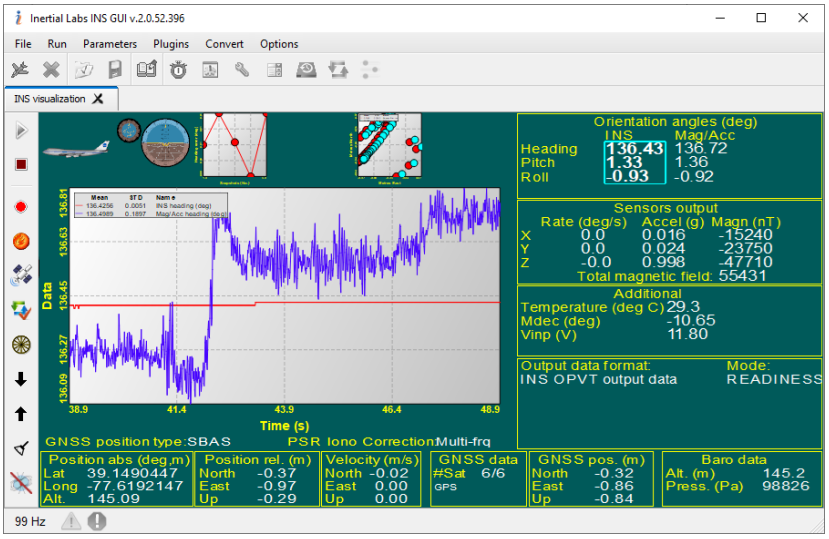



**Fig. 5.5.**

You can select or deselect signals by clicking on their titles:

- INS heading (deg) – plots Heading angle calculated in the INS
- INS pitch (deg) – plots Pitch angle calculated in the INS
- INS roll (deg) – plots Roll angle calculated in the INS
- Mag/Acc heading (deg) – plots Heading angle calculated in the INS GUI software based on the INS magnetometers and accelerometers data
- Accel pitch (deg) – plots Pitch angle calculated in the INS GUI software based on the INS accelerometers data
- Accel roll (deg) – plots Roll angle calculated in the INS GUI software based on the INS accelerometers data
- Gyro X (deg/s) – plots output signal of the gyro X
- Gyro Y (deg/s) – plots output signal of the gyro Y
- Gyro Z (deg/s) – plots output signal of the gyro Z
- Accelerometer X (g) – plots output data of the accelerometer X
- Accelerometer Y (g) – plots output data of the accelerometer Y
- Accelerometer Z (g) – plots output data of the accelerometer Z
- Magnetometer X (nT) – plots output data of the magnetometer X in nanotesla
- Magnetometer Y (nT) – plots output data of the magnetometer Y in nanotesla
- Magnetometer Z (nT) – plots output data of the magnetometer Z in nanotesla
- Magnetic module (nT) – plots full module of the measured magnetic-field vector in nanotesla

- Temperature (deg C) – plots current temperature inside the INS in degrees Celsius
- Latitude (deg) – plots latitude
- Longitude (deg) – plots longitude
- Altitude (m) – plots height
- V_N (m/s) – plots velocity to the north
- V_E (m/s) – plots velocity to the east
- V_V (m/s) – plots vertical velocity
- Latitude GNSS (deg) – plots GNSS latitude
- Longitude GNSS (deg) – plots GNSS longitude
- Height GNSS (m) – plots GNSS height
- Trk_gnd (deg) – plots track over ground
- V_N GNSS (m/s) – plots GNSS velocity to the north
- V_E GNSS (m/s) – plots GNSS velocity to the east
- V_V GNSS (m/s) – plots GNSS vertical velocity
- Baro Temp. (deg C) – plots barometric temperature in degrees Celsius
- Baro Press. (Pa) – plots barometric pressure in Pascal unit
- Baro Alt. (m) – plots barometric altitude

Plotted graphs are scalable. To zoom in, please click and hold the left mouse button and drag in a down-right direction. Click and hold the right mouse button to shift plot. To zoom out, please click and hold the left mouse button and drag in an up-left direction. The legend is located at the upper left corner of the tab. This legend shows mean value, STD, and name of displayed signals.

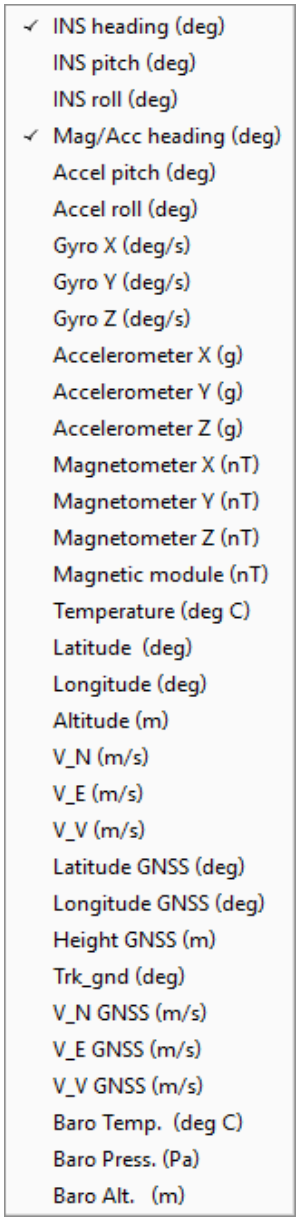



**Fig. 5.6.**

## 5.5. Visualization of INS Relative Position

This is visualization of the INS current position relative to the start point (see Fig. 5.5). To switch visualization to this mode, click on the preview shown in Fig. 5.2 (e).

Changes of the INS latitude and longitude are recalculated to the changes of linear coordinates in the North and East directions. On default, there are coordinates provided by the GNSS receiver (cyan markers) and coordinates calculated by the INS (red markers), see Fig. 5.7. It is possible to select the data you want displayed by

right-clicking on the graphs area. Next, select or deselect data by clicking on their titles, see Fig. 5.8.

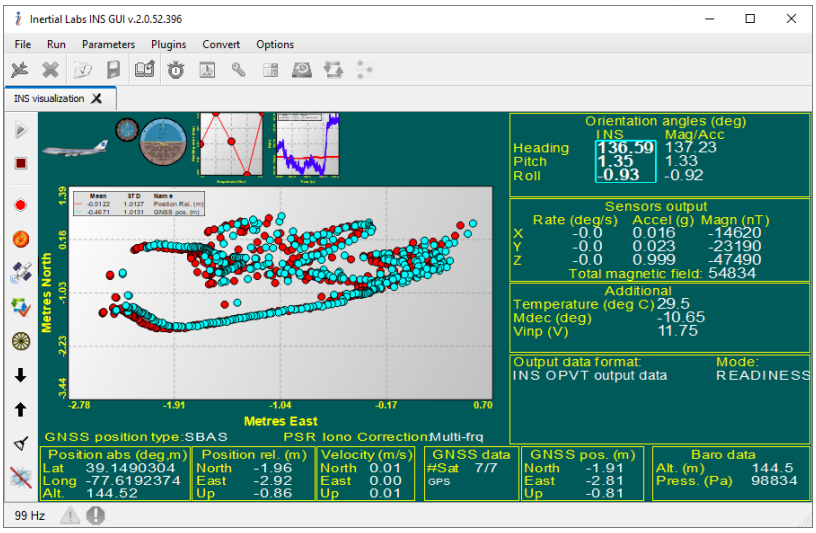



Fig. 5.7.

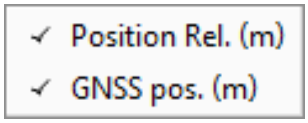



Fig. 5.8.

## 5.6. Peculiarities of Data Displayed at the "INS Sensors Data" Format

At this data format, the INS outputs data from separate internal devices (AHRS, GNSS receiver, and pressure sensor) without integration of these data. Therefore, in the visualization windows Fig. 5.1, Fig. 5.3, Fig. 5.4, Fig. 5.5, Fig. 5.7, and Fig. 5.8, different kinds of data are displayed in contrast to data described in section 5.1. The upper right part of the window shows orientation calculated by the AHRS algorithm.

- The bottom part of the window shows position and linear velocities provided by GNSS receiver, as well as additional information about GNSS data that differs from those described in section 5.1 – in the #Sat field there are two different numbers: the number of tracked satellites and the second one is number of satellites used in navigation solution.
- Ext.sol. – extended solution status of the GNSS data (see Table C.17 in Appendix C).

## 5.7. Other Items of the "Run" Menu

- **Stop INS** – stops the INS. In most cases, this function it is used for correct termination of completed operations. For this command, the hot key **F7** can also be pressed or the icon can be clicked.
- **Device Information** – opens tab with the INS main information: integrated device serial number and firmware version; IMU serial number and firmware version; parameters of GNSS receiver; GPS reference week number; pressure sensor type; availability of the external sensor (see Fig. 5.9).

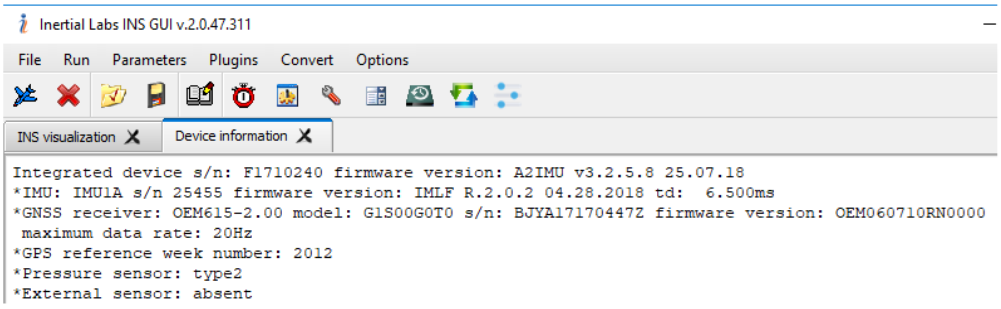



**Fig. 5.9.**

- **Device self test** – opens tab with the result of the INS self-test completed during INS initialization after power on (see Fig. 5.10 for example of a successful self-test and Fig. 5.11 for example of a nonsuccessful test).
- **Get BIT** – opens tab with the INS unit Built-in-Test (BIT) status (temperature and the USW; see Appendix D. The Unit Status Word Definition) (see Fig. 5.12).

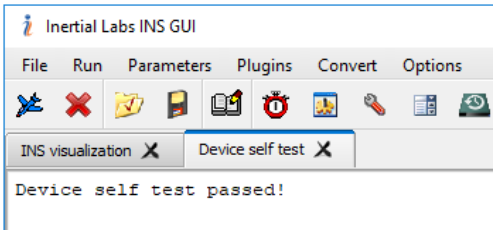



**Fig. 5.10.**

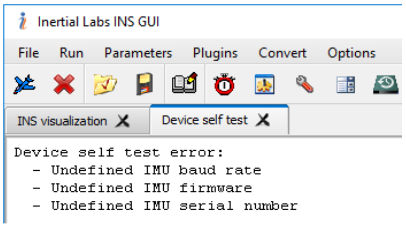



**Fig. 5.11.**

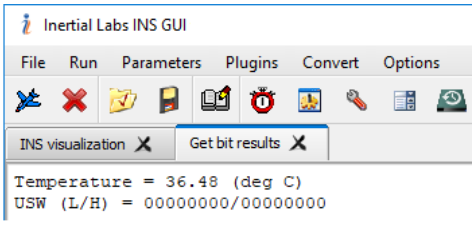



**Fig. 5.12.**

# 6. File Menu

The **"File"** menu enables the user to work with saved INS runs. The following items are in the **"File"** menu:

- Open
- Emulate
- Save as
- Exit

## 6.1. "Open" Item

You can plot data saved to files during the INS run. To open a saved *.bin file, choose **"Open"** (Fig. 3.2) or press **F3**. The standard Windows window "Open file" will appear, in which point it is necessary to choose the needed *.bin file saved previously when the INS was operating in regular mode. After selection of the file, data are read and the new tab **"Data viewer"** (shown in Fig. 6.1) will open.

It is possible to select the data you want to display by right-clicking on the graphs area. As a result, the window shown in Fig. 5.6 will appear, at which point the user can select or deselect shown data by clicking on their titles.

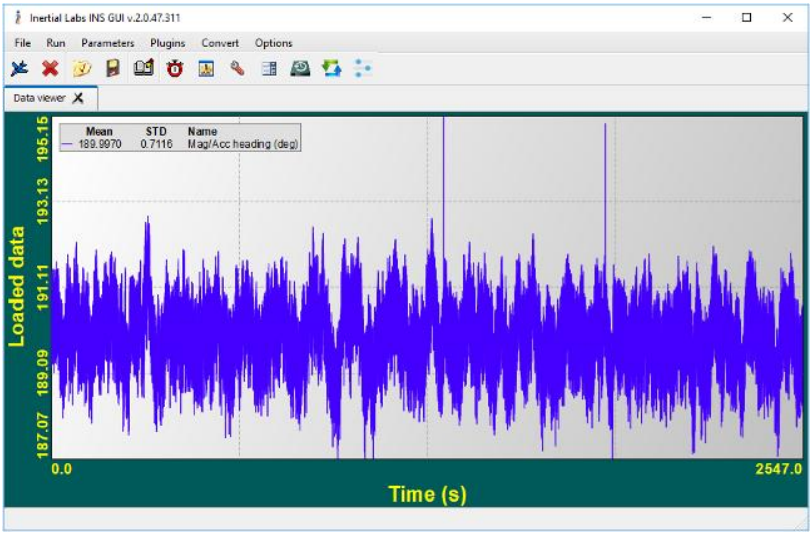



**Fig. 6.1.**

Plotted graphs are scalable. To zoom in, please click and hold the left mouse button and drag in a down-right direction. To zoom out, click and hold the left mouse button and drag in an up-left direction. Click and hold the right mouse button to drag the plot.

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

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

## 6.2. "Emulate" Item

Since INS GUI version 2.01.51.365 from 02/21/2020, it is possible to visualize data saved to files during the INS run. Choose **"Emulate"** (Fig. 3.2) or press **F2** to open the saved *.bin file. The standard Windows "Open file" window will appear, at which point it is necessary to choose the needed *.bin file saved previously.

After selection of a file, INS GUI starts data reading from the file and emulates data in the **"INS visualization"** tab (see Fig. 6.2) as these data come directly from INS unit.

All different styles of visualization (INS 3D, Cockpit, Snapshot, Data graphs, INS relative position) are available. See section "5. Run Menu".

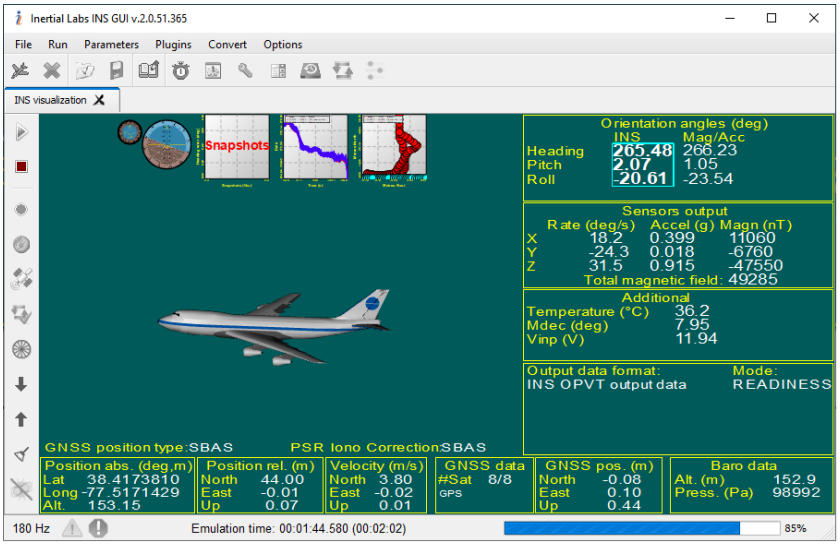



**Fig. 6.2.**

In contrast to the usual "INS visualization" window (see Fig. 5.1), in this window there is only one active icon ("Stop" ) on the vertical toolbar to stop emulation of INS operation. Additionally, in this window's status bar the user will see "Emulation time", which usually is slower than real "Writing time" (as shown in Fig. 5.1) at saving data to file. Correspondingly, the average data rate in the left part of the status bar shows the rate of emulated data, but not rate of saved data.

**Note:** The current version of data emulation in INS GUI supports INS data saved in all formats except "User Defined Data".

## 6.3. "Save As" Item

You can preset a file's name for data writing. For this option, select **"Save as"** (Fig. 3.2) and enter the desired file name.

# 7. Parameters Menu

The **"Parameters"** menu enables work within INS parameters. The following items are in the **"Parameters"** menu:

- Restore parameters
- Save parameters
- Preset parameters

## 7.1. Restore Parameters

The **"Restore parameters"** command (see Fig. 3.4) is used to quickly load the INS parameters to the INS nonvolatile memory. When the **"Restore parameters"** command is selected, or the icon is clicked, a standard Windows "Open" window opens; in this window the user selects one of the previously saved files with *.prm extension. Consequently, the parameters are automatically saved to the INS nonvolatile memory and to the GUI shell. The same procedure is used to restore the factory settings of the INS parameters. To perform this task, the user should select the original file with *.prm extension that comes on the Flash Drive within a delivery package of the Inertial Labs™ INS.

INS GUI software checks matching of serial numbers stored in *.prm files and in the INS unit. INS GUI software does not allow restoration of parameters from *.prm with wrong serial numbers.

Since INS GUI software version 2.0.46.272 from 2018-05-15, it possible to restore parameters from *.prm files where a serial number differs from the serial number of the INS unit that is currently connected. However, the following warning window will appear with information about different serial numbers and a request regarding user action – see Fig. 7.1. This appearance of this window is helpful in case an INS serial number was corrupted.

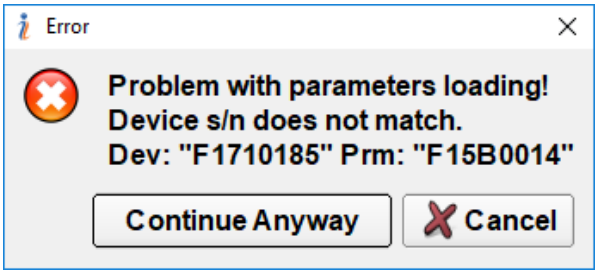



**Fig. 7.1.**

## 7.2. Save Parameters

If you have changed some parameters of the INS (in the **"Devices options"** window from the "**Options**" menu or in other menus), and you want to save these parameters as a variant for future work, you can save the INS current parameters in binary file with a *.prm extension. To do so, use the "**Save parameters**" command (see Fig. 3.4) or the click icon. A standard Windows "Save as" window will open, at which point it is suggested that the user should save current parameters of the INS to a "File of parameters" with a *.prm extension.

## 7.3. Preset Parameters

To achieve better dynamic accuracy of the INS, the Inertial Labs™ INS GUI provides preset of the INS parameters that adjust the INS algorithm for some specific conditions of operations. To modify INS parameters, select **"Preset parameters"** from the **"Parameters"** menu (Fig. 3.4). The window shown in Fig. 7.2 will be opened.

**Note:** The user is able to apply **"Preset parameter"** variants only if the INS is powered and connected to a computer; COM-port number and its baud rate are chosen properly; INS initialization time (about 25 seconds after power on) is completed and the LED indicator lights red.

Click the **"Load Parameters"** icon. The standard MS Windows "Open" menu will appear, in which it is necessary to choose the needed file with a *.prm extension. Inertial Labs™ supplies parameters files with *.prm extensions that contain special sets of the INS parameters for specific conditions of INS operation. Note that the individual INS parameters are not changed at application of the preset parameters.

After selecting the file, two checkboxes ("IMU" and "INS") will appear in the **"Preset parameters"** window (see Fig. 7.3).

The user should choose the "IMU" and / or "INS". Click the "OK" button to load the chosen parameters from the file to the INS. Parameters are then loaded and the information window shown in Fig. 7.4 appears.

A second option is to click the "Cancel" button to close the "Preset parameters" window without loading parameters.

Please pay attention to the possibility of increasing the INS accuracy at object swaying via compensation of linear acceleration at place of the INS mounting (see section "4.5. Swaying Compensation").

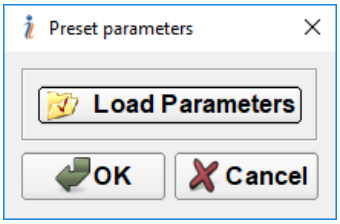



Fig. 7.2.

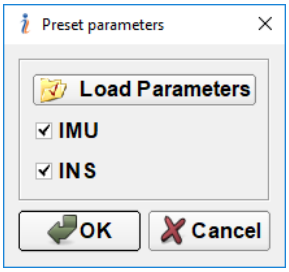



Fig. 7.3.

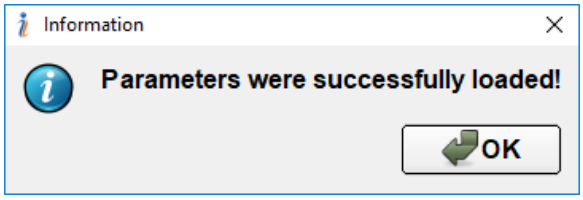



Fig. 7.4.

# 8. Plugins Menu

The **"Plugins"** menu enables the user to run additional parts of the GUI software. The following items are in the **"Plugins"** menu:

- Embedded
- Mag field calibration
- Angles accuracy
- Magnetometers axes alignment
- World Magnetic Model updating
- Firmware and parameters update

## 8.1. Embedded

The INS GUI software allows consideration of the influence of the soft and hard iron of the carrier object on the heading calculation accuracy. For this purpose, field calibration of the INS magnetometers is provided. There are two ways to calibrate the INS: to use INS embedded procedures, or to use procedures provided by INS GUI software. The second way is more convenient (see section "8.2. Magnetometers Field Calibration"). For the INS embedded calibration procedure, the user should access the **"Embedded"** menu. After selecting this menu, the "Embedded Mag field calibration" window will appear (see Fig. 8.1).

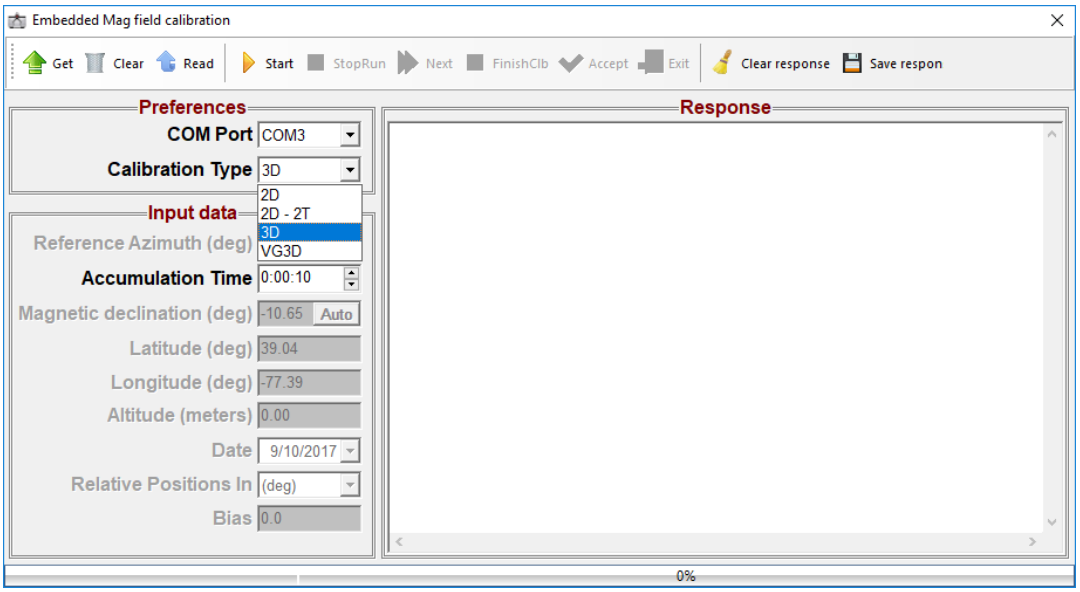



**Fig. 8.1.**

Buttons within the toolbar are used to send commands for the INS calibration that are described in the INS ICD. The chart below provides a list of these icons and corresponding commands:

| Icon | Command | Code | Description |
|---|---|---|---|
| Get | GetClbRes | 0x2A | Views the last calibration results stored in the INS memory. |
| Clear | ClearClb | 0x2F | Clears calibration parameters. |
| Read | – | – | Reads out the INS flash memory. |
| Start | Start2DClb<br>Start2D2TClb<br>Start3DClb<br>StartVG3DClb | 0x21<br>0x22<br>0x23<br>0x25 | Starts the 2D, 2D-2T, 3D, or VG3D calibration. |
| StopRun | StopClbRun | 0x20 | Early stops data accumulation in the calibration run before set accumulation time is reached. |
| Next | StartClbRun | 0x2B | Starts a new run of the 2D-2T calibration. |
| FinishClb | FinishClb | 0x2C | Finishes the calibration procedure with multiple runs (e.g. 2D-2T). |
| Accept | AcceptClb | 0x2E | Accepts the calibration parameters and saves them to the INS nonvolatile memory. |
| Exit | ExitClb | 0xFE | Exits the calibration without calculations and without saving calibration parameters. |
| Clear response | – | – | Clears the response window (see Fig.6.2). |
| Save response | – | – | Saves data from the response window to a *.log file. |

**Note:** Command code in this table is payload of the command with 9-bytes structure.

When the INS answers on the above commands, these answers appear in the Response window (see Fig. 8.2).

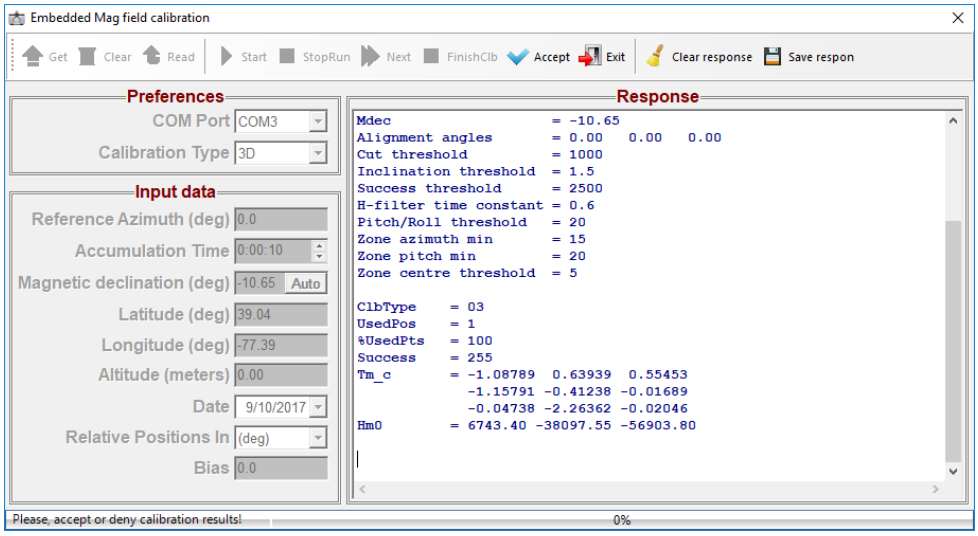



**Fig. 8.2.**

Different buttons will be active depending on calibration type.

See INS ICD for detailed description of the embedded calibration procedures.

## 8.2. Magnetometers Field Calibration

Another and more convenient method for INS hard and soft iron calibration is provided by INS GUI software.

Before calibration, please check the **"Test Options"** dialog box (Fig. 4.1) for the correct COM-port number to which the INS is connected.

To start the calibration, select the **"Plugins"** menu and then **"Mag Field Calibration**" (see Fig. 3.5) from the main menu. The "Magetic field calibrations" window will open (see Fig. 8.3).

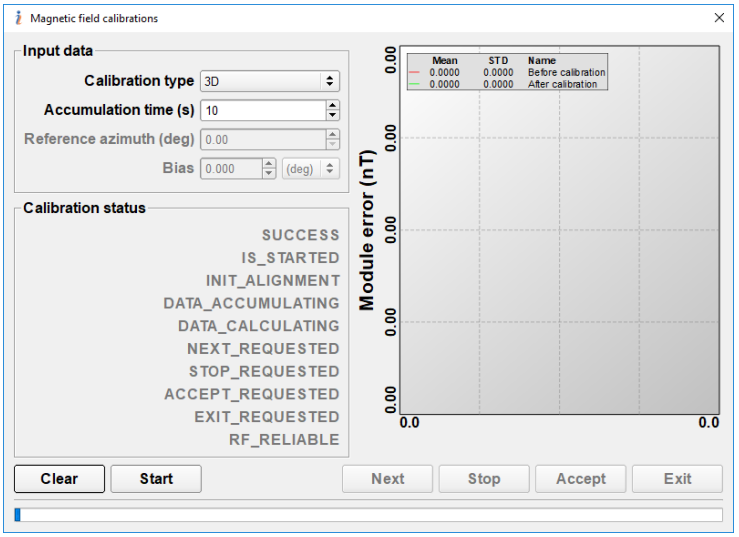



**Fig. 8.3.**

**Important note:** For correct calibration, it is necessary to set the correct coordinates in **"Latitude"**, **"Longitude"**, **"Altitude"** and **"Date"** filds in accordance with the location where the INS is calibrated. These values are set in the **"Devices Options"** window (see Fig. 4.2).

In the "**Calibration Type**" field, choose from the list the type of the calibration – 2D, 2D-2T, or 3D (see section 10.4 for explanation of these types).

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

In the **"Calibration status"** window, captions are highlighted to show current states of INS calibration and actions that can be performed.

See section 10.4 for a detailed description of the INS calibration procedure.

If the location of the INS mounting on the carrier object is changed, or if the carrier itself is changed, then calibration matrices for magnetometer biases and scale factors in the INS memory should be cleared by clicking on the **"Clear"** icon (see Fig. 8.3).

## 8.3. Angles Accuracy

The **"Angles Accuracy"** plugin allows checking the accuracy of the INS calculation of orientation angles (heading, pitch, and roll). For this purpose, any possible equipment should be applied to set the exactly known orientation angles of the INS unit and compare these angles to the INS output.

To start the plugin, select the **"Plugins"** menu and then **"Angles accuracy"** (Fig. 3.5). At this point, the main window will appear (see Fig. 8.4).

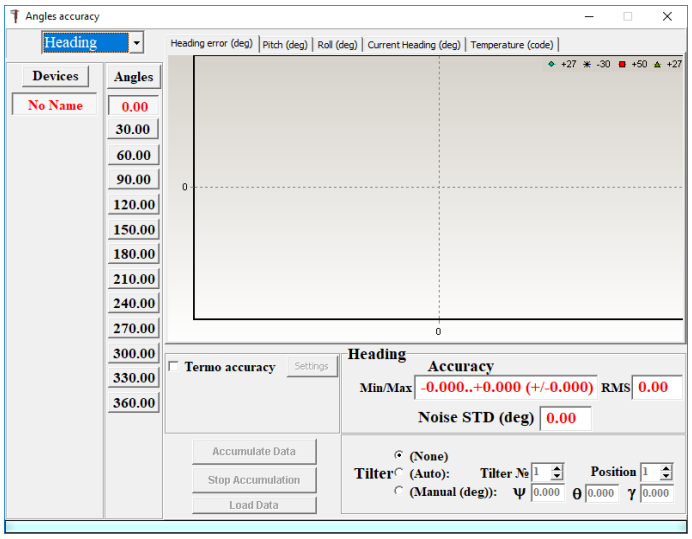



**Fig. 8.4.**

During accuracy tests, it is possible to set the misalignment angles between a test bench platform and INS installation itself on this platform. It is necessary if, for INS installation on the test bench platform, intermediate adaptations are used – for example, tilter. If the deviation angles are known, they must be applied at tests. For this purpose, **"Tilter"** fields are located in the bottom right window corner (Fig. 8.4). the following options available there:

- "(None)" – algorithm not consider deviations angles
- "(Auto)" is to consider deviations for tilter used for Inertial Labs™ internal tests "Tilter №" and a corresponding cell ("Position") in this tilter
- "(Manual)" is to consider manually based deviation angles on corresponding angles "ψ", "θ", and "γ".

See section 10.5.1 for detailed description of the accuracy test for each reference angle.

## 8.4. Magnetometers Axes Alignment

The Inertial Labs™ INS can be factory configured to use the external Stand Alone Magnetic Compass (SAMC) instead of onboard magnetometers to measure components of the Earth magnetic field.

Before using external SAMC, it is necessary to align the SAMC axes with INS axes for accurate operation.

For axes alignment procedures please make sure the "Serial Port" field of the **"Test Options"** dialog box (Fig. 4.1) shows the correct COM-port number to which the INS is connected.

To perform the axes alignment, select **"Mag. axes alignment"** from the main menu **"Plugins"** (see Fig. 3.5). The "Mag. axes alignment" window will open (see Fig. 8.5).

The "**Accumulation Time**" field defines the necessary time of data acquisition during the measurement of each position of a carrier object. At least three positions with essentially different pitch and roll angles are required. The "Accumulation Time" can be set by using the arrows or by keyboard entry of the necessary value. The default value is 10 seconds.

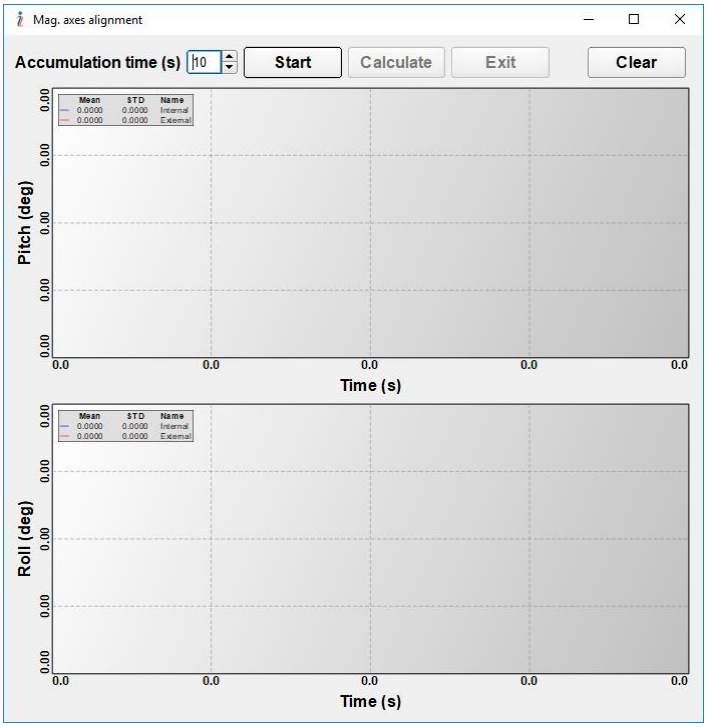



**Fig. 8.5.**

See section 10.9 for a detailed description of the INS and SAMC axes alignment procedure.

## 8.5. World Magnetic Model Updating

The World Magnetic Model (WMM) is used for magnetic declination calculation to determine the true heading using magnetometers. Current World Magnetic Model WMM2020 is valid until the year 2025.

Since INS firmware version 3.4.0.1, the WMM can be updated using the Inertial Labs™ INS GUI version 2.0.49.332 or later.

The INS GUI uses standard file WMM.cof with coefficients of the WMM that can be downloaded from the National Centers for Environmental Information website: https://www.ngdc.noaa.gov/geomag/WMM/soft.shtml.

To start updating, select "**Plugins**" and then "**World Magnetic Model updating**" (see Fig. 3.5) from the main menu. The "World Magnetic Model updating" window will appear (see Fig. 8.6).

The "**Read from device**" button provides readings from existing coefficients of the WMM from flash memory and displays them, as shown in Fig. 8.7.

Fig. 8.6.

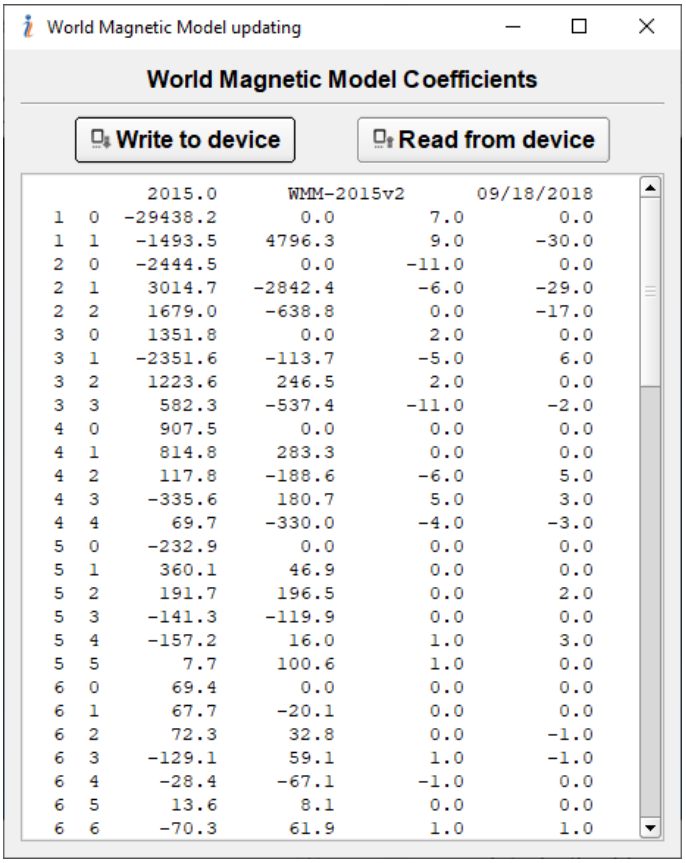



Fig. 8.7.

To load new WMM coefficients into flash memory, please press the "**Write to device**" button. The standard Windows "Open" window will appear, at which point it is necessary to choose the needed "WMM.cof" file previously saved on a PC. After pressing the "Open" button, the update begins; once it is done successfully, Fig. 8.8 will appear on the screen. Otherwise, the message shown in Fig. 8.9 appears.

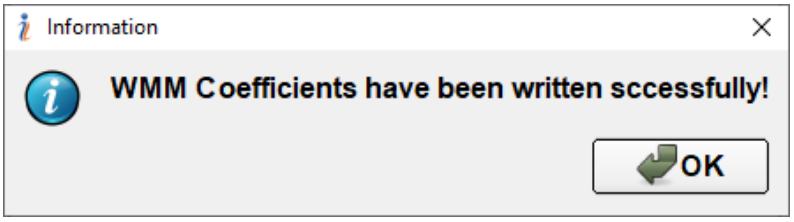



**Fig. 8.8.**

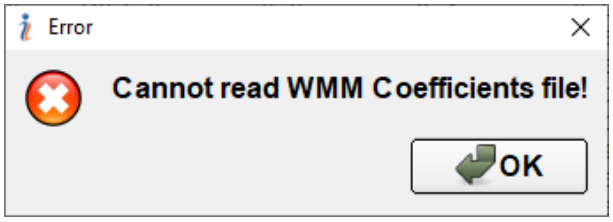



**Fig. 8.9.**

## 8.6. Firmware and Parameters Update

Since INS GUI version 2.0.50.348 from 2019-10-01, the GUI software allows update of device firmware and parameters with specific utility.

**Important note:** Firmware update works for devices with firmware version not earlier than v3.4.0.1, when the command for switch processor to firmware loading mode was implemented. For devices with earlier firmware, this feature will update parameters only. In such a case, the warning window in Fig. 8.10 will appear on the screen.

**Fig. 8.10.**

See section 14 for detailed description of the INS firmware and parameters updating procedure.

# 9. Convert Menu

The following options are in the Convert menu:

- Report of experiment
- Convert to Raw IMU data
- Convert to IMR data
- Convert to DMR data
- Convert log data to bin file
- Combine RAWIMUB and GPS data

## 9.1. Report of experiment

“Report of experiment” used to convert saved binary data (pair of files *.bin and *.prm to the text file).

When the “Report of experiment” item is selected from “Convert” menu, or the icon is clicked, or the F8 button is pressed (see Fig. 3.6), a standard Windows “Open” window appears. In this window, select the *.bin files saved previously when the INS was operating in its ordinary mode. Consequently, a report file with same name but with a *.txt extension is created. Note that a file with an extension *.prm and the same name as the *.bin file should be present as well.

“Report of experiment” creates a text file according to the output data format of data in the binary *.bin file. Necessary data format is set by the user in the “Test Options” window. See “Appendix C.2. Text Presentation of Output Data Formats” for description of the text file.

## 9.2. Convert to Raw IMU data

“Convert to Raw IMU data” converts saved binary data (file *.bin) to special binary file *.imu with raw IMU data used in the NovAtel Inertial Explorer for post-processing of the INS and GNSS receiver data. See section “12.2 Raw IMU Data Generation” for details.

## 9.3. Convert to IMR data

"Convert to IMR data" converts saved binary data (file *.bin) to generic file *.imr used in the NovAtel Inertial Explorer for post-processing. IMR data file contains IMU data and time. See section "12.3. Generation of IMR Data File " for details.

## 9.4. Convert to DMR data

"Convert to DMR data" converts saved binary data (file *.bin) to generic file *.dmr used in the NovAtel Inertial Explorer for post-processing. DMR data file contains odometer data and time. See section "12.4. Generation of DMR Data File with Odometer Data and Time" for details.

## 9.5. Convert log data to bin file

If INS data were saved directly from COM port to a log file, use «Convert log data to bin file» to convert the log file to binary files *.bin and *.prm which can be processed by INS GUI software.

After selecting the «Convert log data to bin file» item a standard Windows «Open» window appears. In this window please select parameters file *.prm with current parameters of the INS unit. Then new «Open» window is opened where the user is asked to select the log file. After this, the pair *.bin and *.prm files will be created with the same name as the log file plus "_Converted" text.

## 9.6. Combine RAWIMUB and GPS data

"Combine RAWIMUB and GPS data" embeds raw IMU data into the GNSS stream, which can be used in the NovAtel Inertial Explorer for post-processing of the INS and GNSS receiver data. Since INS GUI version 2.0.48.317, it is possible to include also TIMEDWHEELDATA logs with raw encoder data. See section "12.5. Embedding Raw IMU and Odometer Data into GNSS Stream" for details.

**Note:** For INS-D, if the user would like to use an *.hmr file in post-processing, it is necessary to use the "Combine RAWIMUB and GPS data" converter. The *.hmr file will be created automatically from the *.gps file when the GNSS converter in NovAtel Inertial Explorer is used. The *.hmr file includes heading calculated by dual-antenna GNSS receiver inside the INS-D unit.

# 10. The INS Operation

## 10.1. The Main Operation Modes of the INS

Step 1.

Connect the data transfer cable to the INS. Connect the other end of the data transfer cable to either the COM-port or the USB-port of the host computer. If connection between the computer and the INS is done through a USB-port, a driver for a COM-to-USB converter must 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, there is no need to install any drivers. Note that the INS manufacturer guarantees reliable operation of the INS if it is connected directly to the COM-port.

Connect an active GNSS antenna to the INS TNC connector.

After power on, the INS LED indicator lights yellow. After completing initialization of the onboard GNSS receiver (about 25 sec), the LED indicator lights red and the INS is ready for operation.

Step 2.

Start the INS_GUI.exe file to begin working with the GUI software. The main menu will appear (Fig. 3.1).

Step 3.

Select **"Test options"** from the **"Options"** menu (see Fig. 3.7) or click the icon. The "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)

If necessary, in the **"Test options"** window (Fig. 4.1), 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:** To find the number of the COM-port to which the INS is connected, see section "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 the **"Test options"** window (Fig. 4.1), set (by checkbox) data output mode in the "**Operating Mode**" group as well as **"Output Data Format"** (see Appendix C for more information on the output data format). Click "**OK**".

Step 7. (Not obligatory)

If user wishes to change some parameters of the INS or its operation, select "**Devices options**" or "**Swaying compensation options**" from the **"Options"** menu (see Fig. 3.7). The appropriate window (Fig. 4.19 or Fig. 4.21) will open. Set the necessary INS operation parameters. Click "**OK**".

Step 8.

Select "**INS Visualization**" from the "**Run**" menu (Fig. 3.3), click the icon on the toolbar, or press **F4**. The window shown in Fig. 5.1 will appear. You can switch to another visualization style by clicking on its preview on the tab. Depending on the selected style, the windows shown in Fig. 5.3 – Fig. 5.5 will appear.

Step 9.

Click the "**Start**" icon. First, initial alignment of the INS will begin. This is signified by the message "Initial alignment. Please wait". In addition, a progress bar of initial alignment will appear in the status line of the main window. During the initial alignment, the INS must be unmovable relative to the Earth. Once the initial alignment time is over, the user must observe changes in numeric data and graphical evolutions of the object.

**Note:** For visual convenience of INS position perception displayed on the monitor and the INS real position, it is recommended to place the INS 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 previously selected the "On Request" operating mode, click the "**Request**" icon to get data from the INS each time necessary. Observe changes in numeric data and graphical evolutions of the object.

Step 11.

To save data, click the "**Write**" icon. The caption "Data are writing in file!" will appear. A progress bar of data writing and timer will appear in the status line of the main window.

In "On Request" operating mode data are written in the file sequentially with each click of the "**Request**" icon.

**Note:** To allow data saving, the appropriate checkbox should be set in the **"Test Options"** window (see Fig. 4.1).

Step 12.

To stop readout and data display click the "**Stop**" icon. If the data were written in a file, then the writing will also stop.

The default directory for saved files is a "data" subdirectory placed in the directory where file INS_GUI_*.exe is located. The default name of file with saved data is generated automatically and consists of the INS 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 the 2 digits of day; and the next digits are hours, minutes, and seconds of operation start). Where the data were saved, two files of the same name with *.bin and *.prm extensions are also saved in the specified folder. In *.bin files, the measured data is saved, while in *.prm files, the INS 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 INS s/n A1240013 on 2012, November 20th, 2012, at 12:14:26.

**Note:** You can preset the name of file for data writing. To do so, select item **"Save as"** in the "File" menu and enter the desired file name.

Step 13.

Repeat Step 9 – Step 12 as many times as needed.

Step 14.

To close the standard operation mode window (Fig. 5.1 – Fig. 5.5), *click* the icon in the title of the current tab.

Step 15.

Select **"Stop INS"** (Fig. 3.3) from the **"Run"** menu, or click the icon.

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

Step 16.

Select **"Report of experiment"** from the **"Convert"** menu (Fig. 3.6), press **F8** in the main menu, or click the icon (Fig. 3.1). A standard Windows "Open" window will appear.

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 the format set in Step 6.

**Note:** When large file data is processed, sometime is necessary for text file saving. If you begin new operations with GUI software before the end of text file saving, then the GUI software will appear as not responding or locked. Simply wait for saving, after which the GUI software will be unlocked.

Additionally, the user can plot saved INS binary data using the **"File"** menu. See section 6.1 for more details.

## 10.2. Control of the GNSS Receiver

The Inertial Labs™ INS has an onboard high-grade Global Navigation Satellite System (GNSS) receiver, which provides highly accurate position using the following GNSS systems:

- GPS L1, L2, L2C
- GLONASS L1, L2
- Galileo E1
- BeiDou B1
- Compass3
- SBAS
- TerraStar
- Oceanix
- QZSS

The base model of the onboard receiver is G1S00G0T0 and has the following possibilities: GPS L1 code position; DGPS; SBAS; measurement data rate 20 Hz; and no raw data output. See section "10.2.2. Control of GNSS Receiver Model" for description of the procedure to change the receiver model to get more features from the GNSS receiver.

See sections "13.1. Control of PPS Output Signal" and "13.2. Processing of Mark Input Signal" for adjustment of synchro output and input signals for the GNSS receiver.

### 10.2.1. GNSS Corrections

The Inertial Labs™ INS has four COM ports. COM3 port can be used to receive data for differential corrections of GNSS.

GNSS corrections are used to improve position accuracy of the INS. There are three types of GNSS corrections: correction data from Satellite Based Augmentation Systems (SBAS); Differential GPS (DGPS) correction data transmitted from a base station; and PPP correction, which uses a global network of multi-GNSS reference stations. To set and use GNSS correction, open the **"GNSS receiver"** tab in the **"Devices options"** menu (Fig. 4.4), and follow these steps:

Step 1.

Set the type of GNSS correction by choosing one of the radio buttons in the "GNSS correction" field (see Fig. 4.4):

- No correction – no GNSS corrections are used.
- AUTO – the GNSS receiver uses the best available source of corrections: RTK, DGPS, PPP, or SBAS.
- SBAS – correction data from SBAS are used.
- PPP – correction uses a global network of multi-GNSS reference stations (TerraStar or Oceanix).
- DGPS – DGPS correction data transmitted from a base station are used.

**Important notes:**

1. If a COM3 port is used for output of GPRMC messages (if any other variant than "No" is set in "GPRMC" field in Fig. 4.4), then only SBAS and PPP corrections can be used, and all other variants are disabled.
2. PPP correction (TerraStar or Oceanix) is not supported for INS-DL and INS-DU model.

Step 2.

If "AUTO" or "SBAS" correction type is chosen, then the user can choose a variant of SBAS correction in the drop-down list (see Fig. 10.1 and Table 10.1). Default value is "Auto SBAS".

**Table 10.1. Available variants of SBAS data**

| Variant | Description |
|---|---|
| Disabled | Does not allow use of SBAS corrections |
| Auto SBAS | Automatically determines satellite system to use and prevents the receiver from using satellites outside of the service area (recommended) |
| Any SBAS | Uses any and all SBAS satellites found |
| WAAS | Uses only WAAS satellites |
| EGNOS | Uses only EGNOS satellites |
| MSAS | Uses only MSAS satellites |
| GAGAN | Uses only GAGAN satellites |
| QZSS | Uses only QZSS SAIF signals |

Step 3.

When "AUTO" or "PPP" correction is chosen, the user can choose a variant of PPP correction in the drop-down list (see Fig. 10.2). Default value is "TerraStar auto".

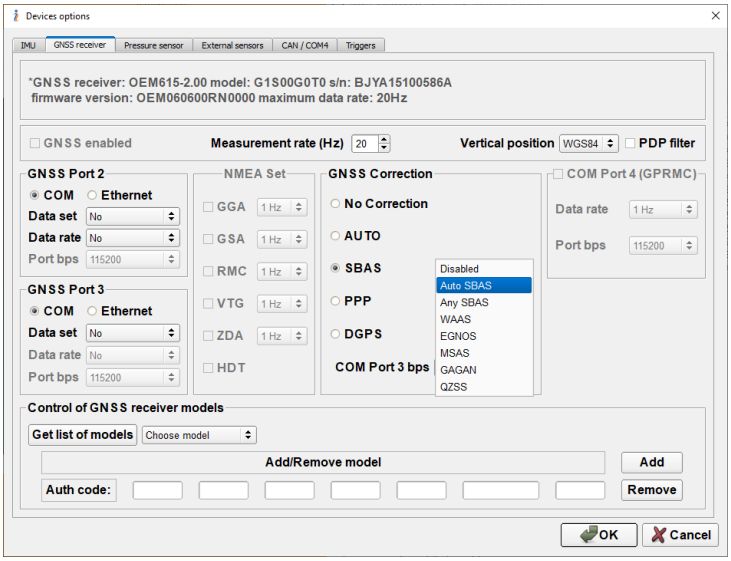



**Fig. 10.1.**

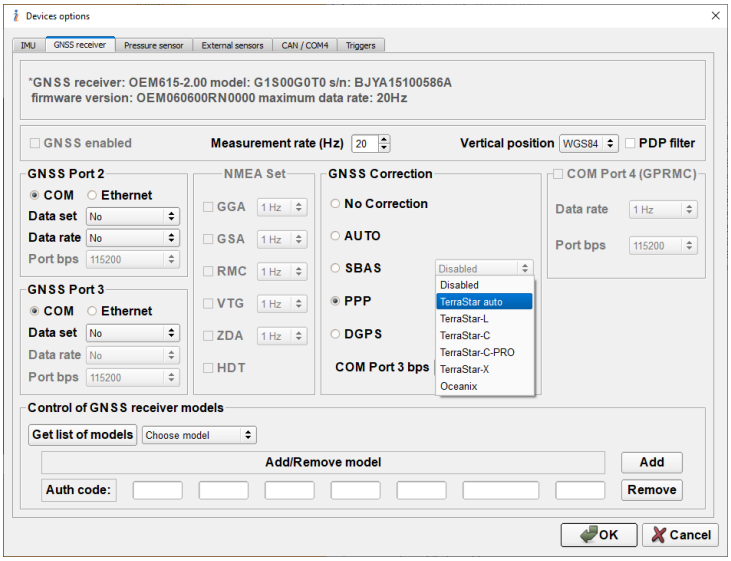



**Fig. 10.2.**

Step 4.

When “AUTO” or “DGPS” correction is chosen, the user can choose a variant of DGPS correction in the drop-down list (see Fig. 10.3):

- AUTO – auto-detection of correction format.
- RTCMv3 – accepting of corrections in RTCM version 3 format.
- RTCMv2 – accepting of corrections in RTCM version 2 format.

Default value is “Auto”. To receive the observation data of a remote base station at the INS and to get RTK solution, the user can choose the STRSVR tool (see “Appendix G. Use of the STRSVR tool” for details).

Step 5.

When “AUTO” or “DGPS” correction is chosen, it is necessary to set the correct baud rate of the COM-port 3, which receives DGPS corrections in the “COM-port 3 bps” field. The user can choose needed COM-port baud rate in the drop-down list (see Fig. 10.4). Default value is “115200”.

Step 6.

Click “OK” to send changed settings to the INS.

**Important note:** It is necessary to power the INS off / on after changing any parameters in GNSS Correction field, in order to restart the GNSS receiver with new settings.

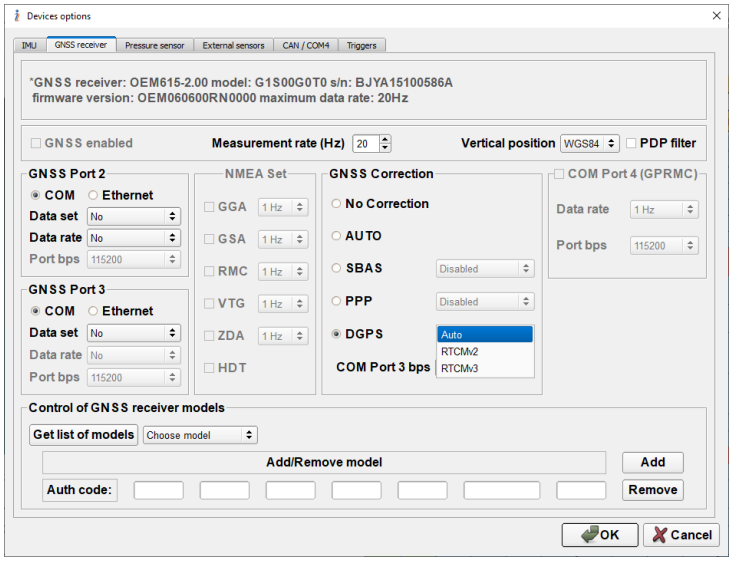



Fig. 10.3.

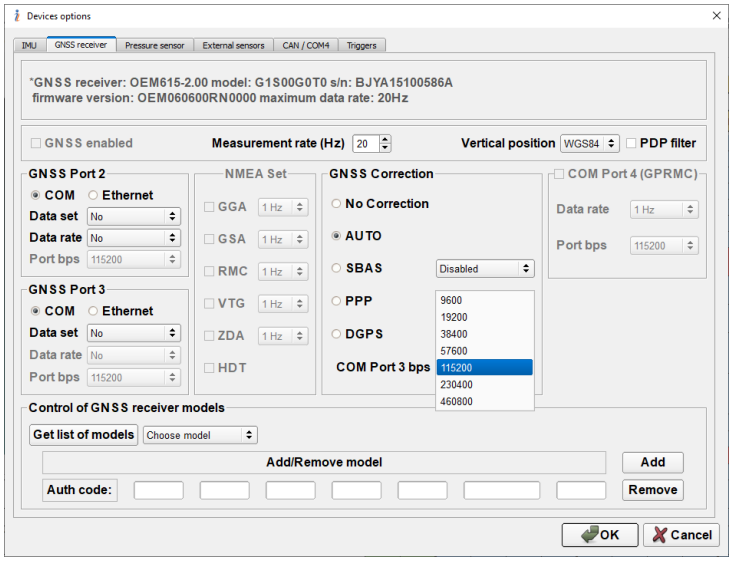



Fig. 10.4.

## 10.2.2. Control of GNSS Receiver Model

The Inertial Labs™ INS contains an internal NovAtel GNSS receiver. NovAtel uses the term “models” to refer to and control different levels of functionality in the GNSS receiver firmware. For example, a user can purchase an INS with the base model of the GNSS receiver that has an L1-only capability. At a later time, the user can easily upgrade this receiver to a more feature-intensive model, like L1 / L2 dual-frequency. All that is needed to upgrade is an authorization code for the higher model and the INS GUI to enter this code into the receiver. To upgrade the model, it is not necessary to reload the INS or GNSS receiver firmware or return the INS for service.

See http://www.novatel.com/assets/Documents/Papers/NovAtelModels.pdf for information about available models for the OEM615 NovAtel GNSS receiver.

### 10.2.2.1. Adding New Model to the GNSS Receiver

To get the authorization code for a new model of the GNSS receiver, it is necessary to send to NovAtel the following information about the GNSS receiver installed in the INS:

- • the receiver model number
- • the receiver serial number
- • the receiver firmware version

Run **"Device Information"** in the "Run" menu. The window shown in Fig. 5.9 will appear. Necessary information will appear in the third row in the following format:

***GNSS receiver: OEM615-2.00 model: G1S00G0T0 s/n: BJYA15100581E firmware version: OEM060600RN0000**

Copy this string and send this information to NovAtel when inquiring about the authorization code for a new model of the GNSS receiver.

NovAtel will send you an authorization code similar to the following, with seven or six text values separated by commas:

**Auth Code: 7H3WT,T6FFCZ,H93N6R,4B5F9P,6XD9MT,G2SB0GTT0,151010**
or
**Auth Code: H7H3WT,T6FFCZ,H93N6R,4B5F9P,6XD9MT,G2SB0GTT0**

The final field is expiry date; it is present if your authorization code is for a limited-time use.

Next, go to the "GNSS receiver" tab of the "Devices options" menu (see Fig. 4.5). Enter these six or seven text values in the **"Auth code:"** fields. (Leave the last field empty if your authorization code contains only six values.) Then click the "Add" button. The receiver will restart after adding the authorization code. Note that the INS must be restarted as well. Therefore, after adding the authorization code, please wait 5 – 10 seconds and power off / on the INS.

### 10.2.2.2. Choosing One of Saved Models for the GNSS Receiver

To perform this feature, click on **"Get list of models"** in the **"GNSS receiver"** tab of the **"Devices options"** window (see Fig. 4.4). A window with the message "GNSS receiver models have been read successfully!" will appear. Click "OK", and then switch the receiver between previously added models as needed.

To do so, click on the "Choose model" button. You will see the list of available models (see Fig. 10.5). Choose one of these models or click "Cancel".

**Note:** The model currently in use appears at the top of the "GNSS receiver" tab of the "Devices options" window (see Fig. 4.4).

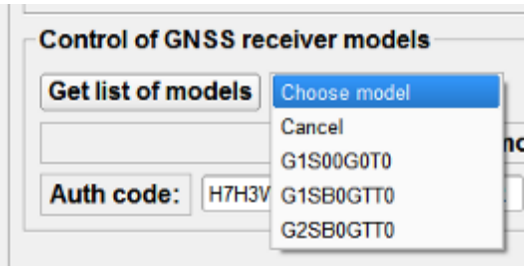



**Fig. 10.5.**

If you chose one of the models in the list of available models, the GNSS receiver restarts. Please wait about 5 – 10 seconds and power off / on the INS to restart it as well.

Go to the "GNSS receiver" tab of the "Devices options" menu item to ensure the change of receiver model. Also, in the field "Set measurement rate (Hz)", set the maximum rate of the GNSS data update supported by the chosen model of the GNSS receiver.

Or click on "Device Information" in the "Run" menu to simply ensure the change of receiver model.

**Notes:**

1. If you changed the GNSS data rate and clicked "OK", you must to power off / on the INS unit to restart the INS,
2. The INS unit controls the entered rate of the GNSS data and does not allow it to be set larger than supported by the current GNSS receiver model.

#### 10.2.2.3. Removing Model from the GNSS Receiver

To remove a model from the GNSS receiver, go to the "GNSS receiver" tab of the "Devices options" menu (see Fig. 4.5). Enter the full authorization code of the model that is removing to the first six (or seven) fields of the "Auth code", and then click the "Remove" button.

After a model is removed, the GNSS receiver restarts. Please wait about 5 – 10 seconds and then power off / on the INS to also restart the INS.

### 10.2.3. Accelerated Start of the NovAtel GNSS Receiver with TerraStar or Oceanix Service at Known Position

When the antenna does not move between power-down and power-up, accurate position seeding can accelerate Precise Point Positioning (PPP) convergence. For this purpose, the **PPPSEED** command controls the seeding of the PPP filter in the NovAtel GNSS receiver when TerraStar or Oceanix licensed based corrections are available.

This ability is implemented in INS firmware since version 3.4.0.1 and it is supported by the INS GUI since version 2.0.49.336 from 2019-07-17.

The following icons on the "INS visualization" tab are available for sending PPPSEED commands to the INS unit in idle or in operation mode (see Fig. 10.6):

**PPPSEED_STORE** – stores the current PPP position in nonvolatile memory for use as a future seed.

**PPPSEED_RESTORE** – retrieves and applies a seed position that was previously saved in nonvolatile memory via the PPPSEED_STORE command.

**PPPSEED_CLEAR** – resets the stored seed.

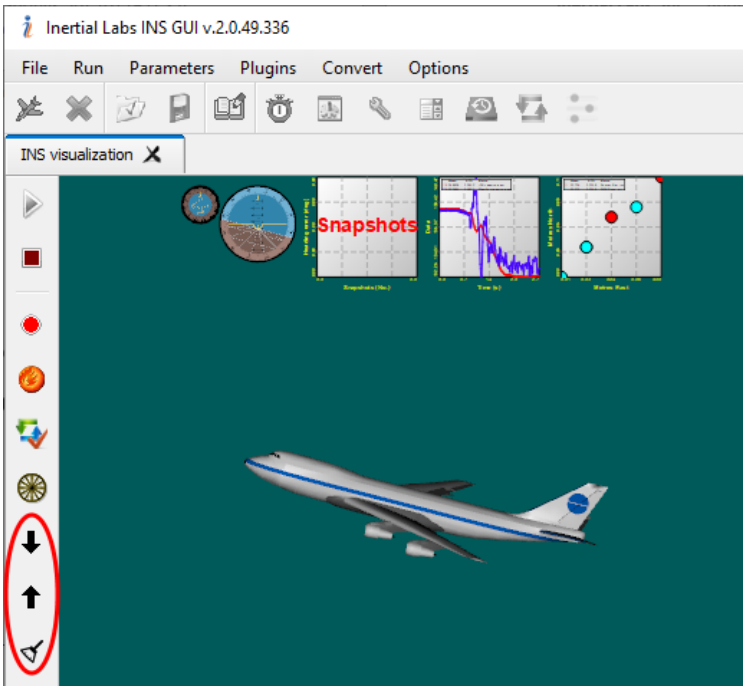



**Fig. 10.6.**

## 10.3. Features of Altitude Calculation in the INS

When operating, the Inertial Labs™ INS calculates position using its sensors data with correction from the onboard GNSS receiver. Also, for altitude calculation, the INS can use correction from the onboard pressure sensor.

In practice the GNSS altitude data are much less accurate than those of the horizontal position (because of high vertical dilution of precision). Using a static pressure sensor (barometer) as an aiding sensor for the altitude increases the vertical accuracy. Though the relation between altitude and pressure is dependent on many factors, the most important is the weather.

The Inertial Labs™ INS allows three variants of the altitude correction that depends on the Baro_altimeter switch (see Fig. 4.11):

1. Correction by altitude and vertical velocity provided by GNSS data (Baro_altimeter = 0).
2. Correction by barometric altitude calculated using pressure sensor data and vertical velocity provided by GNSS data (Baro_altimeter = 1 – primary altitude sensor).

3. Altitude correction is provided by GNSS data if they are valid; otherwise, they use barometric altitude calculated using pressure sensor data (Baro_altimeter = 2 – secondary altitude sensor).

**Important note:** To measure barometric altitude, the pressure sensor in the INS must have access to the ambient external pressure. Additionally, the pressure sensor must not be exposed to high-speed air streams. So if the INS is installed inside a pressurized cabin or outside the high-speed object, please disable the "Baro-altimeter" (see Fig. 4.11) to allow the GNSS altitude for INS correction.

Since firmware version 3.4.6.8 INS can significantly increase accuracy of barometric altitude calculation if "Ambient Air Data" package is received (see section 4.2.4.2 and INS ICD, section "6.6.4. Aiding Data Input Through the Main COM-Port" for details). If true value of ambient temperature is set in this aiding data package, then temperature correction of the scale factor of barometric altitude dependence from measured pressure is applied. If true altitude and ambient pressure are set in "Ambient Air Data" package, then pressure at sea level is re-calculated to increase barometric altitude calculation. If only ambient temperature is known, then leave zero values for altitude and pressure in "Ambient Air Data" fields, in such case INS will use these values calculated on-board.

Note that in all variants of the INS altitude correction, the initial altitude is equal to altitude provided by the GNSS receiver if it has solution. If GNSS data are not available, then the initial altitude is equal to its value stored in the INS nonvolatile memory. Initial altitude can be changed in the "IMU" tab of the "Devices options" window (see Fig. 4.2).

The INS can output altitude above mean sea level (MSL) or above WGS84 ellipsoid. This choice is implemented in INS firmware since version 2.8.3.6 and it is supported by the INS GUI since version 2.0.39.184. (See Fig. 4.4, the "Vertical position" drop-down list.)

## 10.4. Calibration of the INS Magnetometers

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

The Inertial Labs™ INS 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 INS magnetometers is provided. This calibration does not

necessitate any additional equipment, but it does require turns of the carrier object on which the INS is mounted.

**Note:** The INS does not require calibration of its magnetometers on hard / soft iron if the "Use_mags" switch is disabled in the "Settings" tab of the "Correction options" window (Fig. 4.25).

The INS can be calibrated using **2D, 3D, VG3D, or 2D-2T** calibration procedure. On-the-fly VG3D calibration (see section 10.4.4) and automatic calibration (see section 10.4.5) are also provided.

- **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 horizontal plane of the carrier object with the installed INS (see Fig. 10.7). 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 horizontal plane (the Z-axis is up) with periodical stops about each 90 degrees for tilting in pitch and roll (see Fig. 10.7 – Fig. 10.9). After full 360° rotation, the object with the INS 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 great as possible.
- **VG3D calibration** is designed for carrier objects that can operate in full heading, pitch, and roll ranges. VG3D calibration is similar to 3D calibration but allows performing simpler rotation than is necessary for 3D calibration.
- **2D-2T calibration** is designed instead of 3D calibration for a 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 (maximum possible) pitch angles. During every 2D calibration run with a set pitch angle, tilt angles must be as constant as possible. In the calibration, the only INS readings used are those in which pitch and roll differ from their median not more than the inclination threshold set in appropriate field (Fig. 4.3).

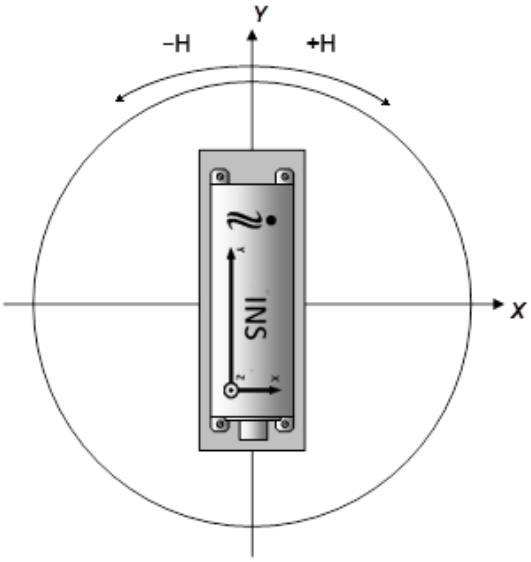



**Fig. 10.7. Rotation of a carrier object with INS in horizontal plane**

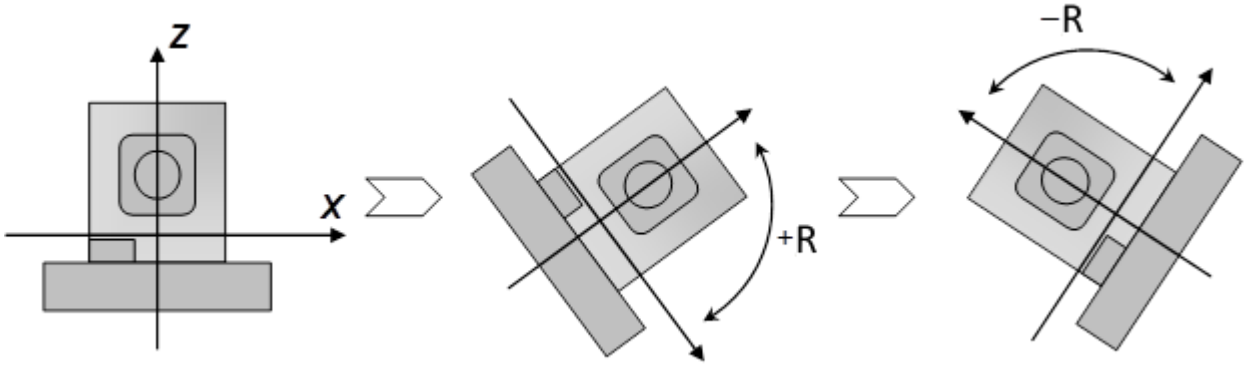



**Fig. 10.8. Rotation of a carrier with INS in roll (R)**

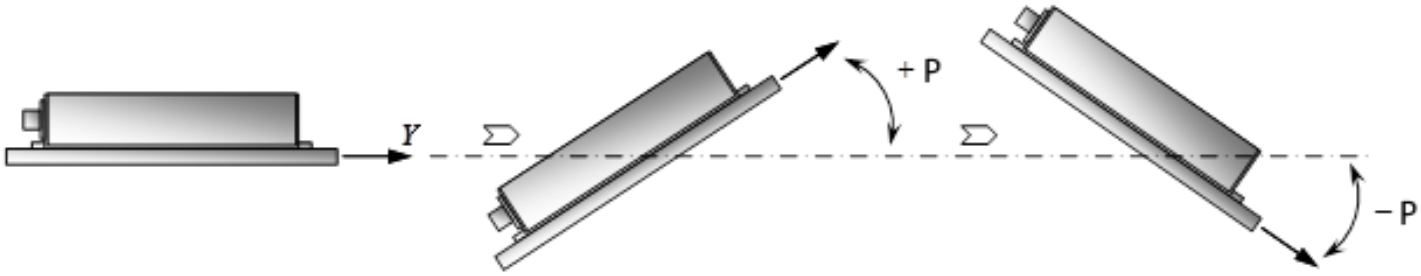



**Fig. 10.9. Rotation of a carrier with INS in pitch (P)**

Note that rotation of the carrier object with the INS both for all calibration procedures <u>must include one or more full 360° turn</u> in the horizontal plane.

**Field calibration procedures are developed by Inertial Labs™ after the type of object on which the Inertial Labs™ INS will be installed is agreed on with a customer.**

### 10.4.1. Description of the 2D, 2D-2T, 3D, and VG3D Calibration Procedures

Step 1.

Perform Step 1 from section 10.1.

Step 2.

Perform Step 2 from section 10.1.

Step 3.

Set correct coordinates **"Latitude"**, **"Longitude"**, **"Altitude"**, and **"Date"** in accordance with the location in which the INS is calibrated. Their values are set in the **"Devices Options"** window (see Fig. 4.19).

Step 4.

Select the "**Mag Field Calibration**" item from the "**Plugins**" menu (Fig. 3.4). The "Mag Field Calibration" window (Fig. 8.3) will open.

Step 5.

Select **"2D"**, **"2D-2T"**, **"3D"**, or **"VG3D"** calibration from the drop-down list in **"Calibration Type"**.

Step 6.

In the "**Accumulation time"** window, use arrows or enter the necessary value from a keyboard to set the time required for accumulating data that would be sufficient to accomplish the calibration procedure. Please set enough time for 1 – 3 full 360° turns of the carrier object in the horizontal plane (usually 60 seconds for 2D calibration and 120 sec for 3D calibration are enough).

Step 7.

Click the "**Start**" button. In the **"Calibration status"** window, a few captions are highlighted (see Fig. 10.10):

- **IS_STARTED** – reports that calibration procedure is started.
- **NEXT_REQUESTED** – asks to click the "**Next**" button to start the calibration run.
- **STOP_REQUESTED** – (if highlighted) informs user that it is possible to click "**Stop**" button to stop calibration run.
- **EXIT_REQUESTED** – informs user to click the "**Exit**" button to exit from the calibration procedure.

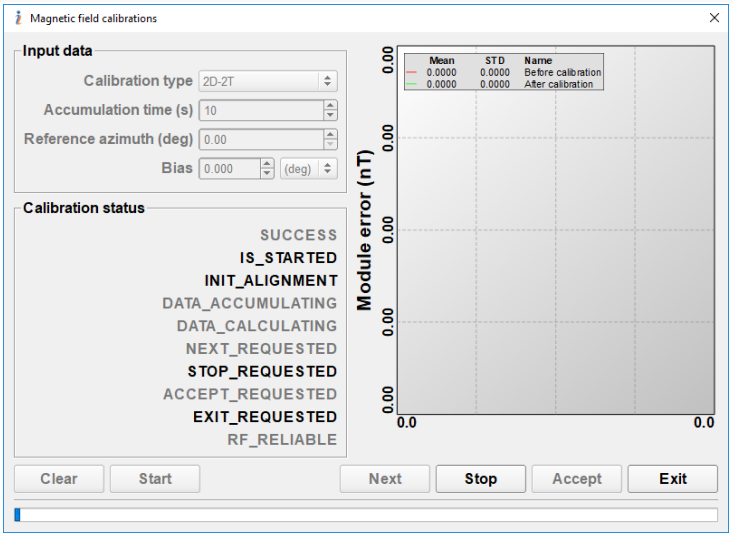



**Fig. 10.10.**

Step 8.

Press the **"Next"** button. Initial alignment of the INS will start, signified by the highlighted caption **INIT_ALIGMENT** (see Fig. 10.11). During the initial alignment, the INS should be unmovable relative to the Earth.

Once the initial alignment is completed, the INS starts accumulating data. This is signified by the highlighted caption **DATA_ACCUMULATING** and the progress bar of data accumulation in the status line (see Fig. 10.12). At this time, the carrier object with the INS should be rotated.

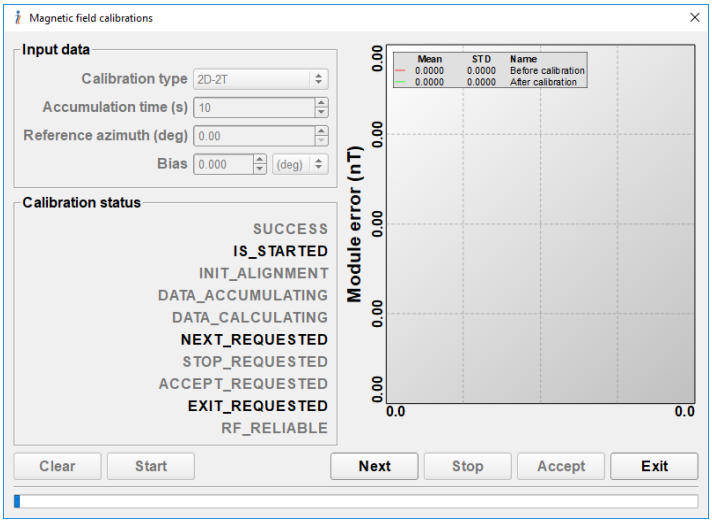



**Fig. 10.11.**

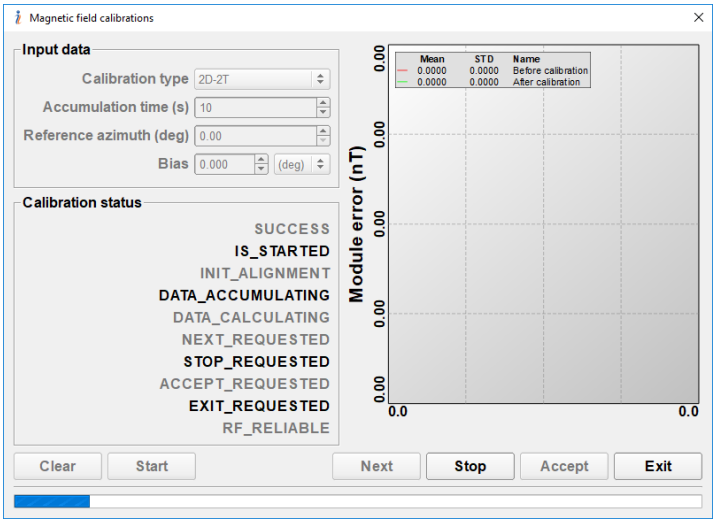



**Fig. 10.12.**

If **2D calibration** is chosen, the object with the INS in the horizontal plane should be rotated (see Fig. 10.7). After the time of the data accumulation expires, a result window will appear (see Fig. 10.13).

For **3D calibration,** the carrier object is rotated in the horizontal plane (the Z-axis is up) with periodical stops at about each 90 degrees for tilting in pitch and roll (see Fig. 10.7 – Fig. 10.9); the carrier with the INS is then 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 a better result, the user should increase the angles range as much as possible.

**Note:** The INS GUI software provides estimation of 3D calibration quality in terms of possible INS heading accuracy. To allow this possibility, it is necessary to include additional rotation of the INS with the carrier object in the horizontal plane of 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 "Magnetometers calibration options" window (Fig. 4.30).

For **VG3D calibration** the carrier object should be rotated in full azimuth range with maximum possible pitch and roll ranges. Allowable object motion should be agreed upon with Inertial Labs™.

After the data accumulation time expires, a result window will appear (see Fig. 10.13).

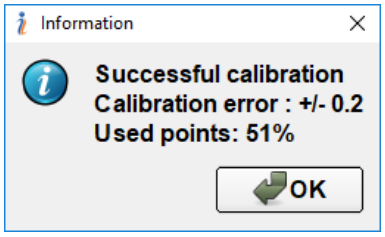



**Fig. 10.13.**

The result window Fig. 10.13 shows the following included information:

- Success of the calibration.
- Calibration error is the predicted maximum (3 sigma) heading error of the INS at accepting the calibration.
- Used points is the percent of accumulated data used at calculations.

Click **"OK"** to close the information message.

The **2D-2T calibration** consists of several runs. Set the object with the INS to specific pitch angle (for example, to the minimum pitch angle). Rotate the object in azimuth with approximately constant pitch and roll. After time of the first run of the INS rotation is reached, a result window will appear (see Fig. 10.14). Based on the calibration accuracy, it is necessary to accept or decline this run. Then it is necessary to set the INS to the next pitch angle and repeat the calibration procedure as the next run.

**Note:** To achieve an acceptable calibration result, it is recommended to change the Pitch angle in every run on maximum possible value (at least on 15 degrees).

Quality of the **3D** and **VG3D** calibration will be estimated in terms “Excellent calibration!”, “Good calibration”, or “Acceptable calibration” (see Fig. 10.15) instead of predicted INS heading error. For 3D calibration, it is true if the 3D run did not include additional rotation of the INS in the horizontal plane on about 360 degrees or more with pitch and roll near the level (see above Note).

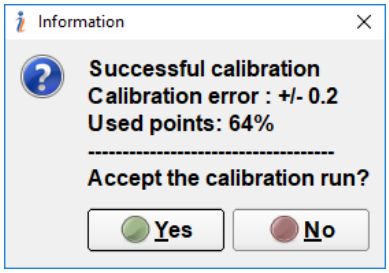



**Fig. 10.14.**

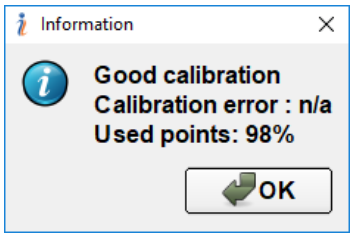



**Fig. 10.15.**

If the INS detected unsuccessful initial alignment or other mistakes in INS operation, then an error such as “Non-zero USW was detected 0000000000000001” appears (Fig. 10.16). (For the meaning of other non-zero bits of USW, see “Appendix D. The Unit Status Word Definition”). In instances of non-zero USW, the calibration run <u>should be not accepted</u>.

If the calibration quality is acceptable, the status **ACCEPT_REQUESTED** is highlighted (see Fig. 10.17).

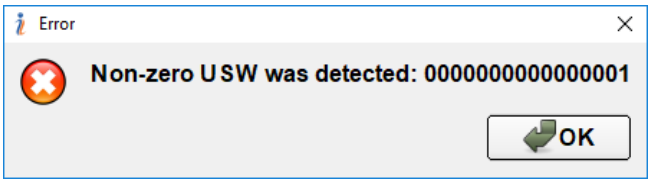



**Fig. 10.16.**

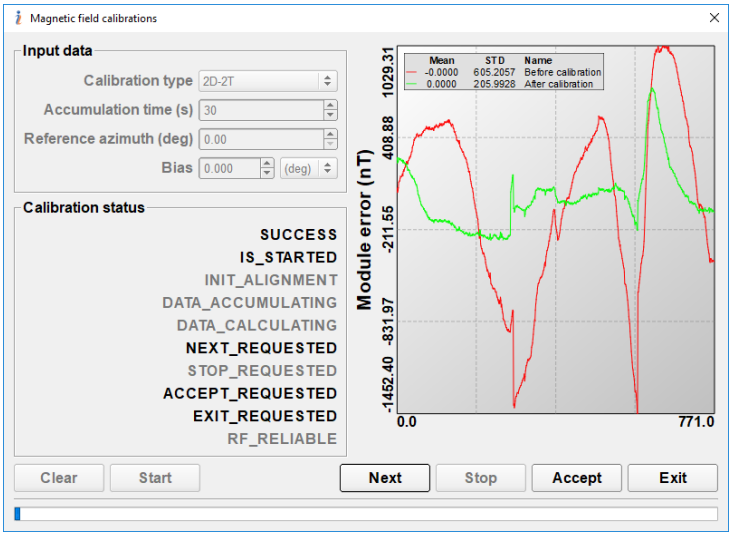



**Fig. 10.17.**

If the INS detected unsuccessful initial alignment or other mistakes in INS operation, then repeat Step 8, above.

For the next run of the **2D-2T calibration**, the object with the INS should be turned to the next pitch angle. Click the "Next" button (see window in Fig. 10.17) and repeat the 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 INS in the horizontal plane for 2D, 2D-2T, and 3D calibration must include one or more full 360° turns. Correct the time required for saving data in the "**Accumulation time"** window to allow for the number of necessary rotations.

Step 9.

Once the 2D, 3D, or VG3D calibration data accumulation time is over or the 2D-2T calibration is stopped after any stage, then the window in Fig. 10.17 appears, in which graphs of errors before and after calibration are shown. Plotted graphs are scalable. To zoom in, click and hold the left mouse button drag down-right direction. Click and hold the right mouse button to shift plot. To zoom out, click and hold the left mouse button and drag in up-left direction. The legend is located at the upper left corner of the tab. This legend shows mean value, STD, and the name of displayed graphs. It is possible to select the graphs you want to display by right-clicking 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 if the caption "Excellent calibration!" or "Good calibration" appears in the window (Fig. 10.15), then click the **"Accept"** button (Fig. 10.17) to accept calibration parameters. An "Acceptable calibration" caption is satisfactory as well, but we recommend recalibrating the INS.

There are two highlighted captions:

- **ACCEPT_REQUESTED** –user canclick **"Accept"** button to accept calibration parameters.
- **EXIT_REQUESTED** – user can click **"Exit"** button to exit from the calibration procedure without saving calibration parameters.

If user clicks the **"Accept"** button, the calibration matrix of the magnetometer biases and scale factors will be calculated and saved to the INS nonvolatile memory automatically.

If calibration results were accepted, then files with *.prm, and *.amd extension will be created in the directory in which the INS_GUI.exe file is located.

**Notes:**

1. File name consists of the INS serial number, text _ MagField _, and 6 digits that indicate time when the file was saved (2 digits of hours, 2 digits of minutes, 2 digits of seconds). The final symbols in the file name corresponds to the type of performed calibration: _2D corresponds to data of 2D calibration; _3D for 3D calibration; _2D_2T for 2D_2T calibration; _VG3D for VG3D calibration. Two examples of file names are 106A0016_MagField_140838_2D.prm and 106A0016_MagField_140838_2D.amd.
2. The default directory for saved files is the "data" subdirectory placed in the directory where file INS_GUI_*.exe is located.

Step 11.

If the calibration is unsuccessful, then the window shown in Fig. 10.18 appears with the caption "Unsuccessful calibration. Try again!".

One cause of unsuccessful calibration may be a small range of angles of the INS real rotation. In this case, the caption "Calibration failure! Rotation of the device is required!" appears (see Fig. 10.19). To avoid this, please repeat the calibration procedure with rotation of the INS as described in the beginning of this section. Further reasons of unsuccessful calibration are discussed in the section "10.4.3.Conditions of Successful Calibration of the INS".

Step 12.

If you want to finish the calibration without accepting the calibration result, click the "**Exit**" button on the calibration window. Calculated calibration parameters will not be saved to the INS nonvolatile memory and no files are created with calibration results.

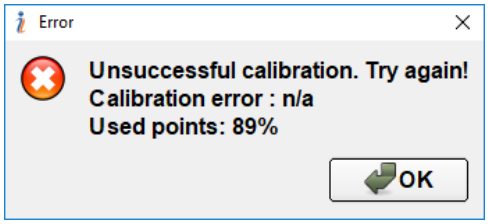



**Fig. 10.18.**

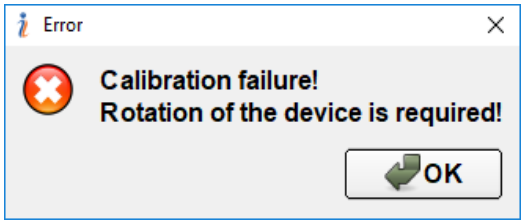



**Fig. 10.19.**

Step 13.

Click the icon to close the calibration window.

### 10.4.2. Clearing of the Soft and Hard Iron Calibration Parameters

To remove results of magnetometers field calibration from the INS memory, follow Steps 1 and 2 from section **10.1.** Then select "**Mag Field Calibration**" from the "**Plugins**" menu, and click the "**Clear**" button in the newly opened window (see Fig. 8.3). Soft and hard iron calibration parameters will be removed from the INS memory. A window with the message "**Magnetic field calibration parameters were cleared successfully!**" will appear (see Fig. 10.20). Click "OK" and close the information window.

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

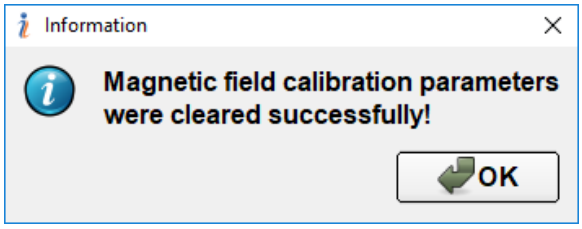



**Fig. 10.20.**

To avoid incorrect heading calculation, user must clear parameters of the soft and hard iron calibration if you uninstall the INS from the carrier object. Please remember that performed soft and hard iron calibration is valid until the INS is mounted on the object with which the calibration was performed.

After calibration is accepted, during operation with the INS in the "INS visualization" window (see Fig. 5.1) the message **"Soft/hard iron corrected"** (see Fig. 10.22) appears in the lower right part of this window. If calibration parameters are cleared in the INS, then "Soft/hard iron corrected" disappears.

### 10.4.3. Conditions of Successful Calibration of the INS

Success of the INS 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 achieved if the calibration is performed in a homogeneous magnetic environment in which the magnetic force lines are parallel to each other. In this case, only the influence of the carrier object on the INS magnetometers takes place, and this influence can be compensated after calibration procedure.

However, the magnetic environment often is not homogeneous at the location where calibration of the INS is performed. This may lead to degradation of the calibration results, because INS magnetometers are disturbed both by iron of the carrier object and by curved outward magnetic field. In such a case, it may be very difficult to separate influence of these two disturbance sources on the INS.

Inertial Labs™ engineers have developed a 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 the environmental magnetic field may still decrease calibration accuracy. After many experiments, Inertial Labs™ engineers have determined acceptable limits of non-uniformity of the environmental magnetic field at which the INS heading accuracy after calibration is satisfactory.

If the INS calibration procedure was performed in strict accordance with the procedure described in section 10.4 but the calibration is unsuccessful, then location of the calibration has a large distortion of the Earth uniform magnetic field. To repair this problem, please change location of the calibration. Bad choices for calibration location are often office rooms, laboratories with large quantities of computers and other electronics equipment, roads with underground communications or pipelines, areas near electric mains, etc.

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

Finally, please remember that if the carrier object is changed or if the location of the INS mounting on the carrier object is changed, then a new calibration should be performed. If the INS will be used alone without mounting on any object, calibration results should be cleared by clicking on the **"Clear"** button (see Fig. 8.3).

### 10.4.4. On-the-Fly VG3D Calibration

Since INS firmware version 2.6.2.2, it is possible to perform on-the-fly VG3D calibration. This calibration is good for airplanes including UAV. For successful calibration, the airplane should perform at least two full 360° coordinated turns (on the right and on the left) with maximum roll angles.

To start VG3D calibration during the operation of the INS, please click the icon on the "INS visualization" tab (see Fig. 10.21).

After pressing this icon, the carrier object with the INS unit should be rotated in full azimuth range and maximum possible pitch and roll ranges. For example, the airplane should perform at least two full 360° coordinated turns (on the right and on the left) with maximum roll angle. The INS accumulates data for the calibration, and the message **"OFC is started"** appears in the right bottom part of the window under the "Mode" header (OFC stands for On-the-Fly Calibration).

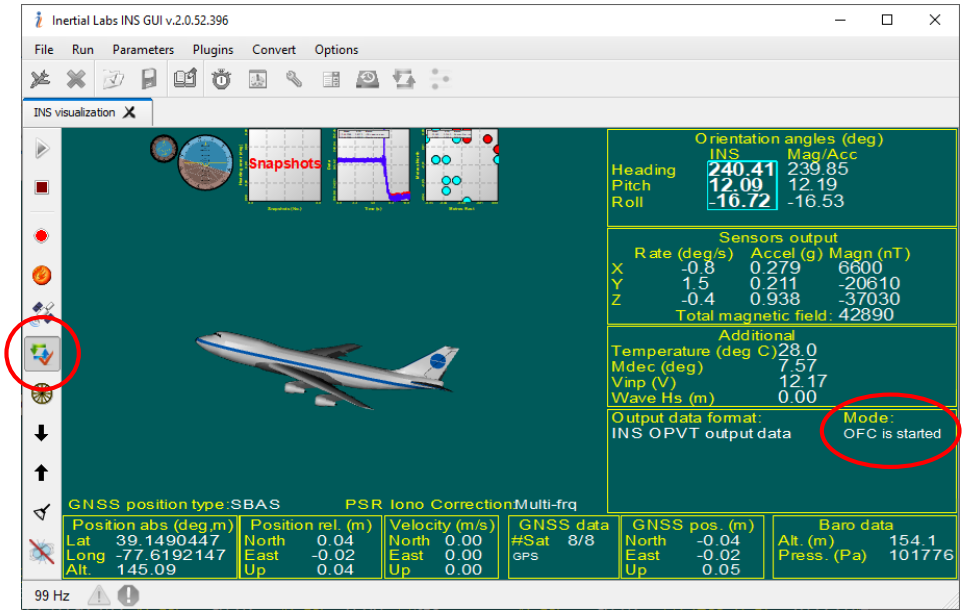



**Fig. 10.21.**

To stop calibration after completing the rotations, please click on the icon (see Fig. 10.22). The INS calculates soft and hard iron calibration parameters. If the calibration is successful, then the message **"OFC is done"** appears in the right bottom part of the window under the "Mode" header. Additionally, "**Soft/hard iron corrected**" appears in this part of window. Then the INS algorithm starts using the calculated parameters of the calibration for compensation of the carrier's soft and hard iron to calculate accurate heading.

If on-the-fly VG3D calibration was estimated as unsuccessful, then the messages "OFC is done" and "Soft/hard iron corrected" will not appear in the window (Fig. 10.22). The INS "Mode" returns to "READINESS" status.

During all data accumulation and performance of necessary calibrations, the INS unit continues its operation, calculates, and outputs the navigation data.

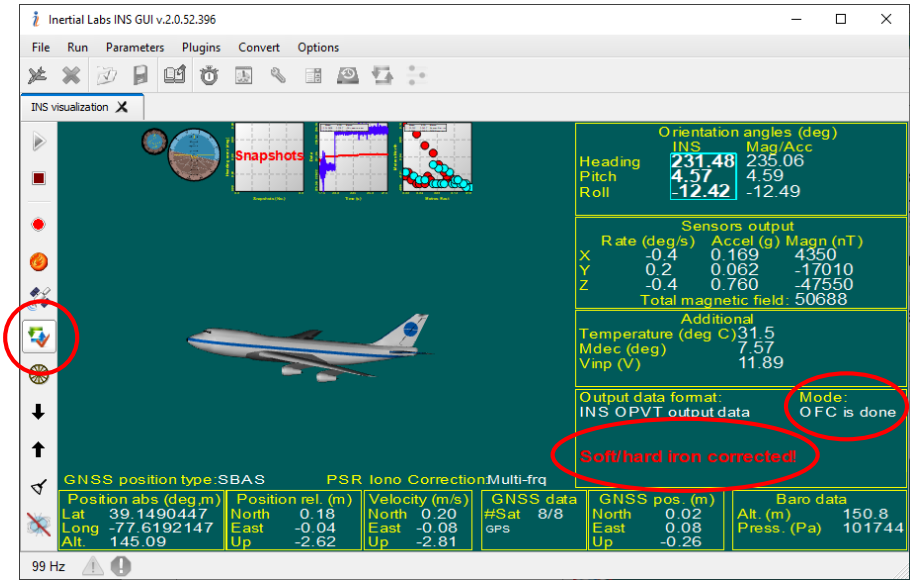



**Fig. 10.22.**

**Note:** After calculation, the parameters of on-the-fly VG3D calibration are used for compensation of the carrier's soft and hard iron, but they a not saved to the INS flash memory until the INS unit is stopped by clicking the "Stop" icon (see Fig. 10.21). If the INS unit is stopped by power off, then parameters of on-the-fly VG3D calibration cannot be stored to the INS flash memory. If this is the case, at the next run the INS unit should be calibrated again.

### 10.4.5. Automatic 2D and 3D Calibration

Since INS firmware version 3.4.3.0, it is possible to perform automatic 3D calibration of magnetometers during ordinary INS run. But it is necessary that the carrier object changes its heading, pitch, and / or roll enough during run. Additionally, since INS firmware version 3.4.3.3, it is possible to perform automatic 2D calibration of magnetometers.

Automatic 2D or 3D calibration is allowed only if magnetometers are not used for INS heading correction in the current INS run. So only the following variants of INS heading correction are acceptable for INS automatic calibration of magnetometers (see parameter Corr.type in section 4.3): GNSS track, Dual GNSS, and Inertial.

To allow automatic 2D or 3D calibration of magnetometers, go to **"Magnetometers calibration options"** from the "Options" menu (Fig. 3.7) or click the icon (Fig. 3.1) and choose the desired type of calibration from the "**Automatic calibration**" drop-down list (as seen in the dialog window in Fig. 10.23).

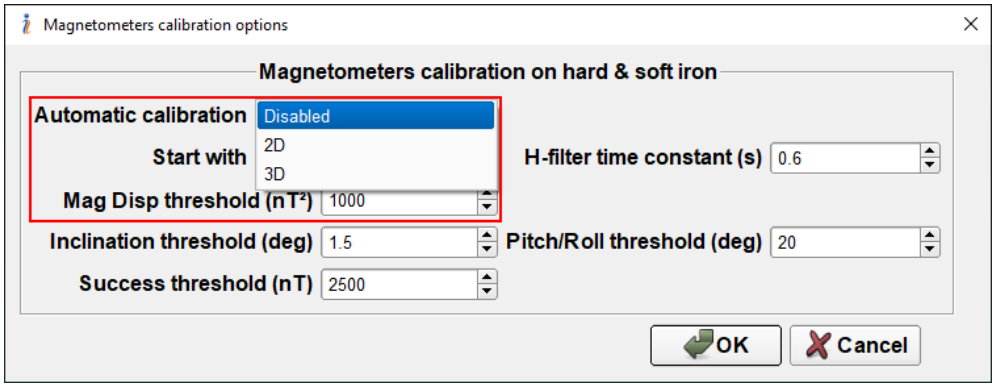



**Fig. 10.23.**

Note that automatic 3D calibration may be less accurate than on-the-fly VG3D calibration (see section 10.4.4) because a user can perform on-the-fly VG3D calibration (to start it and to stop it) when the user estimates a good magnetic environment and can perform maneuvers of the carrier object to get better results of on-the-fly VG3D calibration. In contrast to this, automatic calibration is being

performed during the entirety of the INS run; therefore, this calibration can be affected by magnetic disturbances.

Automatic calibration is in progress when GNSS data are available. Parameters of this calibration are applied immediately for compensation of the carrier's soft and hard iron in magnetometers data. At GNSS data lost, this compensation is continued using the last estimated parameters of calibration.

Automatic calibration can be stopped during an INS run by clicking on the **"Stop MagAutoClb"** icon (see Fig. 10.24). This makes sense when the remaining run of the INS unit is estimated to be in a poor magnetic environment (such as the landing of a UAV).

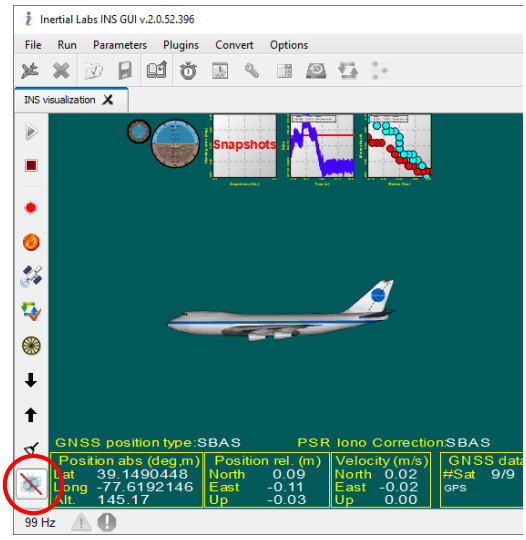



**Fig. 10.24.**

Parameters of automatic calibration of magnetometers will be saved to the INS flash memory after the INS unit is stopped by clicking the "**Stop**" icon (see Fig. 10.24). Note that if the INS unit is stopped by power off, then parameters of automatic calibration cannot be stored to the INS flash memory.

### 10.4.6. Choice of Set of INS Calibration Parameters

The INS has several procedures to perform different variants of magnetometers calibration on soft and hard iron of the carrier object. In its flash memory, the INS keeps four sets of calibration parameters for magnetometers. A user can choose one of them for the next INS operation by selecting the appropriate item from drop-down list **"Start with"** in the "**Magnetometers calibration options**" dialog box from the **"Options"** menu (see Fig. 10.25):

- **Last INS Clb** – parameters of the last calibration of magnetometers.
- **Factory Clb** – factory calibration parameters.
- **2D-2T, 3D, VG3D, 2D Clb** – parameters calculated after one of these calibrations.
- **Previous Auto Clb** – parameters calculated at the end of automatic calibration.

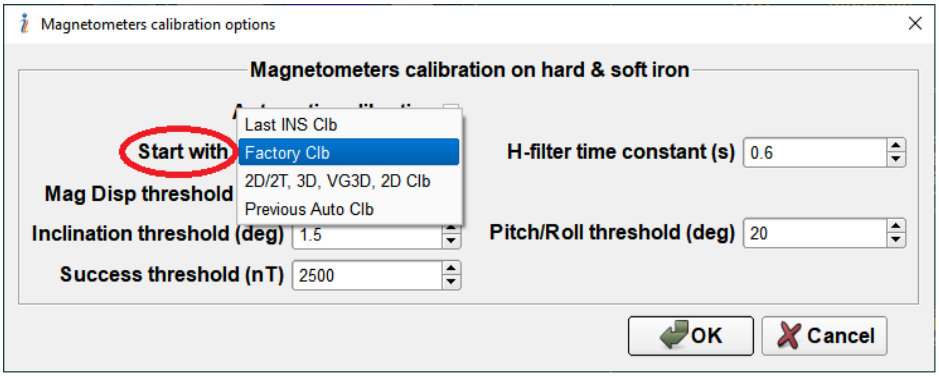



**Fig. 10.25.**

**Notes:**

1. The parameter "Start with" is set automatically to the appropriate value "2D-2T, 3D, VG3D, 2D Clb" or "Previous Auto Clb" after each performed calibration.
2. "Last INS Clb" is always a copy of parameters of the last performed calibration.
3. "Factory Clb" parameters correspond to cleared calibration of magnetometers on soft and hard. User can switch to "Factory Clb" set if wanting the INS to work with magnetometers without calibration on soft and hard iron, without needing to clear calibration parameters.
4. After cleaning of magnetometers calibration on soft and hard iron, parameters "Last INS Clb", "2D-2T, 3D, VG3D, 2D Clb", and "Previous Auto Clb" become cleared, and the parameter "Start with" is set to "Factory Clb".

## 10.5. Orientation Accuracy Test of the INS

To check INS accuracy, it is recommended to use "Inertial Labs™ INS GUI" software, which allows estimating accuracy of the INS in a given range of orientation angles. Simultaneously, it is necessary to use a special device allowing to set angular positions of the INS strong with respect to tested angles. The INS should be rotated only in the plane of one of its base surfaces.

The "Inertial Labs™ INS GUI" software allows two variants of the INS accuracy test:

- Angles accuracy – at which the INS restarts each time after it is set on a new reference angle.
- On-the-fly accuracy – when the INS 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, a separate data file is created for each tested INS position. "On-the-fly accuracy" is designed for continuous INS operation at its setting to different reference angles. This applies to magnetic interference tests, for example.

### 10.5.1. Separate Accuracy Test for Each Reference Angle

Step 1.

Carefully set the INS by two reference surfaces on platform of the test bench designed for accuracy check.

Steps 2 – 5.

Perform Steps 1 – 4 from section 10.1.

Step 6.

Select **"Angles Accuracy"** from the **"Plugins"** menu (Fig. 3.4). The accuracy check window will appear (Fig. 8.4). In the upper left corner of the drop-down window, choose orientation angle (heading, pitch, or roll) for the INS testing.

Step 7.

Click the **"Devices"** button. A "Devices Properties" window (Fig. 10.26) will appear.

Step 8.

Select the required amount of tested INS units in the "Number of Devices" field.

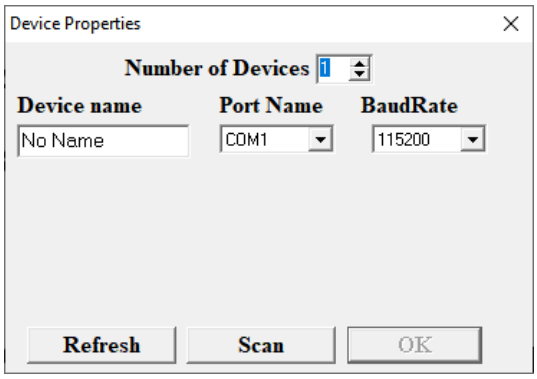



**Fig. 10.26.**

Step 9.

In the column "COM-port" appearing in the drop-down window "COMN", choose the COM-ports to which the INS units are connected. Click the "Scan" button. In the column "Device Name", INS units are determined in accordance with chosen COM ports. The "OK" button becomes active.

Step 10.

After the test, if all INS units are successfully determined, click the “OK” button. The “Devices Properties” window will close and any found connected INSs will appear in the accuracy check window instead of the label “NoName”.

Step 11.

If orientation angles of the INS indicated in the column “Angles…” correspond to angles with which testing will be carried out, then this step can be omitted. Otherwise, click the “Angles” button, and the “Accuracy Properties” window will appear (see Fig. 10.27). Next, the user sets the check of accuracy angles (“Accuracy checking points”), the necessary time of data collecting during the measurement in each position of the INS (“Accumulation Time”), and, if necessary, the temperature control (“Temperature Sensor”).

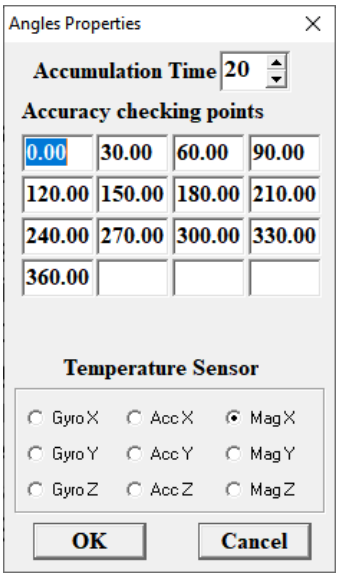



**Fig. 10.27.**

Step 12.

If angles of obliquity of the INS set on the test bench platform are known, input their values in the appropriate fields of the “Tilter” window.

Step 13.

With the help of a special setup device, set sequentially angular positions of the INS in accordance with the values indicated in the “Angles” column. Then click on “Accumulate Data” to start the INS. Check the window for the behavior of INS angle. After run time is complete, a window opens with averaged errors of the INS.

Step 14.

Repeat Step 13 for each reference angle indicated in the “Angles” column.

Step 15.

At the end of the accuracy test cycle, in all positions given in the column “Angles”, the “Angle Error, deg” tab opens automatically. The plot of given angle calculation error is displayed, and the minimum and maximum error values during the test

plus its root-mean-square value (RMS) are indicated. Additionally, standard deviation (STD) of measurement noise at the last position of the INS is displayed.

Step 16.

To close the accuracy check window (Fig. 8.4), click "×" in the upper right corner of the window. At this window a question about saving plot of error to a *.bmp file will appear.

For each run, the *.txt file is created with saved INS data in the "data" subdirectory. The file name consists of INS s/n; indication of which INS angle was tested (H = heading, P = pitch, R = roll); reference angle; reference temperature; and time of run. For example, file "106A0016_H(38.22)_T(+27)_1831.txt" corresponds to data saved from the INS s/n 106A0016 at Heading accuracy test for target angle 38.22° at 18:31.

Also the file of the report (such as Accuracy_2010991830.txt) is created, where numbers are year, month, day, hours, minutes of the performed test. The accuracy test has averaged data for each INS run. In the first column of this file there is INS s/n. The second column is number of reference angle starting from zero. And the sixth and seventh columns are averaged heading, pitch, and roll measured by the INS.

### 10.5.2. On-the-Fly Accuracy Test

Step 1.

Carefully set the INS by two reference surfaces on the platform of the test bench designated for the accuracy check.

Step 2 – Step 7.

Perform Step 1 – Step 6 from section 10.1.

Step 8.

Select **"INS visualization"** in the **"Run"** menu (Fig. 3.3), and then click on the **"**Snapshot**"** preview shown in Fig. 5.2c. The window shown in Fig. 5.4 will appear.

Step 9.

Click the "**Start**" icon. First, initial alignment of the INS will begin. This is signified by the message "Initial alignment. Please wait". A progress bar of initial alignment will also appear in the status line of the main window. During the initial

alignment the INS must be unmovable relatively to the Earth. After the initial alignment completes, see changes in numeric data of the INS.

Step 10. (Not obligatory)

To save INS data, click the "**Write**" icon. A progress bar of data writing and a timer will appear in the status line of the main window. Note that the accuracy test data are written to file *.csv independently on saving the INS main data.

Step 11.

When the INS is set in the necessary position and is ready to save data, click **"Snapshot"** . The window shown in Fig. 10.28 will appear.

Depending on known target orientation (its relative or absolute azimuth and pitch / elevation) select **"Heading"** and / or **"Pitch"** checkboxes (see Fig. 10.28). Enter values according to true reference angles. These angles can be set using the arrows or by entering the necessary value from a keyboard.

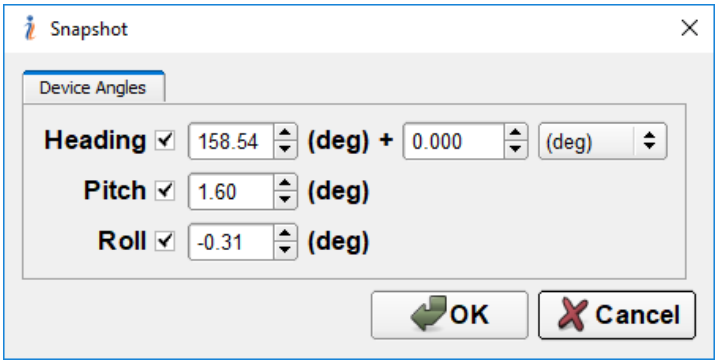



**Fig. 10.28.**

If no checkboxes are selected, then only current INS angles are saved. Next, press the **"OK"** button. A new tab, "Snapshots", shown in Fig. 10.29 will open. Return to the previous tab by clicking on its title "INS visualization".

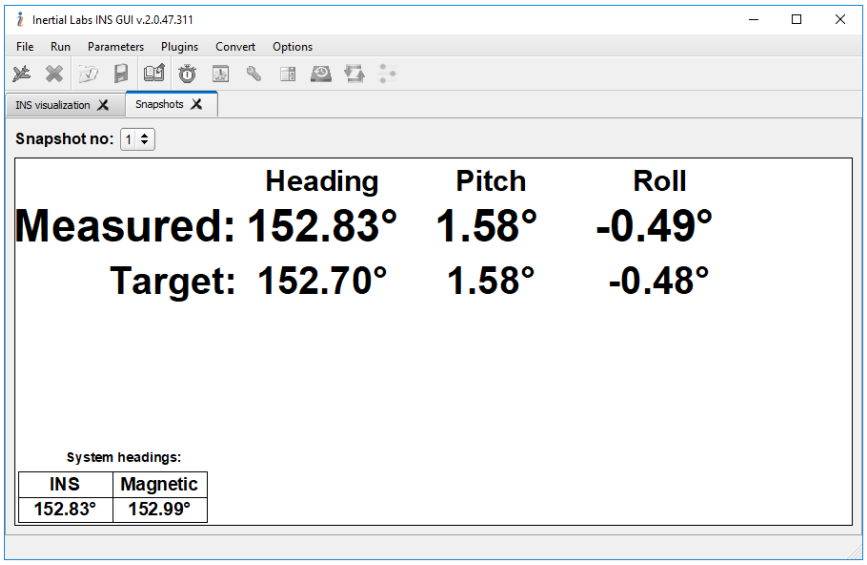



**Fig. 10.29.**

Step 12.

Rotate the INS in the next position and repeat Step 11 as many times as necessary. 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 positions can be set in degrees or in mils, depending on the chosen item in the drop-down list "**(deg) / (mils)**". Relative azimuth <u>in degrees</u> is considered to be positive in case of clockwise rotation from the reference to calibration point and negative in case of counter-clockwise rotation. Relative azimuth <u>in mils</u> 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 **Snapshot no: 7** arrow button after each snapshot calculation is performed and the heading error graph is plotted (Fig. 10.30). The "Heading error (deg)" graph shows the difference between INS measurements and reference angles.

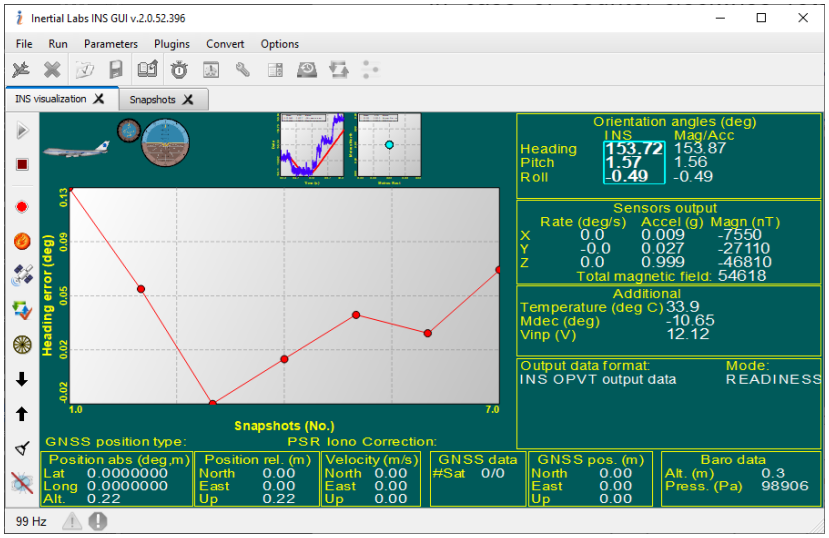



**Fig. 10.30.**

The plotted graph is scalable. To zoom in, click and hold the left mouse button and drag in a down-right direction. To zoom out, click and hold the left mouse button and drag in an up-left direction. Click and hold the right mouse button to shift plot.

Step 13.

To stop the accuracy test, click the **"Stop"** icon. If the INS data were writing and the time set in **"Record time"** in the "Options \ Test option" menu was reached, the accuracy test will be stopped as well.

Step 14.

To close the "On-the-fly accuracy" tab, simply go to another visualization style or close the "INS visualization" tab by clicking the icon in the title of current tab.

Accuracy test data are automatically saved to a *.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, the next 2 digits are the day, then hours, minutes, and seconds of operation (e.g., TestFullData-2013-03-05-15-44-47.csv).

This is common text file with comma-separated values of test data for each snapshot. An example of a *.csv file is shown in Table 10.2.

**Table 10.2. Example of a *.csv file created at accuracy test**

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

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 INS magnetometers
7. “Target_H” – reference (true) heading
8. “Target_P” – reference (true) pitch
9. “Target_R” – reference (true) roll;
10. “Mag_Dec” – the magnetic declination
11. “Vdd” – input voltage of the INS
12. “USW (L) “– Unit Status Word (low byte) (see Appendix D for details)
13. “USW (H) “– Unit Status Word (high byte) (see Appendix D for details)

## 10.6. INS Automatic Start

Since firmware version 1.0.2.0, the Inertial Labs™ INS auto start is implemented that allows start of its operation and data output after power on without any command from the host computer. It is possible to choose the desired output data format for auto start. See Appendix C for more details about data formats.

The auto start option can be enabled or disabled in the drop-down “Auto start” list in the “IMU” tab of the “Devices Options” window (see Fig. 4.2). To allow this option, the INS should be connected to a PC and powered.

The drop-down “Auto start” list contains all available output data formats (Fig. 10.31). Choose the desirable output data format for the INS auto start. Default is the “No Auto start” option, which disables automatic start.

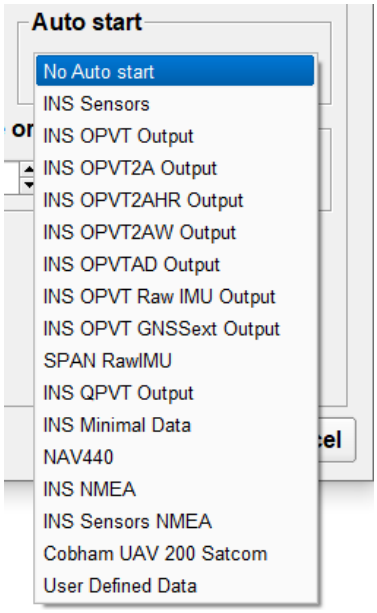



**Fig. 10.31.**

Usually only INS GUI software is used to start and stop the INS operation. To allow the INS GUI to receive data from an INS 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 INS GUI and start it again to apply this setting. Operation with an automatically started INS is similar to how it is described in the section 10.1, with the following slight differences:

Step 1.

Connect the INS to a PC and power on. The INS LED indicator will light yellow for about 15 seconds until the GNSS receiver initialization is completed. At this point, the INS starts calculations and its LED indicator changes color to green.

Step 2.

Wait not less than the configured time for the initial alignment (30 seconds on default) and then run the INS GUI. If the COM-port number was set correctly and the "Allow auto start" checkbox was selected, the INS GUI will show the INS continuous data in the 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.

Save data to file by clicking the "Write" icon.

Step 4.

Stop the INS by clicking the "Stop" icon. If the data were in the process of being written in a file, then the writing is stopped too.

## 10.7. INS Operation with Odometer

INS GUI supports INS operation with three types of odometers:

- OBDII odometer (with RS-232 interface)
- CAN BUS based odometer
- Encoder-based odometer (wheel speed sensor) with pulse / bi-phase signals

Use of odometer data provides essential improvement of INS position and velocity calculation at long-time GNSS outage.

### 10.7.1. INS Operation with OBDII Odometer

OBDII is a diagnostic port that is used in most vehicles. Usually, it is placed inside a cabin close to the driver's feet. Inertial Labs™ uses the OBDLink S cable, https://www.scantool.net/obdlink-s/ for connection of the INS COM4 port to the OBDII port.

Step 1.

Choose **"OBDII odometer"** in **"CAN / COM4"** tab of the **"Devices options"** window (see Fig. 4.17) and set the following parameters there:

- Data rate specifies the frequency of the odometer data input in Hertz. Minimum value of the parameter is 1 Hz, and it can be changed with the arrows or by entering the necessary value from a keyboard. The default value is set to 5Hz.
- Port bps sets the baud rate of COM4, which provides input of the odometer data. Choose the needed COM4 port baud rate in the drop-down list: 4800, 9600, 14400, 19200, 38400, 57600, 115200, 230400, or 460800 bps. The default value is 115200 bps.

Step 2.

Go to the **"External sensors"** tab of the "Devices options" window (Fig. 4.12) and check / set the standard deviation of the odometer noise in the **"STD_Vh (m/s)"** field (usually its value is 0.28 m/s) and Kalman filter residual threshold **"k_Sigma_V"** (usually its value is 10). Please contact Inertial Labs™ to get recommendations on the value of these parameters.

Step 3.

Power off the INS unit. Connect the OBDLink S cable to the INS COM4 port and to the OBDII connector on vehicle. Power on the OBDLink S cable and the INS unit. Wait the initialization time and then start INS operation. The INS unit will use odometer data at GNSS outage automatically for INS position, velocity, and orientation calculation.

### 10.7.2. INS Operation with CAN BUS Based Odometer

To configure the INS to receive velocity CAN messages from car CAN BUS as odometer data, go to the "CAN / COM4" tab of the "Devices options" window, "CAN" section, "Receive" tab (see Fig. 4.16). Then choose **CAN baud rate** in the appropriate field.

**Signal 1** describes a CAN message that contains velocity data.

**Signal 2** can be used to describe a CAN message with additional information about velocity (if it exists – like decimal velocity values).

**Signal 3** can be used to describe a CAN message with information about velocity sign if it is absent in **Signal 1**. Usually the velocity sign can be defined by transmission actual gear.

The following six parameters are available for each signal:

- **Message type** – type of CAN messages (CAN 2.0A or CAN 2.0B).
- **Message id** – CAN message identifier. This number is a positive integer from 0x0 to 0x7FF for a CAN 2.0A identifier and from 0x0 to 0x1FFFFFFF for a CAN 2.0B identifier.
- **Data type** – data type in CAN message.
- **Start bit** – the least significant bit counted from the start of the message data (see examples in Fig. 10.32, Fig. 10.33). The start bit is an integer from 0 to 63.
- **Length [Bit]** – number of bits that the signal occupies in the message. The length is an integer from 1 to 64.
- **Byte order** – a byte order message (little-endian or big-endian)

**Signal 1** and **Signal 2** have two additional parameters:

- **Value type** – specifies signed or unsigned data type.
- **Factor** and **Offset** – define the linear conversion rule to convert the signal's raw value into the signal's physical value (in km/h) and vice versa:
  - physical_value = raw_value * factor + offset;
  - raw_value = (physical_value – offset) / factor.

**Signal 3** has one additional parameter

- **Reverse value** – value of the signal that corresponds to the reverse gear (reverse vehicle motion).

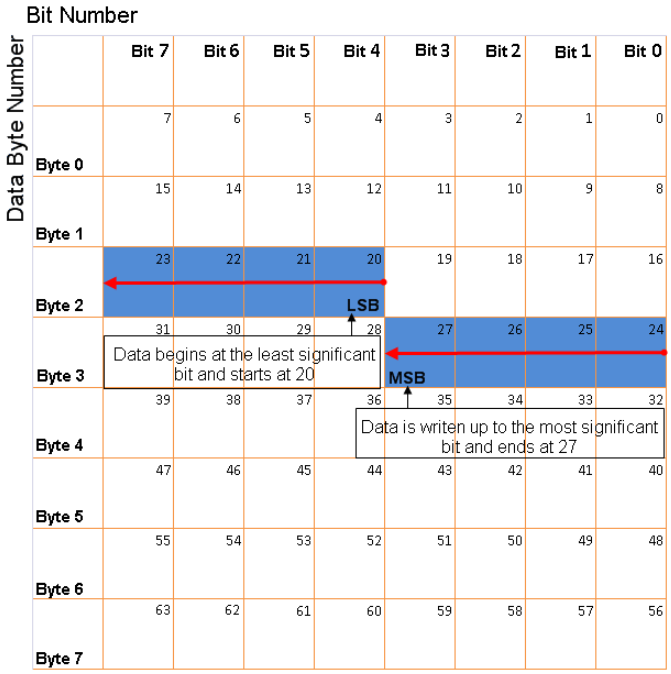



**Fig. 10.32. Example of signal in little-endian format with the length 8 bit and the start bit at 20**

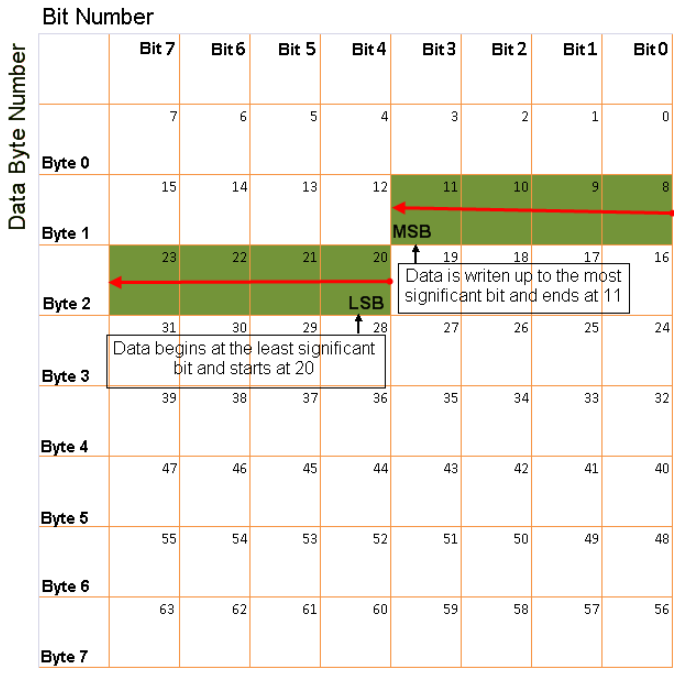



**Fig. 10.33. Example of signal in big-endian format with the length 8 bit and the start bit at 20**

**Note:** Each kind of car has unique CAN messages in the CAN BUS line. An example of parameters configuration of CAN BUS based odometer for a Hyundai Tucson TL is shown in Fig. 10.34.

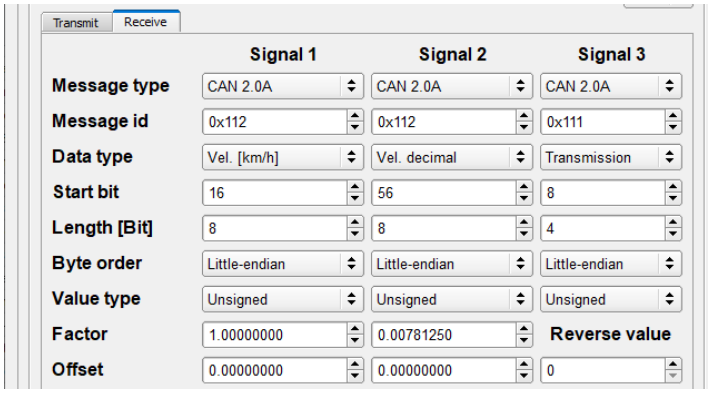



**Fig. 10.34.**

## 10.7.3. INS Operation with Encoder-Based Odometer (Wheel Speed Sensor)

Step 1.

Go to the **"Devices options"** window, **"External sensors"** tab, and check the **"Encoder-based odometer"** box (see Fig. 10.35).

Step 2.

Check / set the following parameters:

- **Pulse length** – the distance in meters between low to high transitions of the encoder signal.
- **ZUPT threshold (m/s)** – threshold for horizontal speed measured with odometer for stop detection in the odometer ZUPT algorithm.
- **External data offset relative to the IMU** – the lever arm measured from the accelerometer mass-center (see Fig. F.1) of the INS unit to external data source (like odometer or DVL) in the vehicle coordinate frame – in the right, forward, and vertical directions.
- **STD_Vh (m/s)** – standard deviation of the odometer noise. Usually its value is 0.10 m/s, but this value depends on encoder.
- **k_Sigma_V** – residual threshold. Its default value is 10.

Please contact Inertial Labs™ to get recommendations for odometer parameters values.

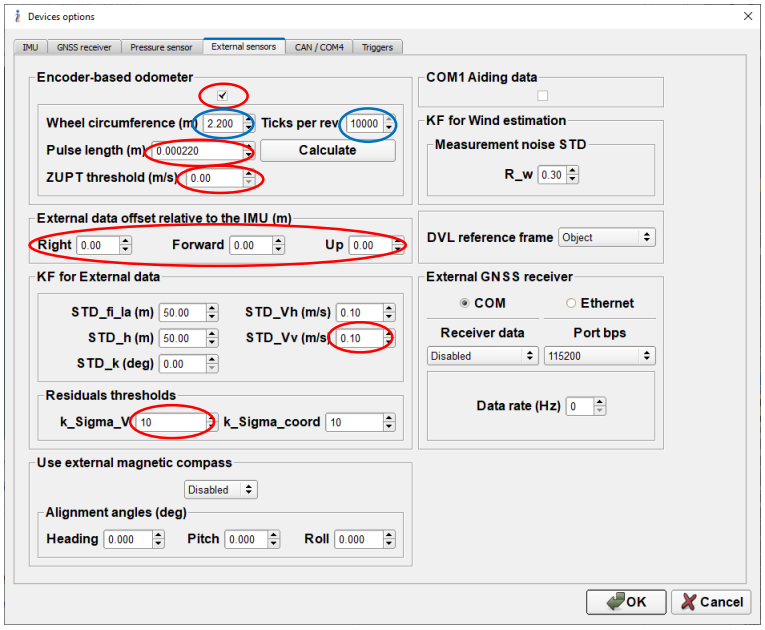



**Fig. 10.35.**

The pulse length can be calculated using formula

$$\textbf{Pulse length} = \textbf{pi*D/n} = \textbf{C/n} \qquad (10.1)$$

where D – is wheel diameter (in meters); C – is wheel circumference (in meters); n – is number of pulses per revolution. Or, simply click on the **"Calculate"** button (see Fig. 10.35) using the "Wheel circumference (m)" and "Tics per revolution" values to calculate the pulse length.

The pulse length should be set accurately because INS position calculation at GNSS outage highly depends on pulse length accuracy. On the other hand, the pulse length can be set approximately or even set to zero if the odometer

calibration procedure will be performed before ordinary operation of the INS with odometer (see section 10.7.3.1).

Note that if INS data are going to be post processed, then raw encoder data can be included to a data file as TIMEDWHEELDATA logs (see section 12.5. Embedding Raw IMU and Odometer Data into GNSS Stream). For this purpose, it is necessary to configure additional parameters marked by blue circles in Fig. 10.35:

- **Wheel circumference (m)** – parameter of the wheel where the encoder is installed.
- **Tics per rev.** – encoder parameter (number of tics per revolution).

The tics per revolution is an obligatory parameter for TIMEDWHEELDATA logs.

Step 3.

Power off the INS unit.

Step 4.

Connect the encoder to the INS's special port, which is factory configured to receive pulse / bi-phase signals from encoder. Power on the encoder and the INS unit, wait for the initialization time, and then start INS operation. The INS unit will use odometer data at GNSS outage automatically for INS position, velocity, and orientation calculation.

#### 10.7.3.1. Encoder-Based Odometer Calibration

The aim of the odometer calibration is accurate estimation of the pulse length.

Start INS ordinary operation, with the encoder connected. Start vehicle run. The odometer calibration can be started at any time after the INS has started calculation of valid position, velocity, and orientation.

**Note:** INS begins valid position, velocity, and orientation calculation when the following two conditions are met:

1. valid GNSS data is present,
2. and depending on the chosen INS heading correction type (see section "4.3. Correction Options"):
   - If "Magnetometers" or "AHRS" correction type chosen, then calculation begins immediately

- If “GNSS track”, “Combined” or “Inertial” correction type is chosen, to begin calculation it is necessary the vehicle achieved speed in twice more than “Vh track min” threshold
- If the “Dual GNSS” correction type is chosen (only available for INS-D operation), to begin calculation it is necessary that the heading from dual GNSS antenna was present.

Click the icon on the left vertical toolbar to start the odometer calibration (see Fig. 10.36). Note that the caption **“OFC is started”** appears in the “Mode” field (OFC stands for On-the-Fly Calibration).

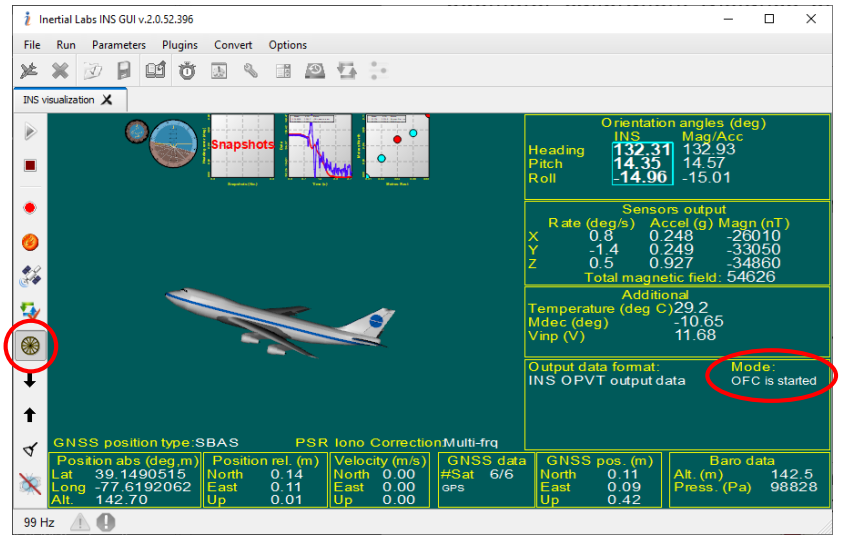



**Fig. 10.36.**

It is desirable for the vehicle to run in an approximately straight line during the odometer calibration. Distance of the run should be not less than 1 km. During this calibration run, GNSS outage is allowed, but it should be not more than 10 seconds.

Press the “Start / Stop Odometer Clb” icon to stop accumulation of data for the odometer calibration. Calibration will take less than a second. If the calibration is successful, then the caption **“OFC is done”** appears in the “Mode” field.

If calibration was successful, then new value of the pulse length is used for odometer data. This value will be written to the INS flash memory after INS receives “Stop” command by clicking on the icon. You can check the calculated value of the pulse length in the “Devices option”, “External sensors” tab (see Fig. 4.12).

Note that you can continue run of the INS after the odometer calibration, without an INS stop. Also, during the INS run you can perform new odometer calibration several times without an INS stop and without vehicle stop. The last calculated pulse length will be written to the INS flash memory after the INS stop.

## 10.8. Operations with CAN Data

Full configuration of both CAN ports is provided by The Inertial Labs™ INS GUI since version 2.0.50.360 from 2020-01-23 in the **"CAN / COM4"** tab of the **"Devices options"** window (see Fig. 10.37).

**Note:** The first CAN port can be configured to receive velocity CAN messages from a car CAN BUS as odometer data. For more information, see section 10.7.2.

① – list of available CAN messages
② – selected messages
③ – to write / read the "CAN message set" to / from INS flash memory
④ – open or save operations with *.ucan configuration file

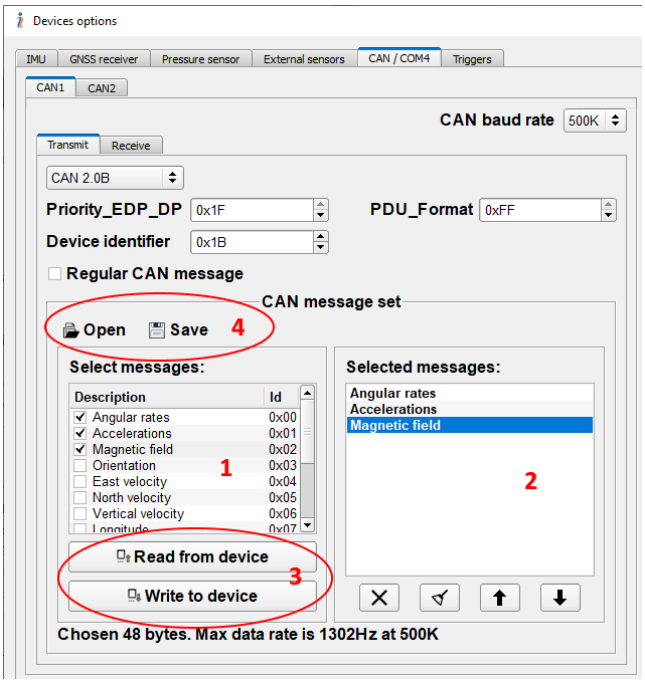



**Fig. 10.37.**

To allow the INS to output CAN messages, go to the "CAN1" or "CAN2" tab (see Fig. 10.37). Next, go to the "Transmit" tab inside to choose the variant of the CAN data (in the drop-down list in the top left corner). The Inertial Labs™ INS supports CAN 2.0A messages with an 11-bit base identifier (see Fig. 10.38) and CAN 2.0B messages with a 29-bit extended identifier (see Fig. 10.39).

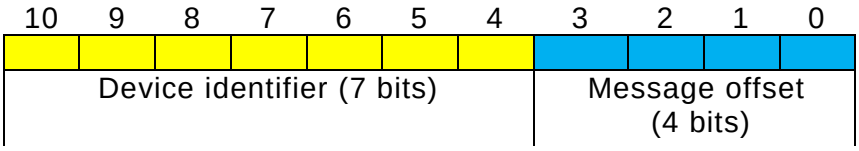



**Fig. 10.38. CAN 2.0A message identifier**

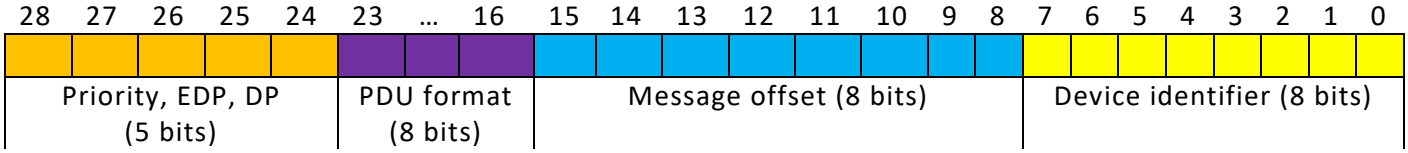



**Fig. 10.39. CAN 2.0B message identifier (according to SAE J1939 standard)**

Then set the necessary value in the **"CAN baud rate**" field (see Fig. 10.37).

If CAN 2.0A messages are chosen for output, the user can set the

- **Device identifier** – part of the 11-bit identifier (see Fig. 10.38), in range 0x00 to 0x7F.

If CAN 2.0B messages are chosen for output then the user can set the following parts of the 29-bit extended identifier (see Fig. 10.39):

- **Priority_EDP_DP** – composed part that includes Priority (3 bits), Extended Data Page (1 bit), and Data Page (1 bit). The Priority_EDP_DP parameter can be changed in range 0x00 to 0x1F.
- **PDU_Format** – PDU format that can be changed in range 0x00 to 0xFF.
- **Device identifier** – can be changed in range 0x00 to 0xFF.

In both CAN 2.0A and CAN 2.0B identifiers, the "Message offset" is the unique ID of specific CAN message according to Table 10.3.

**Table 10.3. List of supported CAN messages**

| Message number | Message offset | Data description |
|---|---|---|
| 0 | 0x0 | Angular rates |
| 1 | 0x1 | Accelerations |
| 2 | 0x2 | Magnetic field |
| 3 | 0x3 | Orientation |
| 4 | 0x4 | East velocity |
| 5 | 0x5 | North velocity |
| 6 | 0x6 | Vertical velocity |
| 7 | 0x7 | Longitude |
| 8 | 0x8 | Latitude |
| 9 | 0x9 | Altitude |
| A | 0xA | Time information |
| B | 0xB | INS solution accuracy |
| C | 0xC | GNSS info |

**Note:** See detailed description of CAN messages in INS ICD, section "6.2.18. The CAN Messages (Transmitted Through CAN Port)".

Since INS firmware version 3.2.6.5, a user can choose desired CAN messages for output.

The **"Select messages"** field (see Fig. 10.37) contains all CAN messages that can be chosen for output. There are two columns in the **"Select messages"** window:

- **Description** – contains the name of the CAN message
- **Id** – contains the ID of the CAN message (see Table 10.3)

Chosen CAN messages appear in the **"Selected messages"** field.

The user can use the **"Regular CAN message"** checkbox to choose a regular set of CAN messages for an INS unit that contains the following messages: Angular rates, Accelerations, Magnetic field, Orientation, and Time information (see Table 10.3).

There are control icons below the **"Selected messages"** field:

– to delete the selected CAN message
– to delete all selected CAN messages
– to move the selected CAN message up in the list
– to move the selected CAN message down in the list

The bottom string in the **"CAN message set"** window (Fig. 10.37) contains the summary information about chosen CAN messages: total number of bytes and the maximum data rate for chosen CAN port baud rate.

**Notes:**

1. Data rate for CAN messages is set in the "IMU" tab of the "Devices options" menu.
2. Maximum data rate is calculated based on full size of the CAN message according to the following formula:

$$\text{max_CAN_data_rate} = \frac{\text{CAN_baud_rate}}{\text{bits_CAN_mes} * \text{nmb_CAN_mes}} \tag{10.2}$$

where CAN_baud_rate is the CAN output baud rate (bits/s); bits_CAN_mes = 128 bits – is the length of one CAN message; nmb_CAN_mes is the number of chosen CAN messages in one package.

After choosing CAN messages, press the **"Write to device"** button (see Fig. 10.37) to write this configuration to the INS unit. If the operation is successful, the message in Fig. 10.40 appears If the operation fails, the message in Fig. 10.41 appears .

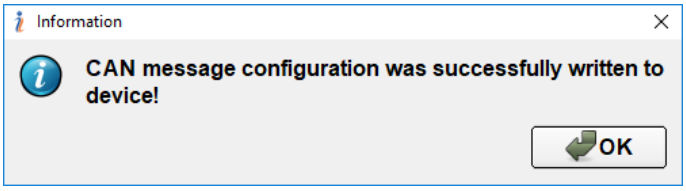



Fig. 10.40.

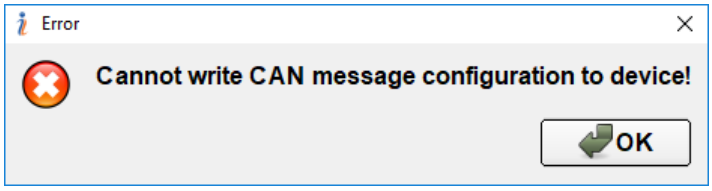



Fig. 10.41.

In the second case, check INS firmware version – it should not be earlier than 3.2.6.5 to support the **"CAN message set"** format.

### 10.8.1. Review and Editing of the Existing Configuration of the "CAN Message Set" Format in INS Unit

Click the **"Read from device"** button (Fig. 10.37) to subtract the current configuration of the "CAN message set" from the INS unit. If the operation is successful, then the message in Fig. 10.42 appears. If the operation fails, then the message in Fig. 10.43 appears.

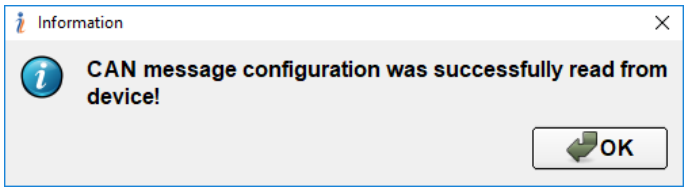



Fig. 10.42.

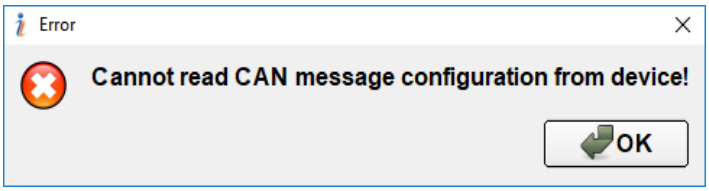



Fig. 10.43.

If the second message appears, do the following:

Check the INS firmware version – it should not be earlier than 3.2.6.5 to support the **"CAN message set"** format.

The current INS configuration will be displayed in the **"Select messages"** and **"Selected messages"** fields (see Fig. 10.37).

User can add or remove data packets. Also, using the control icons under **"Selected messages"** field, the user can arrange the CAN messages in the required order.

Press the **"Write"** button to write the configuration to the INS flash memory. If the operation is successful, then the message in Fig. 10.40 will appear; otherwise the message in Fig. 10.41 will appear.

### 10.8.2. "CAN Message Set" Format Configuration File (*.ucan)

Created configuration of the **"**CAN message set**"** can be transferred to other INS units using a binary file with a ***.ucan** extension.

To save the current configuration to file, please click the **"Save"** button (see Fig. 10.37), after which a standard Windows "Save as" window opens. User can change the file name or keep its default name with a *.ucan extension. After saving, the message in Fig. 10.44 appears To load the **"**CAN message set**"** configuration from file, please click the **"Open"** button (Fig. 10.37). A standard Windows "Open" window is opened; in this window select one of the previously saved files with a *.ucan extension. After opening the selected file, the message in Fig. 10.45 appears.

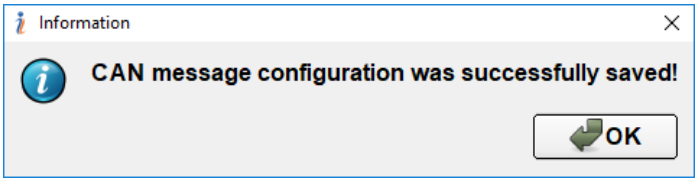



**Fig. 10.44.**

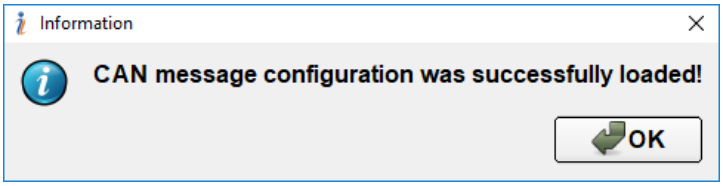



**Fig. 10.45.**

After loading, the configuration of the **"**CAN message set**"** is displayed in the **"**Select messages**"** and **"**Selected messages**"** fields (see Fig. 10.37).

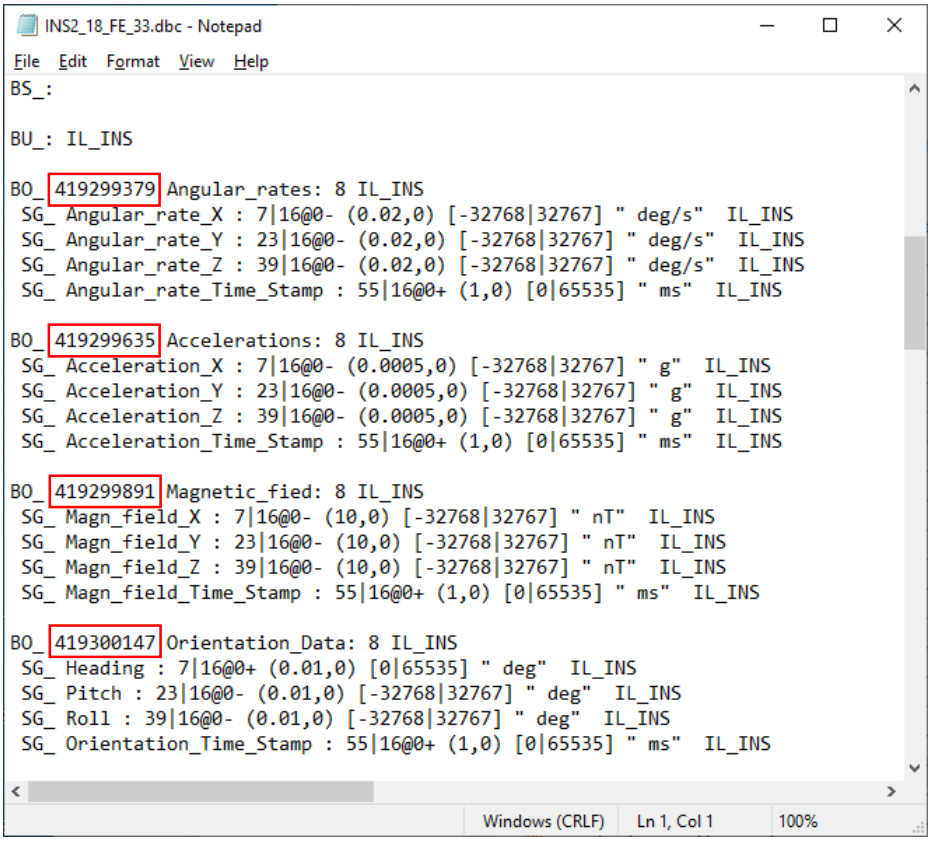
**Notes:**

1. It possible to edit this configuration as described above.
2. To apply configuration of the "CAN message set" to the INS unit, please click the "Write" button.

### 10.8.3. Modifying the DBC File to Interpret the CAN Messages

For CAN interfaces, the DBC file tells the host system how to interpret incoming byte structures when receiving CAN messages from the device. To start operation, Inertial Labs™ supplies users with a fully configured DBC file, including a preset CAN message identifier (CAN ID). User can change CAN ID for messages according to their structure shown in Fig. 10.38 for CAN2.0A and in Fig. 10.39 for CAN2.0B. In these cases, users must also update CAN ID in a DBC file, for every message.

A sample of the DBC file is shown in Fig. 10.46, where CAN ID are highlighted by rectangles.




```
BS_:

BU_: IL_INS

BO_ 419299379 Angular_rates: 8 IL_INS
 SG_ Angular_rate_X : 7|16@0- (0.02,0) [-32768|32767] " deg/s"  IL_INS
 SG_ Angular_rate_Y : 23|16@0- (0.02,0) [-32768|32767] " deg/s"  IL_INS
 SG_ Angular_rate_Z : 39|16@0- (0.02,0) [-32768|32767] " deg/s"  IL_INS
 SG_ Angular_rate_Time_Stamp : 55|16@0+ (1,0) [0|65535] " ms"  IL_INS

BO_ 419299635 Accelerations: 8 IL_INS
 SG_ Acceleration_X : 7|16@0- (0.0005,0) [-32768|32767] " g"  IL_INS
 SG_ Acceleration_Y : 23|16@0- (0.0005,0) [-32768|32767] " g"  IL_INS
 SG_ Acceleration_Z : 39|16@0- (0.0005,0) [-32768|32767] " g"  IL_INS
 SG_ Acceleration_Time_Stamp : 55|16@0+ (1,0) [0|65535] " ms"  IL_INS

BO_ 419299891 Magnetic_fied: 8 IL_INS
 SG_ Magn_field_X : 7|16@0- (10,0) [-32768|32767] " nT"  IL_INS
 SG_ Magn_field_Y : 23|16@0- (10,0) [-32768|32767] " nT"  IL_INS
 SG_ Magn_field_Z : 39|16@0- (10,0) [-32768|32767] " nT"  IL_INS
 SG_ Magn_field_Time_Stamp : 55|16@0+ (1,0) [0|65535] " ms"  IL_INS

BO_ 419300147 Orientation_Data: 8 IL_INS
 SG_ Heading : 7|16@0+ (0.01,0) [0|65535] " deg"  IL_INS
 SG_ Pitch : 23|16@0- (0.01,0) [-32768|32767] " deg"  IL_INS
 SG_ Roll : 39|16@0- (0.01,0) [-32768|32767] " deg"  IL_INS
 SG_ Orientation_Time_Stamp : 55|16@0+ (1,0) [0|65535] " ms"  IL_INS
```

**Fig. 10.46. Sample of DBC file to interpret CAN2.0B messages**

**Important note:** CAN ID for each data package is presented in HEX format, but DBC file shows CAN ID in DEC format.

For instance, if “Angular rates” CAN message has an ID of 0x18FE0033 then it appears in DBC file with ID 419299379 (see Fig. 10.46).

## 10.9. INS and SAMC Axes Alignment

For correct operation of the INS with external SAMC, it is necessary to align the SAMC axes with the INS axes. Otherwise, the heading angle and hence the position of a carrier object will be calculated inaccurately.

The INS GUI offers an INS and external SAMC axes alignment procedure. This procedure does not require any additional equipment; however, it does require the user to place the carrier object on which the INS and SAMC are mounted to a few positions with essentially different pitch and roll angles. Please use the maximum possible pitch and roll angles up to ±90 degrees, though in many cases a +/-15 degree change in pitch and roll angles in different positions will provide good axes alignment.

**Note:** If the procedure of axes alignment between INS and SAMC cannot be performed, it is possible to set the angles manually in the **Alignment angles** area (see Fig. 4.12).

### 10.9.1. Description of the Axes Alignment Procedures

Steps 1 and 2.

Perform Step 1 and Step 2 from section 10.1.

Note**,** SAMC should be connected to the INS as shown in the INS ICD, section "5.9. Connection of Stand Alone Magnetic Compass to INS", in accordance to SAMC type (OS3D-FG or miniAHRS).

Step 3.

Select **"Mag axes alignment"** from the "**Plugins**" menu (see Fig. 3.5). The "Mag axes alignment" window (Fig. 8.5) will open.

Step 4.

Set the time value in **"Accumulation Time"** or leave at the default value of 10 sec.

The axes alignment procedure consists of accumulating data in at least three positions at different pitch and roll angles. See Table 10.4. for examples of angles at which a carrier object should be set while accumulating data.

**Table 10.4. Example of rotation angles**

| Position # | Roll, deg | Pitch, deg |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 90 | 0 |
| 3 | 0 | 90 |

Step 5.

Fix a carrier object in the first position and click the **"Start"** button. The window shown in Fig. 10.47 will appear.

Step 6.

Fix a carrier object in the second position and click the **"Start"** button again.

Step 7.

Fix a carrier object in the third position and click the **"Start"** button again. The **"Calculate"** button gets activated after completion of data accumulation in the third position; however, for more accurate alignment, user may perform data accumulation in more than three positions.

Step 8.

Press the **"Calculate"** button once the satisfactory times of data accumulation at different angles have been performed.

If all steps have been completed accurately, then the image in Fig. 10.48 appears on the screen. Based on the axes alignment accuracy, it is necessary to accept or to decline the result by clicking on the relevant button. Otherwise, if the INS detects unsuccessful alignment or any other errors, an error pop-up appears on the screen (see Fig. 10.49). If this message appears, start at Step 5 and repeat the steps again to reach an acceptable result.

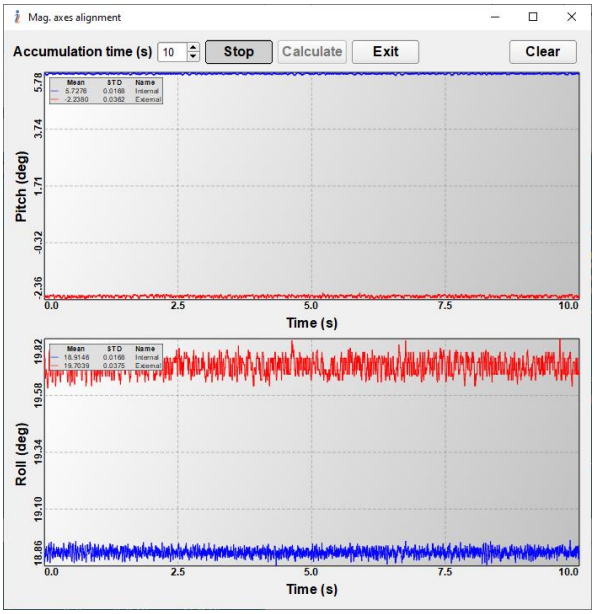



**Fig. 10.47.**

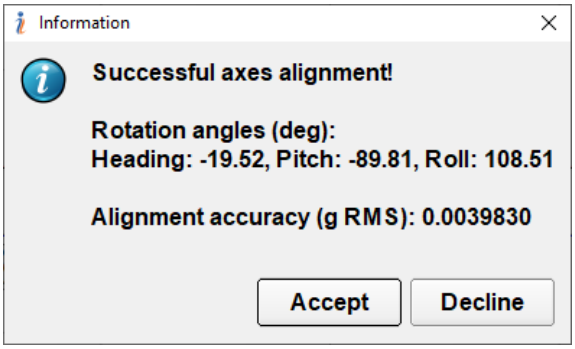



**Fig. 10.48.**

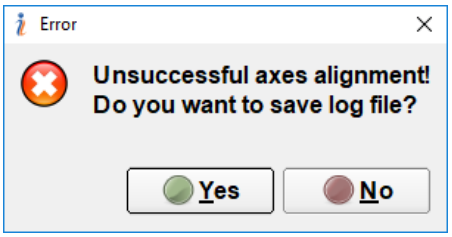



**Fig. 10.49.**

**Notes:**

1. Accepting the result by pressing the "Accept" button (Fig. 10.48), the determined rotation angles will be shown at the **Alignment angles** area in the "External sensors" tab of the "Devices options" window (see Fig. 4.12).
2. Pressing the "Yes" button (Fig. 10.49) saves the log file, which can be used to debug errors. The log file contains information about commands that were sent by the INS GUI and a list of errors occurred. In case of errors, this file should be sent to the Inertial Labs™ with a brief description of user actions.

Step 9.

If the user wishes to finish the axes alignment procedure without accepting the result, click the **"Exit"** button on the calibration window (Fig. 10.47). As a result, calculated alignment parameters will not get saved to the INS nonvolatile memory.

Step 10.

Click the ☒ icon to close the calibration window (Fig. 10.47).

## 10.9.2. Clearing Axes Alignment Parameters

To avoid incorrect heading calculation, axes alignment angles must be cleared in instances of the INS or SAMC unit replacement (position change) on a carrier object. Please remember that performed axes alignment data is valid until the INS and SAMC are mounted onto an object at the very exact spot while the alignment procedure.

To remove results of an axes alignment procedure from the INS nonvolatile memory, first perform **Step 1** and **Step 2** from section 10.1. Then select **"Mag axes alignment"** from the **"Plugins"** menu and click the **"Clear"** button in the window that opens (see Fig. 8.5). Axes alignment angles will be cleared in INS nonvolatile memory, and a pop-

up confirmation will appear on the screen (see Fig. 10.50). Otherwise, an error pop-up will appear on the screen (see Fig. 10.51). Click “OK” to close the information window.

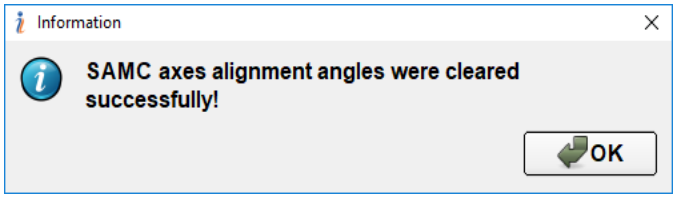



**Fig. 10.50.**

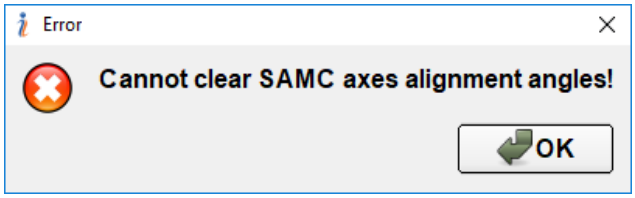



**Fig. 10.51.**

## 10.10. Switching Off / On the GNSS Receiver Data Input

Since firmware version 2.6.0.6, the Inertial Labs™ INS allows switching off / on the GNSS receiver input to the INS algorithm during the INS operation. It is supported in INS GUI version 2.01.51.365 from 02/21/2020.

This feature can be used to check INS operation at GNSS outage. Note that physically the receiver is not disconnected, and the INS unit continues transferring GNSS data to output independently of whether the GNSS receiver input to the INS algorithm is switched on or off.

To run the INS, please follow instructions provided in the User’s Demo Manual, section “10.1.The Main Operation Modes of the INS”. The GNSS receiver is switched on by default.

To switch the GNSS receiver off during the INS operation, click the icon on the **“INS visualization”** toolbar (see Fig. 10.52). At this point, the icon changes to and all GNSS receiver data are reset to zero (see Fig. 10.53).

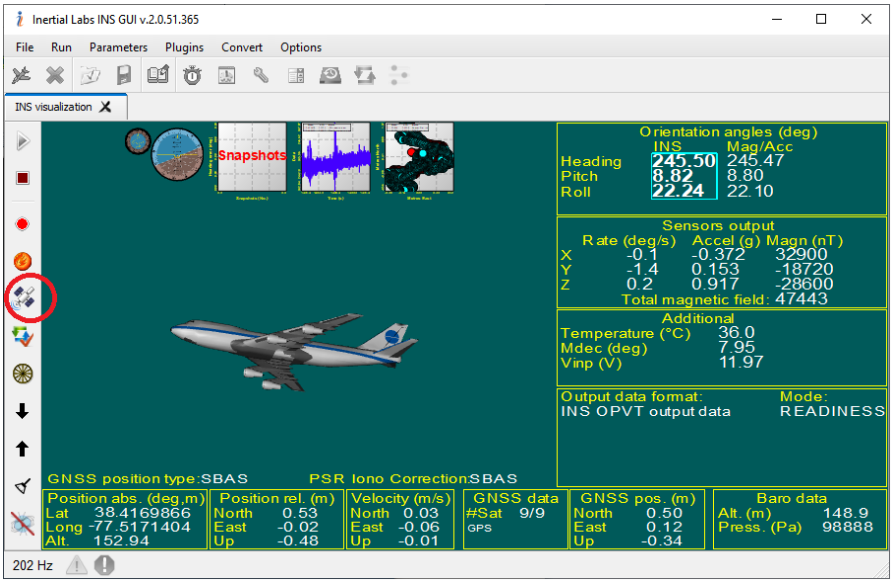



**Fig. 10.52.**

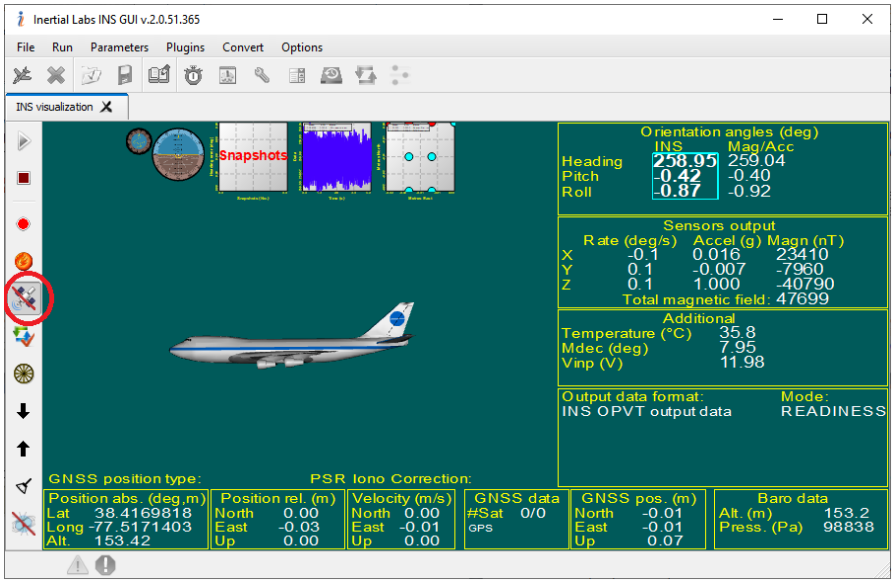



**Fig. 10.53.**

The icon remains pressed until it is necessary to switch the GNSS receiver on. To do so, simply reclick on the icon. If satellites are available, observe changes in numeric GNSS data.

# 11. Continuous Self-Monitoring of the INS Health

The Inertial Labs™ INS has continuous built-in monitoring of its health. In the main operating mode, the INS sends out Unit Status Word (USW) in each data block (see also “Appendix C. Description of Data Files”).

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

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

Since INS GUI version 2.0.29.110, the GUI software stops the INS unit if failure of a gyro or accelerometer is detected. After the INS unit is stopped, an error message with a caption signaling the failure appears.

# 12. INS and GNSS Data Post-Processing

For applications requiring highly accurate post-mission position, velocity, and orientation, INS and GNSS data post-processing can be used. This feature is provided by NovAtel software (see http://www.novatel.com/products/software/). For such post-processing, the raw GNSS and raw IMU data should be used.

## 12.1. Recording of Raw GNSS Data

The Inertial Labs™ INS uses additional COM-ports (COM2 or COM3) for output of raw GNSS receiver data. Please choose “Raw GNSS” or “Min Raw GNSS” data set in “GNSS COM Port 2” or “GNSS COM Port 3” settings in the “GNSS receiver” tab of the “Devices options” window (see section 4.2.2).

Raw GNSS data consist of necessary logs for post-processing. There are synchronous and asynchronous logs. The data for synchronous logs are generated with set frequency. To output the most current data as soon as they are available, asynchronous data are generated at irregular intervals.

Note that not all models of GNSS receiver support the raw GNSS data output. For example, base model G1S00G0T0 does not support the raw data output. Please ask Inertial Labs™ for the necessary model of the GNSS receiver. See section “10.2.2. Control of GNSS Receiver Model” for description of the procedure to change the receiver model. Reloading of the INS or GNSS receiver firmware or returning the INS for service to upgrade the model is not required.

A full list of generated logs of raw GNSS data is shown in Table 12.1. Since INS firmware version 3.2.5.8, the user can select a minimal set of raw GNSS data. An appropriate list of generated logs is shown in Table 12.2.

**Table 12.1. Logs for raw GNSS data**

| Log | Description |
|---|---|
| **Asynchronous** | |
| CLOCKSTEERING | Clock steering status |
| GLOCLOCK | GLONASS clock information |
| ALMANAC | Decoded GPS Almanac |
| GPSEPHEM | Decoded GPS ephemeris |
| RAWALM | Raw Almanac data |
| RAWEPHEM | Raw ephemeris |
| RAWGPSSUBFRAME | Raw subframe data |
| RAWCNAVFRAME | Raw CNAV frame data |
| RAWGPSWORD | Raw navigation word |
| GLOALMANAC | Decoded GLONASS Almanac |
| GLOEPHEMERIS | Decoded GLONASS ephemeris |
| GLORAWALM | Raw GLONASS almanac data |
| GLORAWEPHEM | Raw GLONASS ephemeris data |
| GLORAWFRAME | Raw GLONASS frame data |
| GLORAWSTRING | Raw GLONASS string |
| MARK2POS (1) | Position at time of mark input event |
| MARK2TIME (1) | Time of mark input event |
| BDSEPHEMERIS | Decoded BeiDou ephemeris |
| GALINAVEPHEMERIS | Decoded Galileo INAV ephemeris |
| GALFNAVEPHEMERIS | Decoded Galileo FNAV ephemeris |
| HEADING2 | Heading data (INS-D only) |
| **Synchronous** | |
| CLOCKMODEL | Current clock model status |
| TIMESYNC | Synchronize time between GNSS receivers |
| TIME | Time data |
| RANGE | Satellite range information |
| RANGEGPSL1 | L1 version of the RANGE log |
| TRACKSTAT | Tracking status |

**Table 12.2. Minimal set of raw GNSS data logs**

| Log | Description |
|---|---|
| **Asynchronous** | |
| RAWEPHEM | Raw ephemeris |
| GLOEPHEMERIS | Decoded GLONASS ephemeris |
| BDSEPHEMERIS | Decoded BeiDou ephemeris |
| GALINAVEPHEMERIS | Decoded Galileo INAV ephemeris |
| GALFNAVEPHEMERIS | Decoded Galileo FNAV ephemeris |
| QZSSEPHEMERIS | Decoded QZSS parameters |
| MARK2POS (1) | Position at time of mark input event |
| MARK2TIME (1) | Time of mark input event |
| **Synchronous** | |
| RANGECMP | Compressed version of the RANGE log (satellite range information) |

**Notes:**

1. MARK2POS and MARK2TIME logs marked with (1) are not used in post-processing, but they can be added to the raw GNSS data if input marks are enabled (if the "Mark inputs control" checkbox is checked in the "GNSS receiver" tab of the "Devices options" menu as seen in Fig. 4.4). MARK2POS and MARK2TIME logs appear when a pulse is detected at mark input (see section "13.3. INS Operation with LiDAR").
2. INS-DL and INS-DU supports only logs shown in Table 12.3.

**Table 12.3. Logs of raw GNSS data supported by INS-DL and INS-DU units**

| Log | Description |
|---|---|
| RAWX | Multi-GNSS raw measurements. This message contains pseudorange, Doppler, carrier phase, phase lock and signal quality information for GNSS satellites once signals have been synchronized. This message supports all active GNSS. Additionally, these information can be used to generate a RINEX 3 multi-GNSS observation file. |
| SFRBX | Broadcast navigation data subframe. This message reports a complete subframe of broadcast navigation data decoded from a single signal. The number of data words reported in each message depends on the nature of the signal. |

Frequency of the synchronous logs logging is changeable and is specified in the "Data rate" field (see section "4.2.2. "GNSS Receiver" Tab of "Devices Options" " for details). Note that the standard COM-port baud rate of 115200 bps can provide frequency of GPS L1 raw data up to 5 Hz. Raw data with higher frequency, L1/L2, using GPS + GLONASS, may contain gaps, so it is necessary to use the USB-port on the host computer and to increase COM-port baud rate. Set 921600 bps baud rate to provide the maximum 20 Hz GNSS raw data output. Please contact Inertial Labs™ for details.

For raw GPS data recording from receiver, an external program **GNSS_Reader** can be used. GNSS_Reader is supplied with the **"Inertial Labs™ INS GUI"** software.

The main window of GNSS Reader is shown in Fig. 12.1.

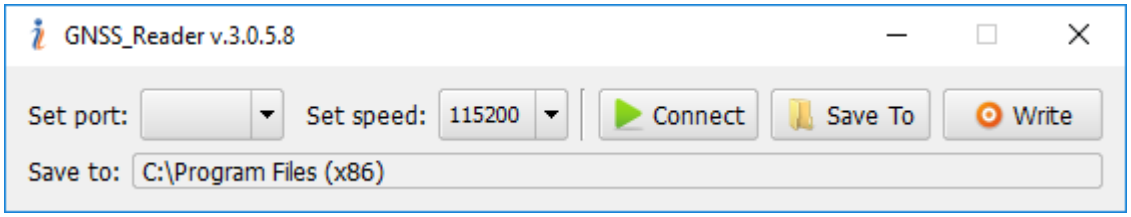



**Fig. 12.1.**

To perform data recording follow these steps:

Step 1.

Click on the

icon to choose the port to which the INS COM2 port is connected. Select the correct COM-port number from the drop-down list (see Fig. 12.2).

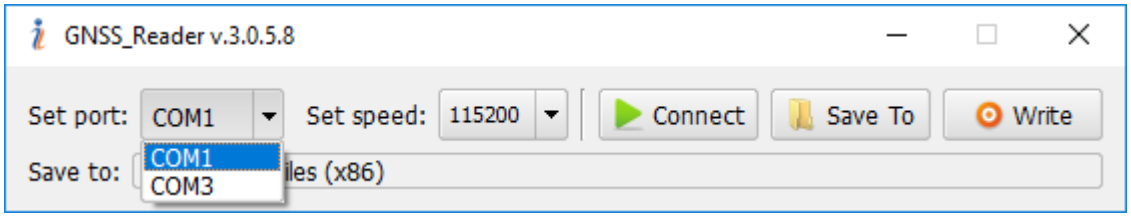



**Fig. 12.2.**

Step 2.

Select the correct speed from the drop-down list (see Fig. 12.3). Make sure this COM-port baud rate corresponds to the baud rate that is set in the GNSS receiver tab in the “Devices options” menu (see section 4.2.2. “GNSS Receiver” Tab of “Devices Options” ”, Fig. 4.6).

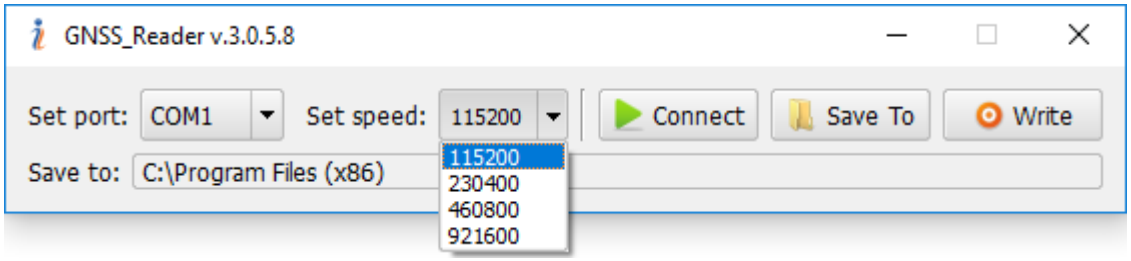



**Fig. 12.3.**

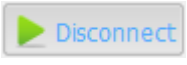
Step 3.

The default folder for saving GNSS data is the same as for files written by the INS GUI software. To change the folder for raw GNSS data, click on the

icon. A standard Windows “Save” window will open. After specifying the file path, click the “OK” button. Then a full path to the folder will be shown in the “Save to” field.

Step 4.

To connect the program to the chosen COM-port, click on the

icon, after which the name of the button will be changed to 

, and the COM-

port button will become inactive. To disconnect, simply click on the “Disconnect” icon.

Step 5.

To begin the data recording, click on the

button, and data recording will begin. The button will remain pressed

during the entire recording process.

**Note:** Each click on the “Write” button will create a new file for the data recording.

Step 6.

When the required amount of data is recorded, unpress the “Write” icon and then click the “Disconnect” button.

If data recording was performed correctly, a new file with a *.gps extension will appear in the folder that was specified during Step 3.

**Note:** Name of the file with recorded GPS data consists of date and time when the test was performed. For example, file name 2015-09-01-10-59-40.gps means that the test was performed on September 1, 2015 at 10:59:40.

## 12.2. Raw IMU Data Generation

Raw IMU data can be created from pair files with extensions *.bin, *.prm that were saved during the test run. It is highly recommended to save INS data with “INS OPVT & Raw IMU Data” or “SPAN rawimu” output data formats because they contain very accurate GPS IMU Time of raw IMU data packages (see Appendix C, Table C.21 and Table C.22). Such accurate time allows to the user to get a highly accurate post-processing result. All other output data formats contain GPS time of navigation data instead of raw IMU data time that is less accurate for post-processing.

**Note:** The “INS OPVT & Raw IMU Data” and “SPAN rawimu” output data formats are implemented in INS firmware since version 3.2.1.8.

To convert *.bin, *.prm files to raw IMU data, do the following:

Step 1.

Select **“Convert to IMU data”** from the **“Convert”** menu (Fig. 3.6). A standard Windows “Open” window will open.

Step 2.

Select the necessary file with extension *.bin. A window as shown in Fig. 12.4 appears, with a prompt to enter a GPS Time shift of data saved in the *.bin file. Leave the value at zero if the INS unit has firmware version 3.0.0.0 and newer; for older firmware, enter negative time shift –10 ms.

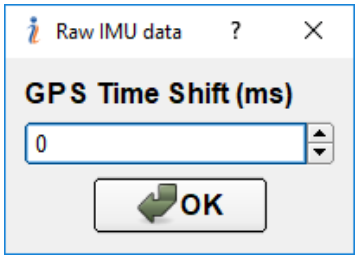



**Fig. 12.4.**

After clicking **"OK"**, an *.imu file will be created with the same name and in the same folder as the selected *.bin file. Binary Structure of the IMU file is shown in Table 12.4.

**Table 12.4. Binary Structure of raw IMU data**

| Word | Size (bytes) | Type | Description |
|---|---|---|---|
| GpsTime | 8 | real | time of the current IMU rate measurements in GPS seconds of the week |
| GyroX | 4 | long | scaled X-body axis gyro measurement as angular rate in deg/s ∗10000 |
| GyroY | 4 | long | scaled Y-body axis gyro measurement as angular rate in deg/s ∗10000 |
| GyroZ | 4 | long | scaled Z-body axis gyro measurement as angular rate in deg/s ∗10000 |
| AccelX | 4 | long | scaled X-body axis accelerometer measurement as acceleration in $m/s^2$ ∗10000 |
| AccelY | 4 | long | scaled Y-body axis accelerometer measurement as acceleration in $m/s^2$ ∗10000 |
| AccelZ | 4 | long | scaled Z-body axis accelerometer measurement as acceleration in $m/s^2$ ∗10000 |

To use this *.imu file for post-processing with NovAtel software, the user must convert it into the Waypoint's generic IMR format. See section "12.3. Generation of IMR Data File " for the details on it.

## 12.3. Generation of IMR Data File with IMU Data and Time

There are two ways to generate the IMR data file from collected INS data for further post-processing with NovAtel software:

- Using INS GUI embedded "Convert to IMR data" convertor with previously saved pair files (*.bin and *.prm) during the test run. In such a case see section 12.3.1.
- Using "IMU Data Converter" developed by NovAtel with previously generated *.imu file as described in section 12.2. In such a case see section 12.3.2.

### 12.3.1. INS GUI Embedded Convertor

To convert *.bin and *.prm files to IMR data file, do the following:

Step 1.

Select **"Convert to IMR data"** convertor from the **"Convert"** menu (Fig. 3.6). A standard Windows "Open" window will open.

Step 2.

Select the necessary file with extension *.bin. A window as shown in Fig. 12.5 appears, with a prompt to enter a GPS Time shift of data saved in the *.bin file. Leave the value at zero if the INS unit has firmware version 3.0.0.0 and newer; for older firmware, enter negative time shift – 10 ms.

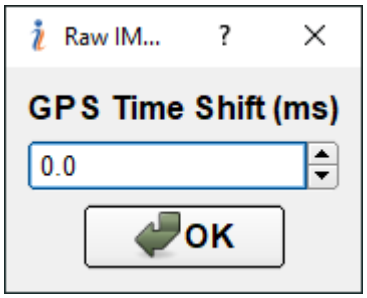



**Fig. 12.5.**

After clicking **"OK"**, an *.imr file will be created with the same name and in the same folder as the selected *.bin file.

### 12.3.2. NovAtel Converter

To convert *.imu file to IMR data file, **IMU Data Converter** developed by NovAtel should be used (for more details refer to the manual provided with NovAtel software).

First, it is necessary to create new **Conversion Profile**. Do the following:

Step 1.

Launch the **IMU Data Converter**.

Step 2.

In the main window of **IMU Data Converter,** click on the "New" button. The window shown in Fig. 12.6. will appear. In the "Name" field, type the name of the new profile and click the "OK" button.

Step 3.

In the newly opened window in the **"Sensor/Timing Settings"** tab, insert the following parameters (see Fig. 12.7):

In the **"Gyro Measurements"** field:

- In the **"Inverse Scale Factor"** edit box, set value of 10000;
- Select the **"Angular rates"** units by radio button.

In the **"Accelerometers Measurements"** field:

- In the **"Inverse Scale Factor"** edit box, set value of 10000;
- Select the **"Accelerations"** units by radio button.

In the **"Timing Settings"** field:

- In the **"Data Rate"** edit box set the measurement rate according to the value in the IMU tab of the "Devices Options" menu (see section 4.2. Devices options);
- Select the **"GPS"** units by radio button.

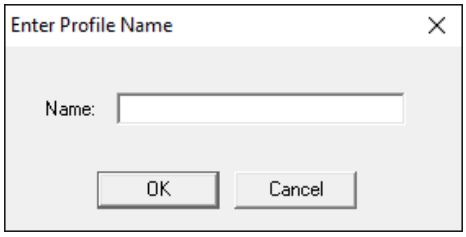



**Fig. 12.6.**

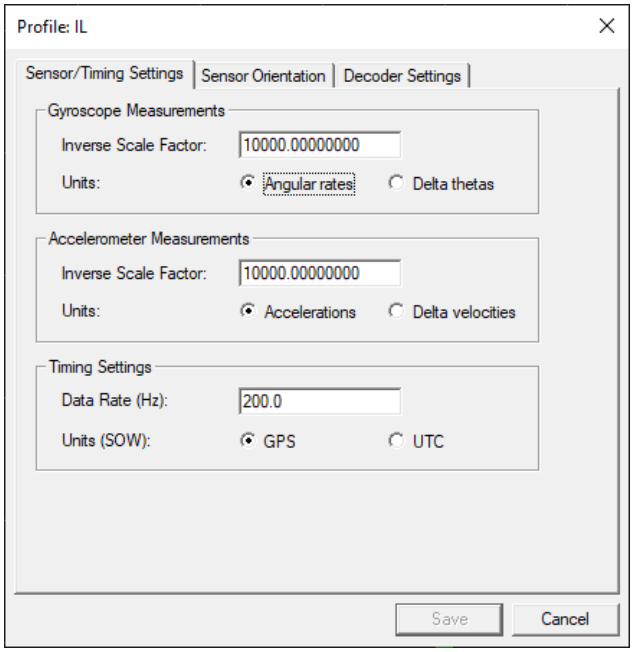



**Fig. 12.7.**

Step 4.

To save all configurations and close this window, click on the "Save" button. No changes are needed in the **"Sensors Orientation"** and **"Decoder Settings"** tabs. The created conversion profile is saved in the **IMU Data Converter** and is available in the list of profiles at future operations.

## 12.4. Generation of DMR Data File with Odometer Data and Time

To convert *.bin and *.prm files to DMR data file, do the following:

Step 1.

Select **"Convert to DMR data"** convertor from the **"Convert"** menu (Fig. 3.6). A standard Windows "Open" window will open.

Step 2.

Select the necessary file with extension *.bin. A window as shown in Fig. 12.8 appears.

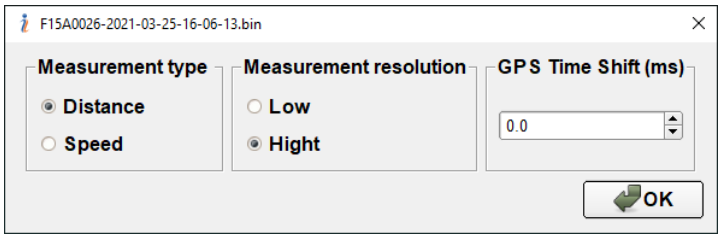



**Fig. 12.8.**

Choose the following options:

- **Measurement type** – shows what odometer data are present in file. If both distance and speed data are present, then converter proposes to choose desired data for DMR file
- **Measurement resolution** – to choose resolution of odometer data:
  - low resolution (measurements on full wheel revolutions)
  - high resolution (measurements on partial wheel revolutions or fixed time intervals)
- **GPS Time shift (ms)** – sets time shift of GPS data saved in the *.bin file. Leave the value at zero if the INS unit has firmware version 3.0.0.0 and newer; for older firmware, enter negative time shift – 10 ms.

After clicking **"OK"**, an *.dmr file will be created with the same name and in the same folder as the selected *.bin file.

## 12.5. Embedding Raw IMU and Odometer Data into GNSS Stream

Since INS GUI version 2.0.47.309 from 2019-02-25, it is possible to convert INS data to raw IMU data and then combine that data with raw GNSS data into a single file. This file can be used with Inertial Explorer easier than separate files with raw IMU data and raw GNSS data.

Since INS GUI version 2.0.48.317, from 2019-03-29 it is possible to add the TIMEDWHEELDATA log with odometer (wheel sensor data) to this combined data file.

To embed raw IMU data into the GNSS stream it is necessary to have three files:

1. Log file with raw GNSS data (usually with *.gps or *.bin extension)
2. INS binary data files – a pair of files with extensions *.bin and *.prm

**Essential notes:**

1. INS data must be saved with data rate 200 Hz.
2. The following INS output data formats contain the necessary information for creation of combined raw IMU and raw GNSS data: INS OPVT; INS QPVT; INS OPVT2A; INS OPVT2AW; INS OPVT2AHR; INS OPVTAD; INS OPVT & Raw IMU Data; SPAN rawimu; INS OPVT GNSSext; and User Defined Data. For User Defined Data (see detailed description of how to set User Defined Data type in section 4.7), the following data types are required: [0x02 or 0x01 or 0x03]; [0x21 or 0x20]; [0x23 or 0x22]; [0x36]; [0x52]; and [0x53]. Otherwise the message shown in Fig. 12.9 appears. Also, [0x60], [0x61], and [0x65] data types are necessary in order to add the TIMEDWHEELDATA log (see Table 4.3 for descriptions of data types).
3. It is recommended to use either INS OPVT & Raw IMU Data or SPAN rawimu, as these formats contain more precisely timestamped IMU data.

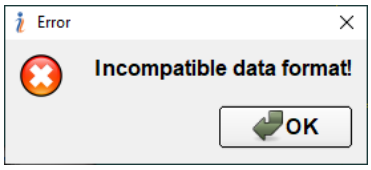



**Fig. 12.9.**

***Additional limitations for including TIMEDWHEELDATA logs:***

1. Only INS OPVTAD output data format can be used for creation of TIMEDWHEELDATA logs.
2. It is necessary to enter “Tics per revolution” and “Pulse length (m)” parameters of the encoder-based odometer in the “External sensors” tab of the “Devices options” window (see Fig. 4.12). Alternatively, it is possible to enter “Tics per revolution” and “Wheel circumference (m)”, and then click the “Calculate” button to calculate the “Pulse length (m)”.

To combine Raw IMU and GPS data do the follows:

Step 1.

Select **“Combine RAWIMUB and GPS data”** from the **“Convert”** menu (Fig. 3.6). A standard Windows “Open” window will open.

Step 2.

Select file with INS data that has the extension *.bin or *.span.

Step 3.

If this INS data file has INS OPVTAD output data format, then a pop-up window will appear on the screen with a prompt to include TIMEDWHEELDATA logs to the new combined data file (see Fig. 12.10).

If the user clicks “Yes” to include TIMEDWHEELDATA logs but there is no information in the INS file about “Tics per revolution” and “Pulse length (m)”, then the pop-up window in Fig. 12.11 will appear on the screen.

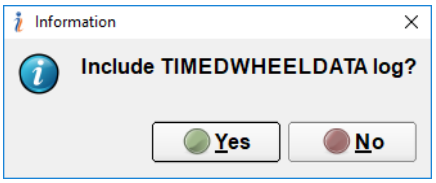



**Fig. 12.10.**

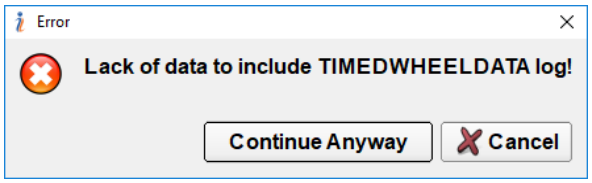



**Fig. 12.11.**

User can click the “Continue Anyway” button to continue creation of the combined raw IMU and raw GNSS data file but without TIMEDWHEELDATA logs, or click “Cancel” to abort this data conversion.

Step 4.

A new “Open” window will appear where it is necessary to select the log file with raw GNSS data (with a *.gps or *.bin extension).

Step 5.

If combination of raw IMU and raw GNSS data was successful, then a pop-up window will appear on the screen (see Fig. 12.12) and a data file with combined data will be created.

If combination of raw IMU and raw GNSS data was not successful, then the pop-up window shown in Fig. 12.13 will appear on the screen.

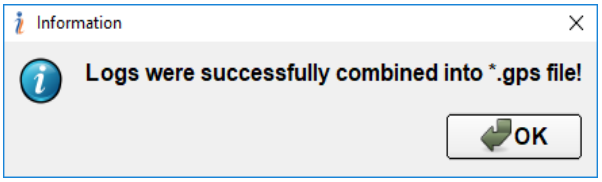



**Fig. 12.12.**

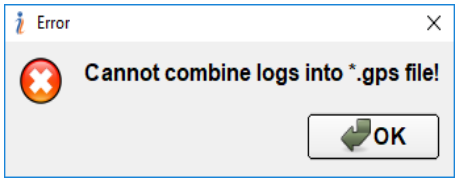



**Fig. 12.13.**

The converter will create the new GNSS data file, with the same name as the file with INS data, but with the extension *.gps

The new file can be imported directly into the Inertial Explorer during project creation. Inertial Explorer will automatically recognize the file as containing GNSS and IMU data, extract the data, detect the IMU model, and add the necessary files to the project.

## 12.6. INS Sensors Error Model for INS + GNSS Data Post-Processing

For data post-processing in the NovAtel Waypoint Inertial Explorer, it is necessary to choose the error model of IMU sensors. For post-processing in the Inertial Labs™ INS, it is necessary to create a profile with the recommended parameters.

Follow these steps to create a profile in the NovAtel Waypoint Inertial Explorer:

Step 1.

Select **"Settings"** and then **"Manage profiles"** in the top menu.

Step 2.

In the opened window, copy the **"SPAN Ground (STIM 300)"** profile as the most similar to the Inertial Labs™ INS profile and rename it.

Step 3.

Select the newly created profile, click **"Edit IMU"**, and then go to the **"States"** tab.

Step 4.

In the block **"Error Model"**, click **"Lock selection"**, choose any model of errors, and click **"Add From"**. In the window that appears, you can rename the error model and correct all parameters according to Fig. 12.14.

Step 5.

After making all changes, click **"Ok"** in all windows and save the changes.

User can contact Inertial Labs™ support to request a file with the required profile for post-processing. This file has the extension *.DefOpt and should be placed to

the **"User"** folder, which is located in the directory with the NovAtel Waypoint Inertial Explorer installed. After that, the profile will automatically appear in the NovAtel Waypoint Inertial Explorer.

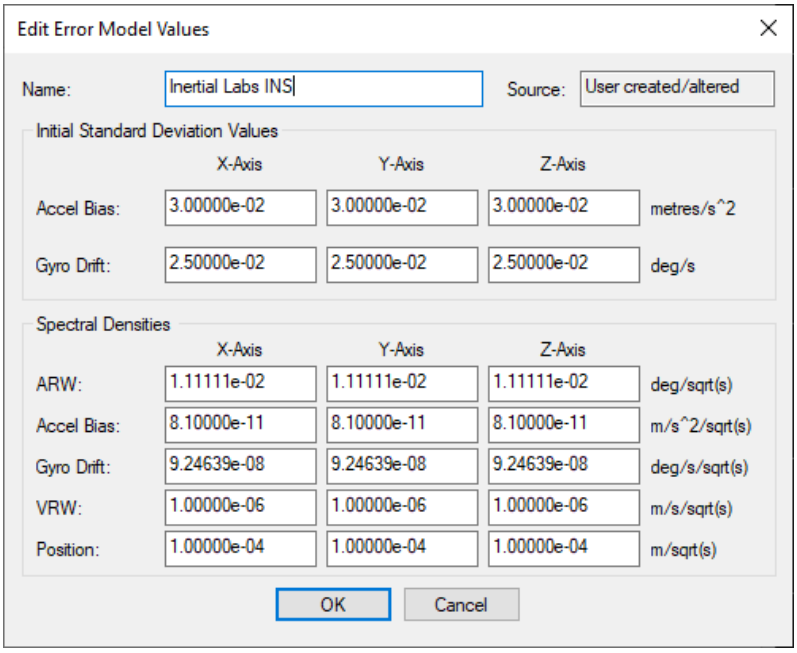



**Fig. 12.14.**

# 13. Synchronization of INS Data with LiDAR and Other Devices

Synchronization of the Inertial Labs™ INS measurements with data form other devices is very important in many applications. The INS can trigger other devices, or an external device can trigger the INS measurements.

To trigger external devices, the Inertial Labs™ INS outputs an accurate pulse-per-second (PPS) signal generated by the onboard GNSS receiver. The PPS signal is provided by appropriate pin of the INS main connector (see INS ICD, Table 5.1 and Table 5.3). Additionally, the INS unit can be configured to input external PPS signal on that pin to synchronize INS calculations and data output with the source of PPS. The Inertial Labs™ INS GUI allows adjustment of the PPS signal (see section "13.1. Control of PPS Output Signal").

There are two ways to trigger the INS data from external devices. First, the INS can operate in the "On Request" (on demand) mode when the INS sends one data block after each Request command issued from the host computer. See INS ICD, section "6.3.2. SetOnRequestMode Command – Getting INS Data on Request (On Demand)" for details.

The second way of INS data synchronization is using mark input line to trigger the INS output data by external devices. Mark input line is connected to the appropriate pin (MARK IN pin) of the INS main connector (see INS ICD, Table 5.1 and section "5.6. Mark Input Description"). Currently, mark input is used to trigger GNSS raw data in INS. The Inertial Labs™ INS GUI allows user to adjust receipt of synchro pulses through mark input signal (see section "13.2. Processing of Mark Input Signal").

## 13.1. Control of PPS Output Signal

The Inertial Labs™ INS outputs the pulse-per-second (PPS) signal generated by GNSS receiver. PPS pulse is shown in Fig. 13.1 and Fig. 13.2.

Also, the INS unit can be configured to input an external PPS signal on that pin of the INS connector to synchronize INS calculations and data output with the source of PPS. In this case, all of the adjustable PPS parameters should correspond with the actual provided PPS signal.

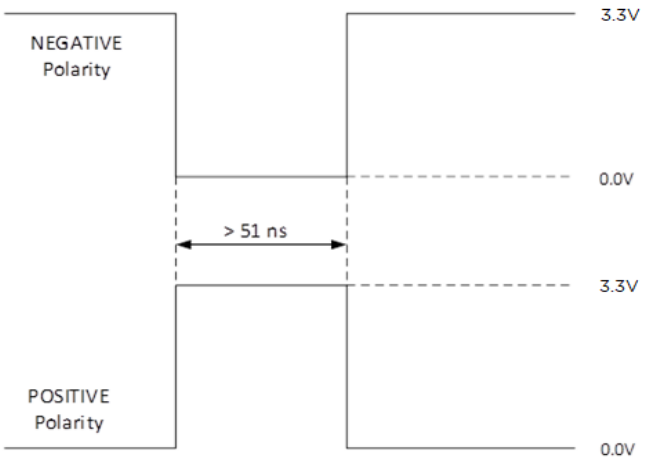



**Fig. 13.1. PPS pulse**

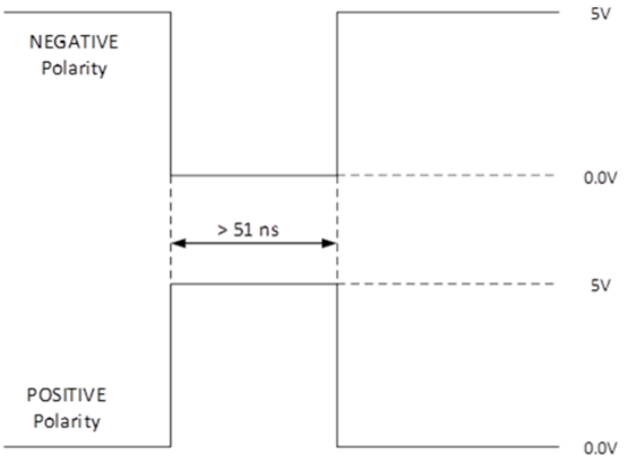



**Fig. 13.2. PPS pulse; 5V TTL (optional)**

The leading edge of the PPS pulse is always the trigger / reference:

- **Negative** – generates a normally high, active low pulse with the falling edge as the reference.
- **Positive** – generates a normally low, active high pulse with the rising edge as the reference.

Since INS firmware version 2.2.0.3, the PPS parameters are adjustable and can be set using the Inertial Labs™ INS GUI since version 2.0.22.84. To adjust PPS parameters, go to **"Options"** menu, then to **"Devices Options"**, **"Triggers"** tab (see Fig. 4.18). The following settings, inside the **PPS control** group, are available:

- **PPS signal** – allows configuring PPS signal mode (disabled, output, input). Default value is output PPS signal.
- **Polarity** – specifies the pulse polarity: negative or positive. Default is negative polarity.
- **Period (s)** – allows user to set period of PPS in seconds. To change this parameter, please select required value of the period from the drop-down list. Default value is 1.0 second.
- **Pulse width (µs)** – specifies the pulse width in microseconds. Default value of the parameter is 1000µs, and it can be changed to ±1 with arrows or by entering the necessary value from a keyboard.

## 13.2. Processing of Mark Input Signal

Since INS firmware version 2.2.0.3, the MARK IN pin can be used for mark input signal to trigger specific GNSS raw receiver data. TTL mark pulse configuration is the same as shown in Fig. 13.1. Adjustment of processing of the mark input signal is provided by the Inertial Labs™ INS GUI since version 2.0.22.84.

To control the processing of the mark input please go to the **"Options"** menu, then to **"Devices Options"**, **"Triggers"** tab (see Fig. 4.18). User will be able to do the following:

- enable or disable processing of the mark input signal, using the check box. Default is disabled processing of mark input.
- specify mark polarity (negative or positive). Default is negative polarity.
- set an offset, in nanoseconds, to be applied to the time the mark input pulse occurs. Default value is zero offset.
- set a time period, in milliseconds, during which subsequent pulses after an initial pulse are ignored. Default value is 4 milliseconds; minimum value is 2 milliseconds.

When a pulse is detected at mark input, the GNSS receiver generates asynchronous MARK2POS and MARK2TIME logs, which are added to the raw GNSS data listed in Table 12.1 in section "12. INS and GNSS Data Post-Processing".

## 13.3. INS Operation with LiDAR

For integration of Inertial Labs™ INS data with LiDAR, it is necessary to make the following connections of the INS to the LiDAR system:

- Use INS COM1 port for output of the main INS data.
- Use INS COM2 port for output of GNSS raw data generated by the INS onboard GNSS receiver.
- Connect INS COM3 port for output of $GPRMC messages issued by the INS onboard GNSS receiver to LiDAR.
- Connect pulse-per-second (PPS) signal generated by the INS onboard GNSS receiver to LiDAR.
- Optionally, for camera synchronization, connect the MARK IN pin for input signal from camera to trigger-specific GNSS receiver data (MARK2POS and MARK2TIME logs).

All of these data and signals are available on the main INS connector (see INS ICD, section “5. Electrical Interface”).

It is then necessary to adjust INS data and signals using the INS GUI. Note that the INS unit must be connected to a PC and powered to allow adjustments. Additionally, the correct PC COM-port number and its baud rate should be set.

### 13.3.1. Configuration of INS Main Data

Using **“Devices options”** from the **“Options”** menu (see section 4.2), set the required baud rate of the main COM-port and the measurement rate of INS data, and change other settings if necessary.

If the INS should be started automatically after power on, choose the necessary variant of output data in the **“Auto start”** field (see section 10.6 for details).

If the INS will be started using INS GUI, leave the **“No Auto start”** variant in “Auto start” field. Required variant of INS output data is set in **“Test options”** from the **“Options”** menu (see section “4.1.Test Options”).

### 13.3.2. Configuration of COM2 Port for Output of GNSS Raw Data

From the **“Devices options”** menu, use the **“GNSS receiver”** tab from the **“Options”** menu to make necessary settings in the “GNSS COM-Port 2” fields (see Fig. 4.4) Note that COM2 port baud rate restricts the maximum rate of GNSS raw data. See section “12.1. Recording of Raw GNSS Data” for details.

### 13.3.3. Configuration of COM3 Port for Output of $GPRMC Messages

From the **“Devices options”** menu, use the **“GNSS receiver”** tab from the **“Options”** menu to make necessary settings in the “GNSS COM-Port 3” fields (see Fig. 4.6). For example, if Velodyne VLP-16 LiDAR is used, then set as follows:

- 1 Hz for GPRMC data
- 9600 bps for COM3 port

### 13.3.4. Configuration of PPS Signal

From the **"Devices options"** menu, use the **"GNSS receiver"** tab from the **"Options"** menu to make necessary settings in the "PPS control" fields (see Fig. 4.6). For example, if Velodyne VLP-16 LiDAR is used then set as follows:

- positive polarity
- default 1.0 second period
- default 1000 microseconds pulse width

### 13.3.5. Configuration of Mark Input Signal

If mark input signal processing is enabled, then when the INS gets a mark pulse (from camera), it adds MARK2POS and MARK2TIME logs into raw GNSS data transferred through the COM2 port of the INS. NovAtel Waypoint Inertial Explorer can then process raw data and output results that only contain the marked points.

From the **"Devices options"** menu, use the **"GNSS receiver"** tab from the **"Options"** menu to make necessary settings in the "Mark inputs control" fields (see Fig. 4.6). See section "13.2. Processing of Mark Input Signal" for details.

# 14. The Procedure of INS Firmware and Parameters Updating

Since INS GUI version 2.0.50.348 from 2019-10-01, GUI software allows updates of device firmware and parameters with specific utility.

To begin, unpack the received ZIP file (such as **Device_fw_vx_x_x_x_and_prm_update.zip**) to any folder on the PC. The figures x_x_x_x shows the firmware version. This file consists of utility and configuration items for the updating procedure.

Utility can be run in two ways:

- with INS GUI
- directly with run of *.exe file

## 14.1. Using INS GUI for Firmware and Parameters Update

Step 1.

Connect device to a PC and power on.

Step 2.

Run INS GUI version 2.0.50.348 or higher.

Step 3.

In the **"Test options"** window, choose the COM-port to which the main port of the INS is connected, and set its baud rate (see Fig. 4.1), press "OK" button;

Step 4.

Choose **"Firmware and parameters update"** under the **"Plugins"** menu (see Fig. 14.1). The standard Windows "Open" window will appear, in which it is necessary to find the saved utility file **Device_fw_vx_x_x_x_and_prm_updating.exe** and press "Open". The utility's window will appear (see Fig. 14.2) with the COM-port number and its baud rate, as previously defined in the "Test options" window.

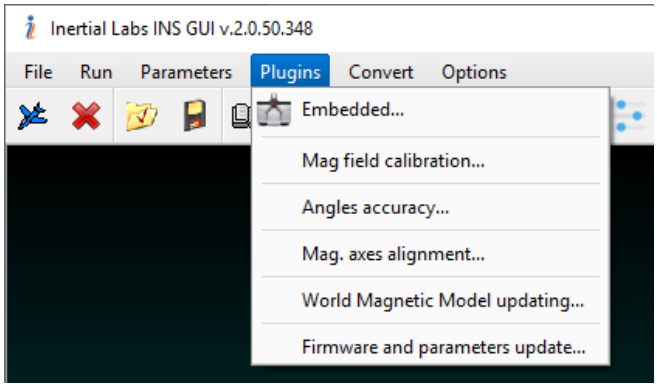



**Fig. 14.1.**

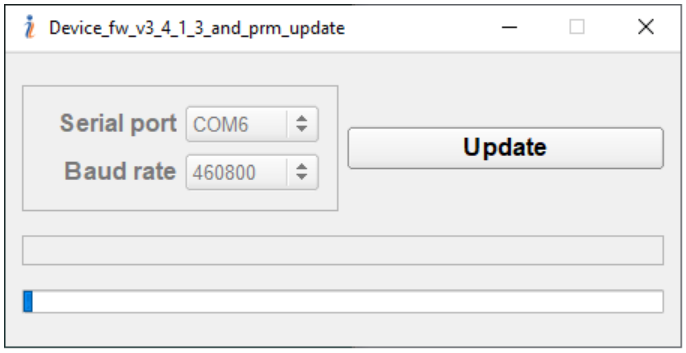



**Fig. 14.2.**

Step 5.

Click **"Update"**. The utility will ask for a file name for backup of current INS parameters. You can set this name or decline backup. Waite when INS parameters will be updated, after that the window in Fig. 14.3 will appear. Click **"OK"** to close this window. The firmware update is then started (see Fig. 14.4). Do not unplug or power off the device during the firmware update process.

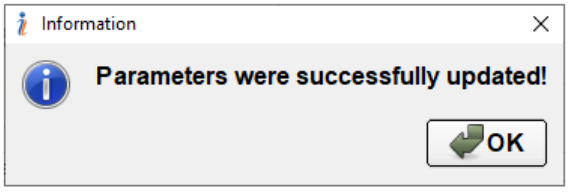



**Fig. 14.3.**

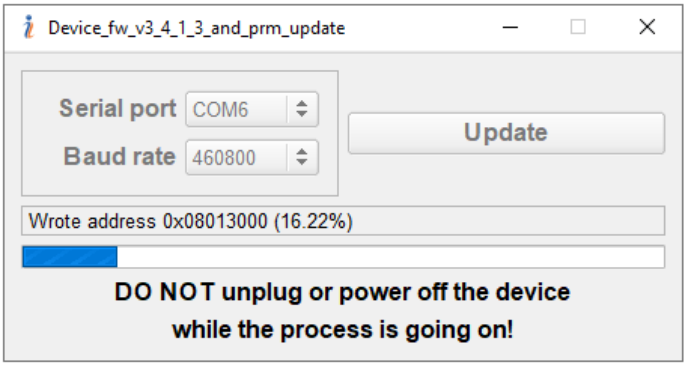



**Fig. 14.4.**

Step 6.

After completed, the firmware update INS will start, and window Fig. 14.5 will appear.

Device is ready for use.

**Note:** Some devices require a manual power-cycle after a firmware update. In such case, the window shown in Fig. 14.6 appears on the screen.

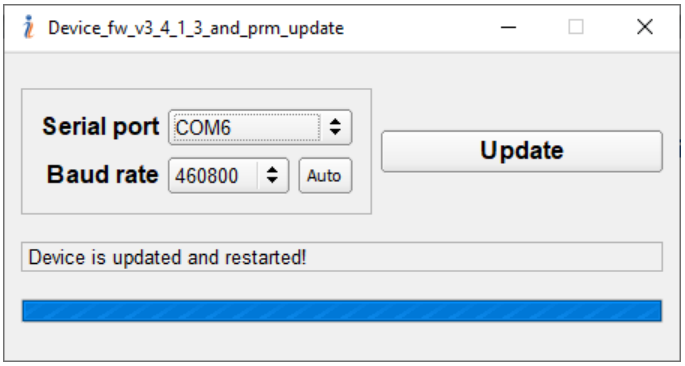



Fig. 14.5.

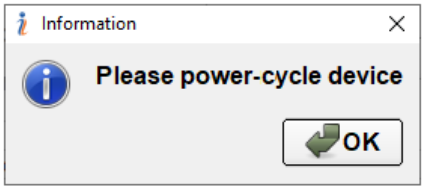



Fig. 14.6.

## 14.2. Direct Run of Firmware and Parameters Update Utility

The user has the ability to run the utility directly, excluding use of INS GUI. If this is the desired process, perform the following steps:

Step 1.

Connect the device to a PC and power on.

Step 2.

Find the utility file (**Device_fw_vx_x_x_x_and_prm_updating.exe**) in the unpacked folder and execute it. The window shown in Fig. 14.7 will appear on the screen. At this point, it is necessary to manually set the COM-port to which the main port of the INS is connected, as well as its baud rate.

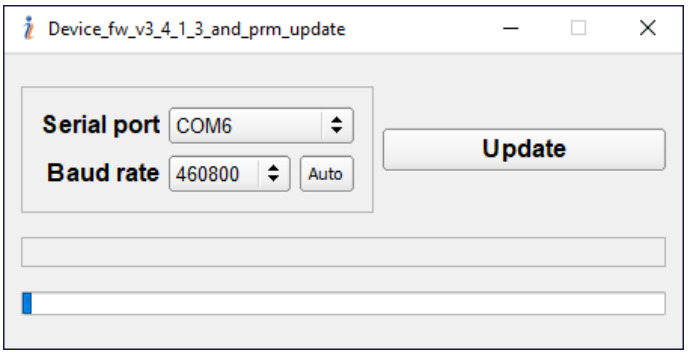



Fig. 14.7.

Step 3.

From this point, instructions to update device firmware and parameters are the same as the previous section shows. Perform Step 5 and Step 6 from section 14.1.

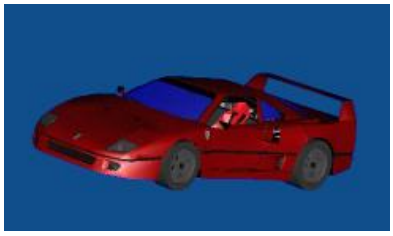
# 15. Choice of 3D Model for Visualization of the INS Orientation

The INS GUI software allows using different 3D models for visualization of the INS orientation angles when **"INS visualization** from the **"Run"** menu is used for work with the INS.

The default 3D model is an aircraft, as Fig. 5.1 shows. Other models are on flash drive in the subfolder "3D_Models" (in the folder containing the INS GUI software). The files model.mgl contain these models and appropriate screenshot files.

To set a desired 3D model for INS visualization, just copy the file **model.mgl** from the appropriate folder of 3D models to the "configs" subfolder (in the folder containing INS GUI software). Upon doing so, you should replace the existing file. Some examples of 3D models for the INS visualization are shown in Fig. 15.1.

Helicopter



Land Vehicle

Vessel

Submarine

**Fig. 15.1.**

# 16. Troubleshooting

## 16.1. What to do at Strange Behavior of the INS

Upon strange behavior of the INS, first check which parameters are loaded in the connected INS. This may occur, for example, if the user has restored parameters that correspond to another INS without a proper serial number. Please use the **"Restore parameters"** command to avoid wrong parameters loading into the INS's memory.

To check which parameters are loaded in the connected INS, please select **"Devices options"** from the **"Options"** menu (or click the icon) – see Fig. 3.7. The "Devices options" window (Fig. 4.2) will open.

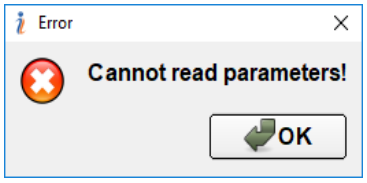
The field **"INS s/n"** lists the serial number of the INS. It must correspond to the serial number that is placed on the label on the INS's nose.

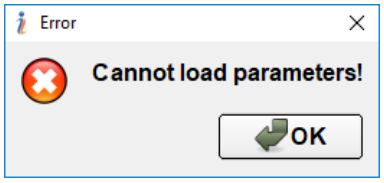
If **"INS s/n"** doesn't correspond to the serial number of the connected INS, the user must restore the original parameters as described in the above section.

If **"INS s/n"** corresponds to the INS serial number, but user continues witnessing strange behavior of the INS in heading, then this may be due to improper soft / hard iron calibration parameters loaded into the INS's memory.

If the INS has been removed from the carrier object, the user must clear parameters of soft / hard iron calibration. See section "10.4.2. Clearing of the Soft and Hard Iron Calibration Parameters" for details.

If the INS is mounted in another place in the carrier object or moved to another carrier object, then the user must repeat the soft / hard iron calibration procedure as described in section "10.4. Calibration of the INS".



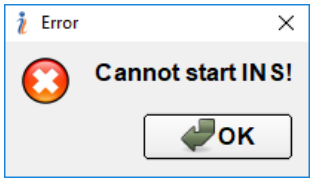




**Fig. 16.1.**

## 16.2. How to Repair the INS Parameters

In some cases, for example at incorrect loading of parameters into the INS memory, the INS parameters need to be repaired. If the INS parameters are corrupted, then the INS LED blinks red after power on.

You can use the original file with *.prm extension that comes on the flash drive within the Inertial Labs™ INS delivery package, or use your own files created by the **"Save parameters"** command (if these files contain valid data).

Follow these steps to restore INS parameters:

Step 1.

Connect the INS to a PC and power on.

Step 2.

Start the INS GUI software. The main menu will appear (see Fig. 3.1).

Step 3.

Select **"Test options"** from the **"Options"** menu (or click the icon) – see Fig. 3.7. The "Test options" window (Fig. 4.1) will open.

Step 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 INS is connected, see section "2. Installation of Drivers and Configuration of PC Parameters" and "Appendix A. Installation of the COM-to-USB converter drivers and configuration of the PC parameters".

Step 5.

Select **"Restore parameters"** in the **"Parameters"** menu (see Fig. 3.4) or click the icon. A standard Windows "Open" window will appear.

Step 6.

Select the file with extension *.prm containing the factory settings of the INS parameters or user's own file created by the "Save parameters" command (if this

file contains valid data). Click **"OK"**. These parameters will be loaded into INS memory automatically.

Step 7.

Switch off / on the INS unit to restart with correct parameters.

## 16.3. What to do if Messages "Cannot read parameters!", "Cannot load parameters!", or "Cannot start INS" Appear

When you use the Inertial Labs™ INS GUI" software, most operations are begun with reading data from the INS nonvolatile memory to control correct INS status. For this purpose, the INS should be powered and connected to a COM-port or USB-port using a COM-to-USB adapter.

When you see one of messages in Fig. 16.1, check the following:

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

Then simply click "**OK**" and repeat the operation.

# APPENDIX A.
# Installation of the COM-to-USB Converter Drivers and Configuration of PC Parameters

If connection of the INS to a computer is through a USB-port, in some cases it may be necessary to install a COM-to-USB converter driver. The converter driver is in the folder **COM_to_USB_Driver** on the flash drive within the Inertial Labs™ INS delivery package.

The sequence of the converter driver installation is as follows:

Go to the **Device Manager** window (Control Panel/System and Security/System/Device Manager). Under "Other Devices", user should see a device with a yellow warning symbol to indicate a problem once no driver installed, as shown in Fig. A.1. The text next to this icon will depend on the device attached. In this example, the device was a "USB Serial Cable".

Do right-click on the text (in this case "USB Serial Cable"), from the displayed menu and select **"Update Driver"** (see Fig. A.2).

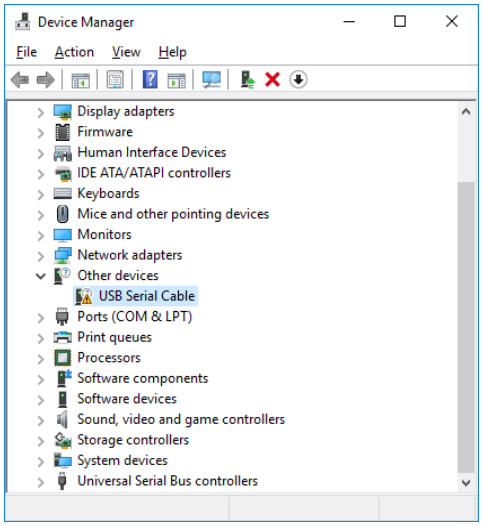



**Fig. A.1.**

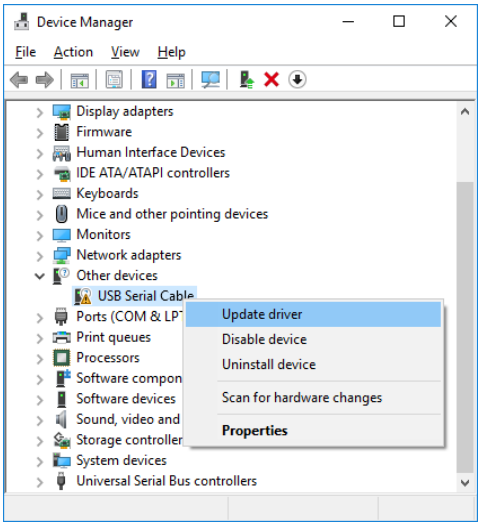



**Fig. A.2.**

Select **"Browse my computer for driver software"** (Fig. A.3), and in the address field put the exact location where the drivers have been saved (Fig. A.4). The location should be the top-level folder of the extracted files and contain two *.inf files.

Press the **"Next"** button. After the installation process, a completion screen is displayed, as shown in Fig. A.5.

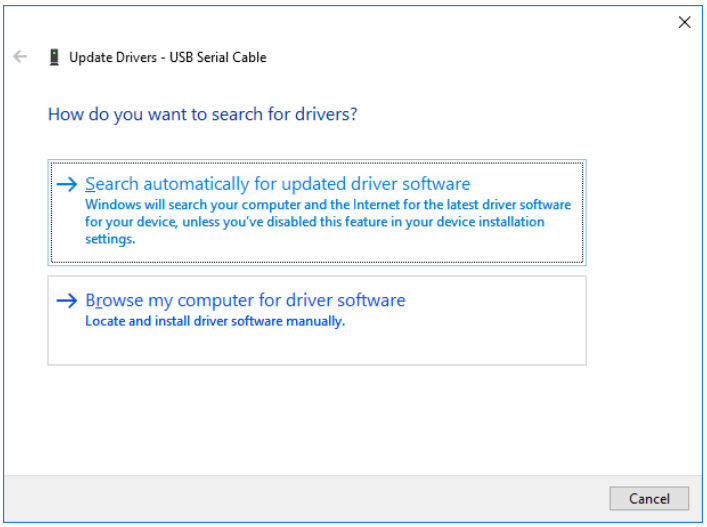



**Fig. A.3.**

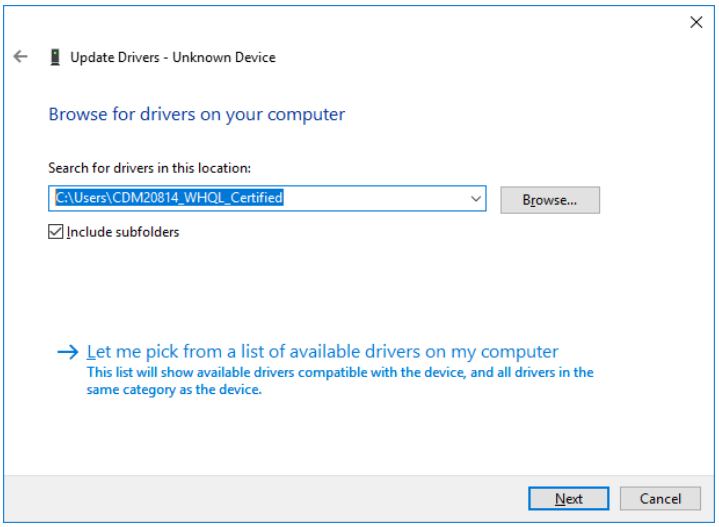



**Fig. A.4.**

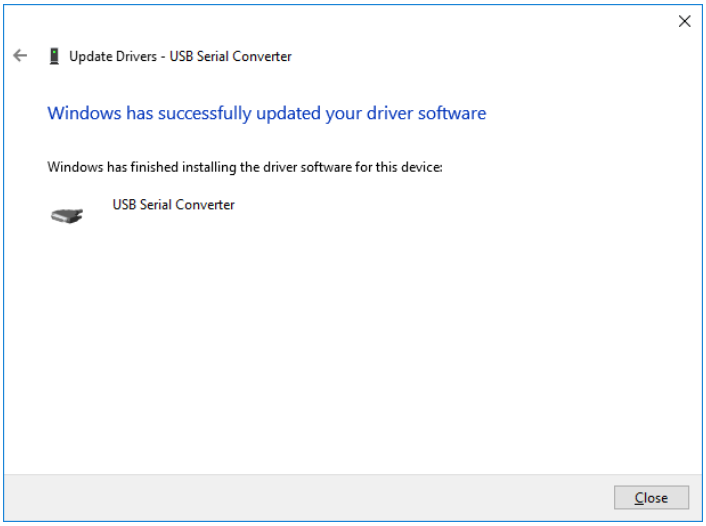



**Fig. A.5.**

Press **"Close"** to close this window and go back to the Device Manager Window.

There will be a new item under "Universal Serial Bus Controllers", as indicated in Fig. A.6 as the "USB Serial Converter". This indicates the bus layer of the driver has been installed.

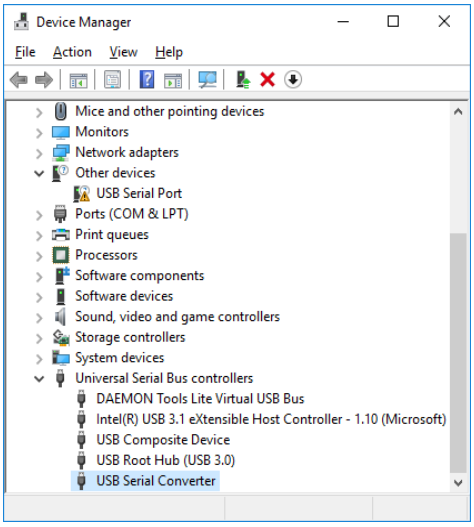



**Fig. A.6.**

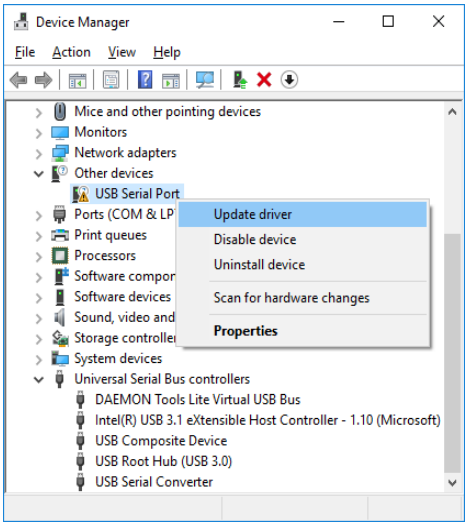



**Fig. A.7.**

Installing the Virtual COM-port layer of the driver is almost a repeat of the last few steps.

Do right-click on **"USB Serial Port"**, and from the displayed menu select **"Update Driver"**, as shown in Fig. A.7. Select **"Browse my computer for driver software"** (Fig. A.3), and in the address field put the location where the drivers have been saved (Fig. A.4).

Press **"Next"**. After the installation process, a completion screen is displayed, as shown in Fig. A.8.

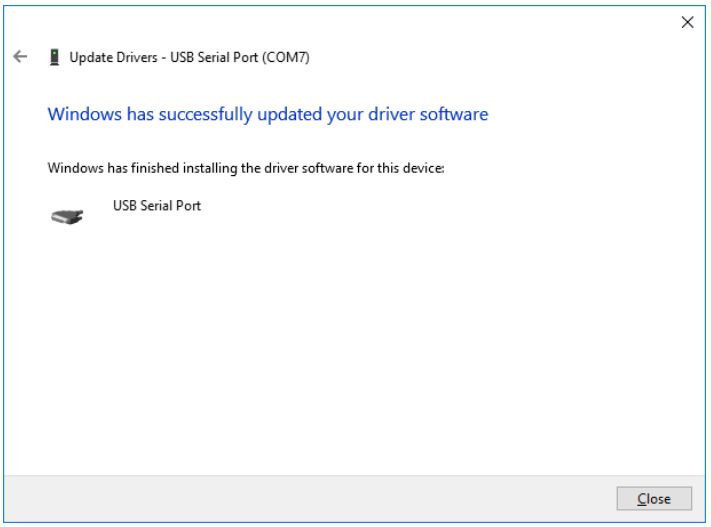



**Fig. A.8.**

Note, at the top of this screen also displays the COM-port number assigned to the device. Press **"Close"** to close this window and go back to the Device Manager Window.

This time the Device Manager does not have an item under “Other Devices” but it does show items under “Universal Serial Bus Controllers” and “Ports (COM & LPT)”. Fig. A.9 displays a correct installation. In this instance, the device is now ready to use on “COM7”.

Once the converter driver is installed, you will need to configure parameters of this port for correct operation of the INS.

Open the Properties window of this port by right-clicking on **“USB serial port (COM7)”** and select **“Properties”**, as Fig. A.10 shows.

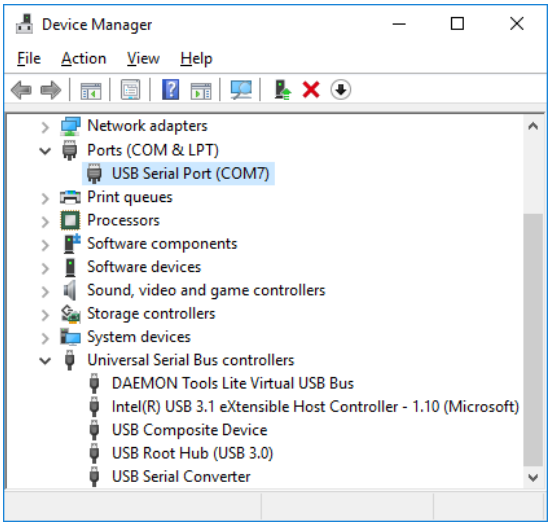



**Fig. A.9.**

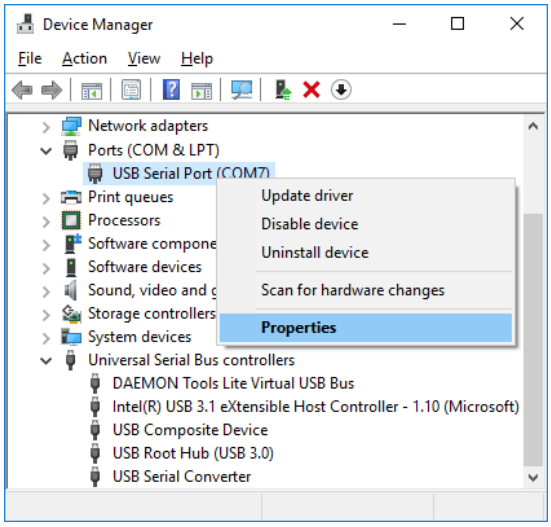



**Fig. A.10.**

At the new window, go to the **“Port Settings”** tab and press the **“Advanced”** button (see Fig. A.11).

In the opened **“Advanced Settings for COM7”** window, set the following parameters:

- Latency Timer (msec) to **4**
- Minimum Read Timeout (msec) to **0**
- Minimum Write Timeout (msec) to **0**

as it is shown on Fig. A.12, and click **“OK”.**

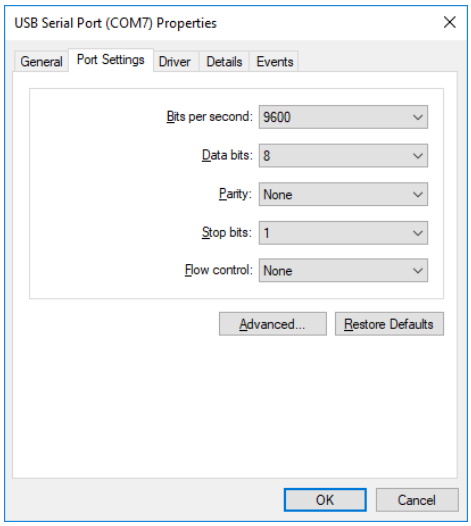



**Fig. A.11.**

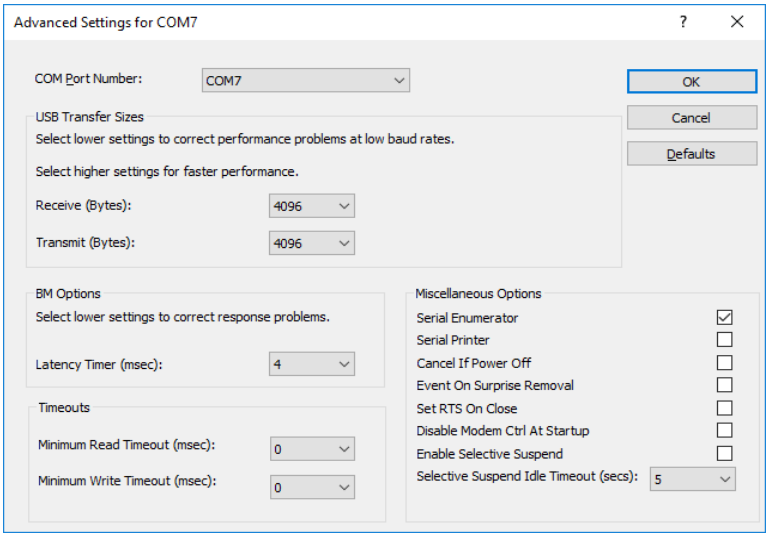



**Fig. A.12.**

In case of problems in COM-to-USB driver operation, user must make one more adjustment of the driver. In the **"Device Manager"** window go to the **"Universal Serial Bus controllers"** list, **"USB Serial Converter"** (see Fig. A.13). Click twice on this item to set properties. The window "USB Serial Controller Properties" will open; then go to the **"**Advanced**"** tab and check the **"**Load VCP**"** box (see Fig. A.14).

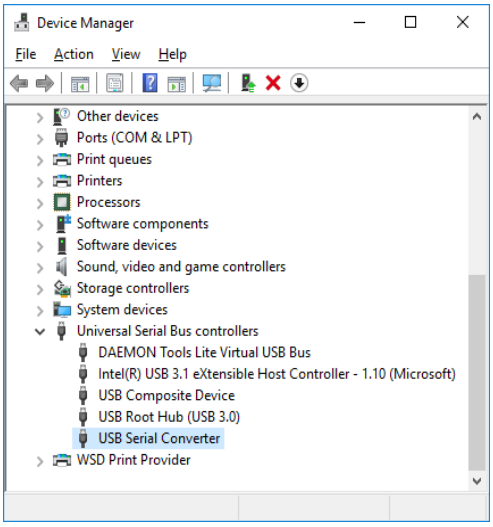



**Fig. A.13.**

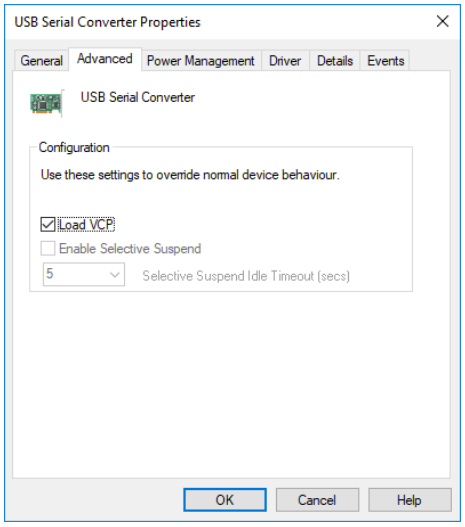



**Fig. A.14.**

# APPENDIX B.
# Installation of the MOXA Serial-to-USB Converter Drivers (for INS with RS-422 Interface)

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

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

Step 1.

Click twice on the icon of the downloaded driver window, shown in Fig. B.1.

Step 2.

Click the **"Next"** button, and the window shown in Fig. B.2 will appear. In the address box put the exact location where the drivers have been installed.

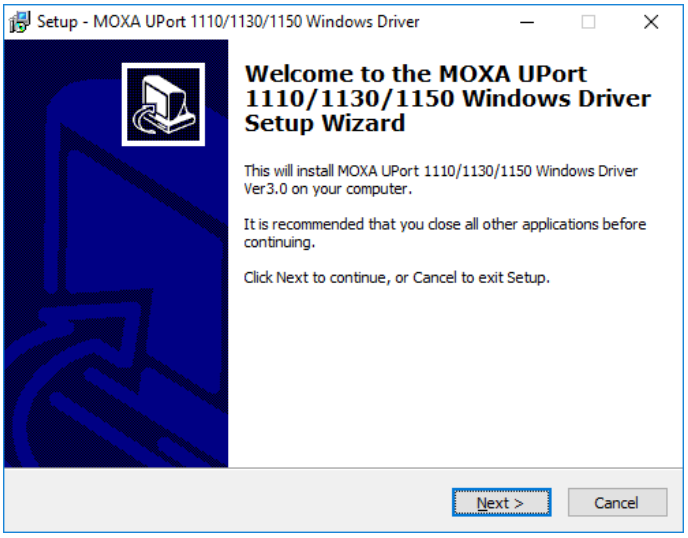



**Fig. B.1.**

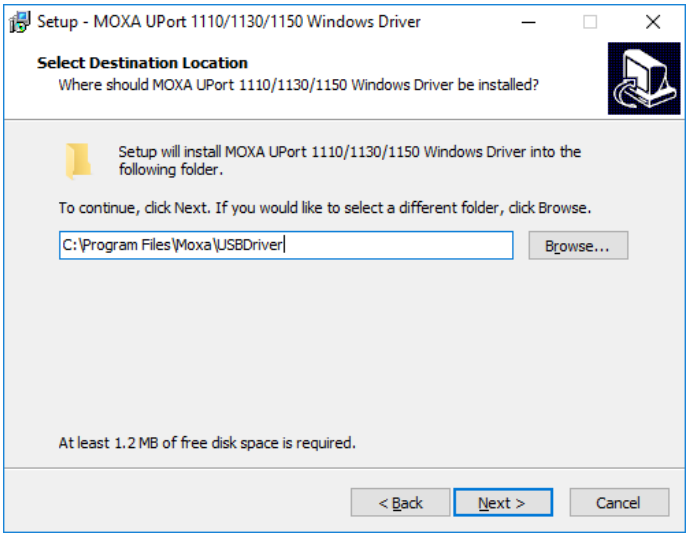



**Fig. B.2.**

Step 3.

Click **"Next"** to continue installation. Then the window shown in Fig. B.3 will appear. In the address box, put the location and name of the program's shortcuts, and click **"Next"**.

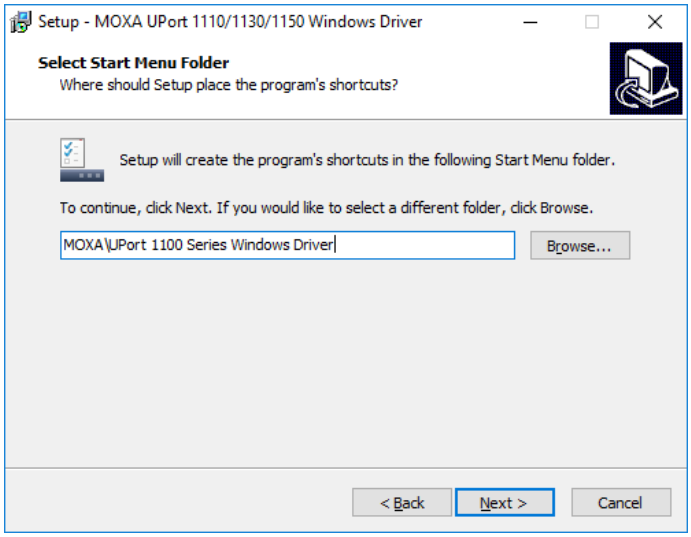



**Fig. B.3.**

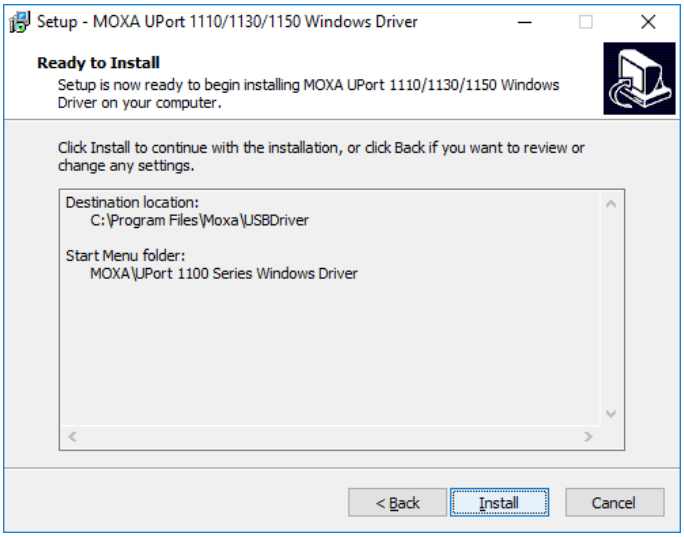



**Fig. B.4.**

Step 4.

Window Fig. B.4. will appear, at which point the user can check the setting correctness. If data are correct, click the **"Install"** button. If not, click the **"Back"** button to review and change any settings. When the installation is completed successfully, the window shown in Fig. B.5 will appear. Click **"Finish"** to close the installation window.

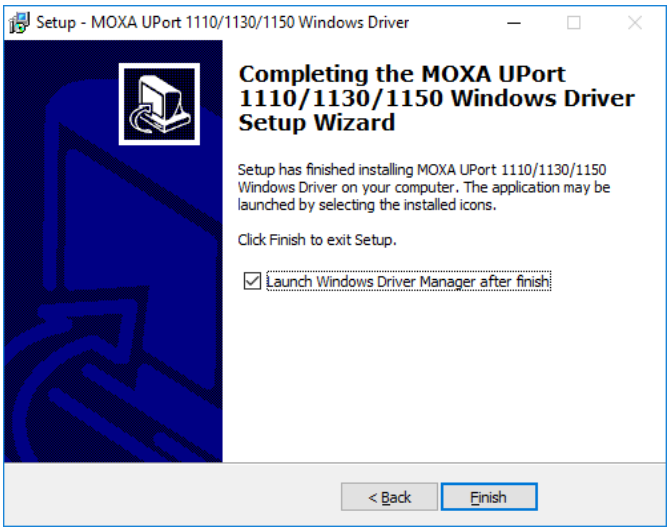



**Fig. B.5.**

Step 5.

The next step is configuration of the installed driver. To do this, press the **"Device Manager"** button in the **"System Properties"** window, located in the **"Hardware"** page. In the opened "Device Manager" window (see Fig. B.6), select **"Uport 1130"** in the "**Multiport serial adapters**" group.

Step 6.

Double-click on “Uport 1130” row to show window with its properties and then there go to the **“Ports Configuration”** tab (see Fig. B.7). Check that the **RS-422** interface is set (as Fig. B.7 shows). If another interface is set, then click **“Port Setting”**, and in the newly opened window (Fig. B.8), select only the **RS-422** interface. Click **“OK”** to accept this configuration.

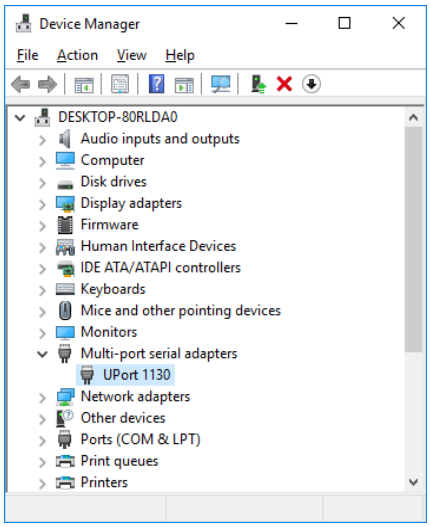



**Fig. B.6.**

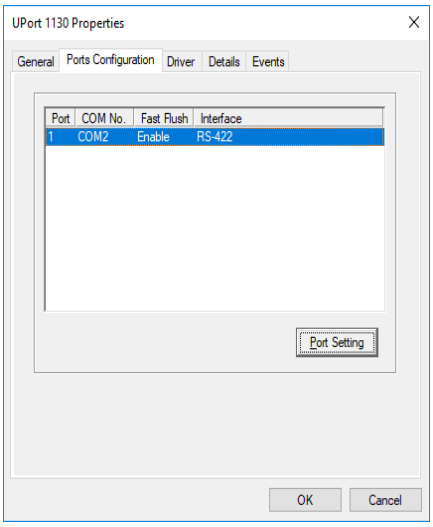



**Fig. B.7.**

Step 7.

For correct operation of the INS, once the converter driver is installed and configured, the user must determine the number of the additional COM-port set by the system and configure parameters of this port. To do this, return to the **“Device Manager”** window (Fig. B.6) and find the **“Ports (COM & LPT)”** list. There, an additional COM-port should have appeared: **“MOXA USB serial port (COMN)”** (see Fig. B.9). The letter “N” in the port name is the necessary port number assigned by the computer.

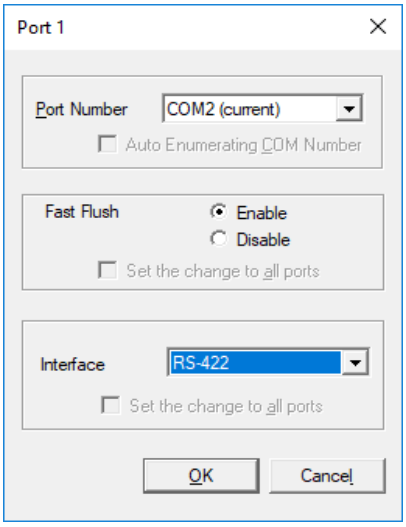

Port 1
Port Number
COM2 (current)
Auto Enumerating COM Number
Fast Flush
Enable
Disable
Set the change to all ports
Interface
RS-422
Set the change to all ports
OK
Cancel

Fig. B.8.

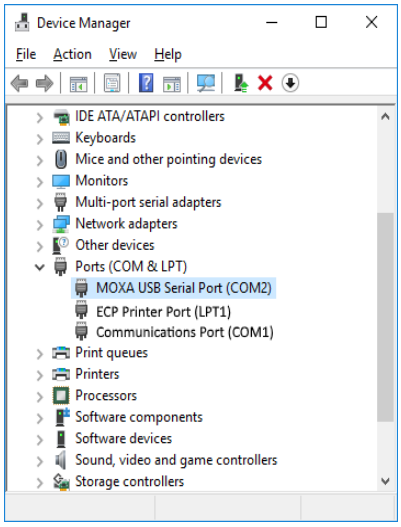

Device Manager
File
Action
View
Help
IDE ATA/ATAPI controllers
Keyboards
Mice and other pointing devices
Monitors
Multi-port serial adapters
Network adapters
Other devices
Ports (COM & LPT)
MOXA USB Serial Port (COM2)
ECP Printer Port (LPT1)
Communications Port (COM1)
Print queues
Printers
Processors
Software components
Software devices
Sound, video and game controllers
Storage controllers

Fig. B.9.

# APPENDIX C.
# Description of Data Files

The Inertial Labs™ INS GUI software creates data files if the **"Write"** button is pressed after INS start. These are two binary files with the same name plus extensions *.prm and *.bin, where the *.prm file contains the INS parameters and the *.bin file contains the INS outputs. Select **"Report of experiment"** from the **"Convert"** menu of the INS GUI, or press F8, or click the icon to convert these binary data to a text file (see section 9 for more details).

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

## C.1. Structure of Binary File

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

The first 50 bytes of the *.bin file are results of the INS initial alignment (see Table C.1).

**Table C.1. Structure of the first 50 bytes of *.bin file (short block of initial alignment data)**

| Byte | Parameter | Format | Length | *Note* |
|---|---|---|---|---|
| 0 – 11 | Gyros bias | float | 3*4 | 3 numbers in ADC codes |
| 12 – 23 | Average acceleration | float | 3*4 | 3 numbers in ADC codes |
| 24 – 35 | Average magn. field | float | 3*4 | 3 numbers in ADC codes |
| 36 – 39 | Initial heading | float | 4 | degrees |
| 40 – 43 | Initial roll | float | 4 | degrees |
| 44 – 47 | Initial pitch | float | 4 | degrees |
| 48 – 49 | USW | word | 2 | 0 – successful initial alignment;<br>≠0 – unsuccessful initial alignment |

**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 following text it is denoted that
   - word = unsigned 2-byte integer
   - sword = signed 2-byte integer
3. LSB is transmitted first.

Since INS firmware version 2.6.2.0, the user can choose extended block of the initial alignment data in the **"Devices options"** menu item, **"IMU"** tab, **"Extended initial alignment data"** check-box (see Fig. 4.19). In this case, the first 128 bytes of the *.bin file are an extended form of results of the INS initial alignment (see Table C.2).

**Table C.2. Structure of the first 128 bytes of *.bin file at extended block of initial alignment data**

| Byte | Parameter | Format | Length | *Note* |
|---|---|---|---|---|
| 0 – 11 | Gyros bias | float | 3*4 | 3 numbers in ADC codes |
| 12 – 23 | Average acceleration | float | 3*4 | 3 numbers in ADC codes |
| 24 – 35 | Average magn. field | float | 3*4 | 3 numbers in ADC codes |
| 36 – 39 | Initial heading | float | 4 | degrees |
| 40 – 43 | Initial roll | float | 4 | degrees |
| 44 – 47 | Initial pitch | float | 4 | degrees |
| 48 – 49 | USW (see Appendix D) | word | 2 | 0 – successful initial alignment<br>≠0 – unsuccessful initial alignment |
| 50 – 53 | Pressure sensor temperature, UT_sr | long | 4 | in ADC codes |
| 54 – 57 | Pressure data, UP_sr | long | 4 | in ADC codes |
| 58 – 75 | Temperatures in 3 gyros, 3 accelerometers, 3 magnetometers | sword | 9*2 | in ADC codes |
| 76 – 83 | Latitude | double | 8 | degrees |
| 84 – 91 | Longitude | double | 8 | degrees |
| 92 – 99 | Altitude | double | 8 | m |
| 100 – 103 | Velocity V_east | float | 4 | m/s |
| 104 – 107 | Velocity V_north | float | 4 | m/s |
| 108 – 111 | Velocity V_up | float | 4 | m/s |
| 112 – 119 | Gravity, G_true | double | 8 | $m/s^2$ |
| 120 – 123 | Reserved1 | float | 4 | |
| 124 – 127 | Reserved2 | float | 4 | |

It is recommended to choose the extended block of the initial alignment data, which contains more information about results of initial alignment procedure. Short block is kept more for compatibility with older versions of INS firmware and INS GUI.

All of the following data in the *.bin file are blocks of the INS output data written at INS operation with set data rate. Each data block has a structure according to the chosen output format: "INS OPVT" (Table C.3), "INS QPVT" (Table C.8), "INS OPVT2A" (Table C.9), "INS OPVT2AW" (Table C.10), "INS OPVT2AHR" (Table C.11), "INS OPVTAD" (Table C.12), "INS Sensors Data" (Table C.14), "INS Minimal Data"(Table C.20), "INS OPVT & Raw IMU Data" (Table C.21), "SPAN rawimu" (Table C.22), "INS OPVT GNSSext" (Table C.26), "User Defined Data" (Table C.28), "INS NMEA", "INS Sensors NMEA", "Cobham UAV 200 Satcom" (Table C.31), and "NAV440" (Table C.32).

**Table C.3. The INS message payload at the "INS OPVT" (Orientation, Position, Velocity, Time) data format**

| Byte number | 0 – 1 | 2 – 3 | 4 – 5 | 6 – 11 | 12 – 17 | 18 – 23 |
|---|---|---|---|---|---|---|
| Parameter | Heading | Pitch | Roll | GyroX, GyroY, GyroZ | AccX, AccY, AccZ | MagX, MagY, MagZ |
| Length | 2 byte word | 2 byte sword | 2 byte sword | 3×2 byte sword | 3×2 byte sword | 3×2 byte sword |
| *Note* | Orientation angles, deg*100 | | | Angular rates, deg/s*KG | Accelerations, g*KA | Magnetic fields, nT/10 |

**Table C.3 (continued)**

| Byte number | 24 – 25 | 26 – 27 | 28 – 29 | 30 – 33 | 34 – 37 | 38 – 41 |
|---|---|---|---|---|---|---|
| Parameter | USW | Vinp | Temper | Latitude | Longitude | Altitude |
| Length | 2 byte word | 2 byte word | 2 byte sword | 4 byte integer | 4 byte integer | 4 byte integer |
| *Note* | | Supply voltage, VDC*100 | Temperature, °C*10 | deg *1.0e7 | deg *1.0e7 | m*100 |

**Table C.3 (continued)**

| Byte number | 42 – 45 | 46 – 49 | 50 – 53 | 54 – 57 | 58 – 61 | 62 – 65 |
|---|---|---|---|---|---|---|
| Parameter | East speed | North speed | Vertical speed | Latitude GNSS | Longitude GNSS | Altitude GNSS |
| Length | 4 byte integer | 4 byte integer | 4 byte integer | 4 byte integer | 4 byte integer | 4 byte integer |
| *Note* | m/s*100 | m/s*100 | m/s*100 | deg *1.0e7 | deg *1.0e7 | m*100 |

**Table C.3 (continued)**

| Byte number | 66 – 69 | 70 – 71 | 72 – 75 | 76 – 79 | 80 | 81 |
|---|---|---|---|---|---|---|
| Parameter | Horizontal speed GNSS | Track over ground GNSS | Vertical speed GNSS | ms_gps | GNSS_info1 | GNSS_info2 |
| Length | 4 byte integer | 2 byte word | 4 byte integer | 4 byte | 1 byte | 1 byte |
| *Note* | m/s*100 | deg*100 | m/s*100 | ms | | |

**Table C.3 (continued)**

| Byte number | 82 | 83 | 84 | 85 – 86 | 87 – 90 | 91 |
|---|---|---|---|---|---|---|
| Parameter | #solnSVs | Latency ms_pos | Latency ms_vel | P_bar | H_bar | New GPS |
| Length | 1 byte | 1 byte | 1 byte | 2 byte word | 4 byte integer | 1 byte |
| *Note* | | ms | ms | Pa/2 | m*100 | |

**Notes:**

1. Orientation, position, and velocity data can be presented in the form of instant or average values (see section 4.2.1, "Averaged Output Data" checkbox and INS ICD Appendix E.1 for details).
2. Gyros, accelerometers, and magnetometers data can be presented in the form of instant, average, or incremental values (see section 4.4).
3. Values of KG, KA are scale factors depending on gyro and accelerometer range (see Table C.4).
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 INS orientation relative to the carrier object axes is set by alignment angles (see "Appendix E. Variants of the Inertial Labs™ INS Mounting Relative to the Object Axes").
5. g = 9.8106 m/s$^2$.
6. USW is unit status word (see Appendix D for details).
7. Vinp is input voltage of the INS.
8. Temper is averaged temperature in 3 gyros.
9. ms_gps are milliseconds from the beginning of the GPS reference week.
10. GNSS_info1 and GNSS_info2 contain information about GNSS data (see Table C.5 amd Table C.6);
11. #SolnSVs is the number of satellites used in the navigation solution.
12. V_latency is latency in the velocity time tag in milliseconds.
13. P_bar, H_bar are pressure and barometric height.
14. New_GPS is indicator of new update of GPS data (see Table C.7).
15. LSB is transmitted first.

**Table C.4. Values of KG, KA factors for gyro and accelerometer scaled data**

| Gyro range, deg/sec | 450 | 950 |
|---|---|---|
| KG | 50 | 20 |

| Accelerometer range, g | 8 | 15 | 40 |
|---|---|---|---|
| KA | 4000 | 2000 | 500 |

**Table C.5. GNSS_info1 – information about GNSS data**

| Bit | Value and Description |
|---|---|
| 0 – 3 | Position type:<br>0 – Single point position<br>1 – DGPS (pseudorange differential solution)<br>2 – Solution calculated using corrections from SBAS<br>3 – PPP solution<br>4 – RTK (other) solution<br>5 – RTK (narrow-int) solution<br>6 – Other<br>7 – Converging TerraStar-C, TerraStar-C PRO, TerraStar-X solution or Oceanix<br>8 – Converged TerraStar-C, TerraStar-C PRO, TerraStar-X solution or Oceanix<br>9 – Converging TerraStar-L solution<br>10 – Converged TerraStar-L solution |
| 4 – 7 | Pseudorange iono correction:<br>0 – unknown or default Klobuchar model |

| | |
|---|---|
| | 1 – Klobuchar Broadcast<br>2 – SBAS Broadcast<br>3 – Multi-frequency Computed<br>4 – DGPS (pseudorange differential correction)<br>5 – NovAtel Blended Iono Value |

**Table C.6. GNSS_info2 – information about GNSS data**

| Bit | Value and Description |
|---|---|
| 0 – 1 | Solution status: 0 – GNSS solution is computed<br>1 – insufficient observations<br>2 – not yet converged from cold start<br>3 – other reason of absent solution |
| 2 – 3 | GPS reference time status: 0 – time validity is unknown<br>1 – time is coarse set and is being steered<br>2 – position is lost and the range bias cannot be calculated<br>3 – time is fine set and is being steered |
| 4 | 1 – GPS GNSS signal is used |
| 5 | 1 – GLONASS GNSS signal is used |
| 6 | 1 – Galileo GNSS signal is used |
| 7 | 1 – BeidDou GNSS signal is used |

**Table C.7. New_GPS indicator of new update of GNSS data**

| Bit | Value and Description |
|---|---|
| 0 | 1 – GNSS position data update |
| 1 | 1 – GNSS velocity data update |
| 2 | 1 – GNSS heading data update |
| 3 | 1 – valid 1PPS signal received |
| 4 | 1 – GNSS BESTXYZ log update |
| 5 | 1 – GNSS PSRDOP log update |

***Note:*** INS onboard GNSS receiver generates 1PPS signal at all times, but the New_GPS indicator sets bit #3 to 1 only if GPS reference time status is fine (see also Table C.6).

**Table C.8. The INS message payload at the "INS QPVT" (Quaternion of orientation, position, velocity, time) data format**

| Byte number | 0 – 7 | 8 – 13 | 14 – 19 | 20 – 25 | 26 – 27 |
|---|---|---|---|---|---|
| Parameter | q0,q1,q2,q3 | GyroX, GyroY, GyroZ | AccX, AccY, AccZ | MagX, MagY, MagZ | USW |
| Length | 4×2 byte sword | 3×2 byte sword | 3×2 byte sword | 3×2 byte sword | 2 byte word |
| *Note* | Quaternion of orientation *10000 | Angular rates, deg/s*KG | Accelerations g*KA | Magnetic fields, nT/10 | |

**Table C.8 (continued)**

| Byte number | 28 – 29 | 30 – 31 | 32 – 35 | 36 – 39 | 40 – 43 | 44 – 47 |
|---|---|---|---|---|---|---|
| Parameter | Vinp | Temper | Latitude | Longitude | Altitude | East speed |
| Length | 2 byte word | 2 byte sword | 4 byte integer | 4 byte integer | 4 byte integer | 4 byte integer |
| *Note* | Supply voltage, VDC*100 | Temperature, °C*10 | deg *1.0e7 | deg *1.0e7 | m*100 | m/s*100 |

**Table C.8 (continued)**

| Byte number | 48 – 51 | 52 – 55 | 56 – 59 | 60 – 63 | 64 – 67 | 68 – 71 |
|---|---|---|---|---|---|---|
| Parameter | North speed | Vertical speed | Latitude GNSS | Longitude GNSS | Altitude GNSS | Horizontal speed GNSS |
| Length | 4 byte integer | 4 byte integer | 4 byte integer | 4 byte integer | 4 byte integer | 4 byte integer |
| *Note* | m/s*100 | m/s*100 | deg *1.0e7 | deg *1.0e7 | m*100 | m/s*100 |

**Table C.8 (continued)**

| Byte number | 72 – 73 | 74 – 77 | 78 – 81 | 82 | 83 |
|---|---|---|---|---|---|
| Parameter | Track over ground GNSS | Vertical speed GNSS | ms_gps | GNSS info1 | GNSS info2 |
| Length | 2 byte word | 4 byte integer | 4 byte | 1 byte | 1 byte |
| *Note* | deg*100 | m/s*100 | ms | | |

**Table C.8 (continued)**

| Byte number | 84 | 85 | 86 | 87 – 88 | 89 – 92 | 93 |
|---|---|---|---|---|---|---|
| Parameter | #SolnSVs | Latency ms_pos | Latency ms_vel | P_bar | H_bar | New GPS |
| Length | 1 byte | 1 byte | 1 byte | 2 byte word | 4 byte integer | 1 byte |
| *Note* | | ms | ms | Pa/2 | m*100 | |

**Notes:**

1. The "INS QPVT" data format is implemented in INS firmware since version 2.1.2.0.
2. Orientation, position, and velocity data can be presented in the form of instant or average values (see section 4.2.1, "Averaged output data" checkbox and INS ICD Appendix E.1 for details).
3. Gyros, accelerometers, and magnetometers data can be presented in the form of instant, average, or incremental values (see section 4.4).
4. See detailed description for the correct relationship between orientation angles and quaternion in the INS ICD, rev.1.7 or higher, "Appendix D. Forms of the Inertial Labs ™ INS Orientation Presentation".
5. Values of KG, KA are scale factors depending on gyro and accelerometer range (see Table C.4)

6. 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 INS orientation relative to the carrier object axes is set by alignment angles (see "Appendix E. Variants of the Inertial Labs™ INS Mounting Relative to the Object Axes").
7. g = 9.8106 m/s$^2$.
8. USW is unit status word (see Appendix D for details).
9. Vinp is input voltage of the INS.
10. Temper is averaged temperature in 3 gyros.
11. ms_gps are milliseconds from the beginning of the GPS reference week;
12. GNSS_info1 and GNSS_info2 contain information about GNSS data (see Table C.5 and Table C.6).
13. #SolnSVs is number of satellites used in navigation solution.
14. V_latency is latency in the velocity time tag in milliseconds.
15. P_bar and H_bar are pressure and barometric height.
16. New_GPS is indicator of new update of GPS data (see Table C.7).
17. LSB is transmitted first.

**Table C.9. The INS message payload at the "INS OPVT2A" (Orientation, Position, Velocity, Time, Dual-antenna receiver data) format**

| Byte number | 0 – 1 | 2 – 3 | 4 – 5 | 6 – 11 | 12 – 17 | 18 – 23 |
|---|---|---|---|---|---|---|
| Parameter | Heading | Pitch | Roll | GyroX, GyroY, GyroZ | AccX, AccY, AccZ | MagX, MagY, MagZ |
| Length | 2 byte word | 2 byte sword | 2 byte sword | 3×2 byte sword | 3×2 byte sword | 3×2 byte sword |
| *Note* | Orientation angles, deg*100 | | | Angular rates, deg/s*KG | Accelerations, g*KA | Magnetic fields, nT/10 |

**Table C.9 (continued)**

| Byte number | 24 – 25 | 26 – 27 | 28 – 29 | 30 – 33 | 34 – 37 |
|---|---|---|---|---|---|
| Parameter | USW | Vinp | Temper | Latitude | Longitude |
| Length | 2 byte word | 2 byte word | 2 byte sword | 4 byte integer | 4 byte integer |
| *Note* | | Supply voltage, VDC*100 | Temperature, °C*10 | deg *1.0e7 | deg *1.0e7 |

**Table C.9 (continued)**

| Byte number | 38 – 41 | 42 – 45 | 46 – 49 | 50 – 53 | 54 – 57 | 58 – 61 |
|---|---|---|---|---|---|---|
| Parameter | Altitude | East speed | North speed | Vertical speed | Latitude GNSS | Longitude GNSS |
| Length | 4 byte integer | 4 byte integer | 4 byte integer | 4 byte integer | 4 byte integer | 4 byte integer |
| *Note* | m*100 | m/s*100 | m/s*100 | m/s*100 | deg *1.0e7 | deg *1.0e7 |

**Table C.9 (continued)**

| Byte number | 62 – 65 | 66 – 69 | 70 – 71 | 72 – 75 | 76 – 79 |
|---|---|---|---|---|---|
| Parameter | Altitude GNSS | Horizontal speed GNSS | Track over ground GNSS | Vertical speed GNSS | ms_gps |
| Length | 4 byte integer | 4 byte integer | 2 byte word | 4 byte integer | 4 byte |
| *Note* | m*100 | m/s*100 | deg*100 | m/s*100 | ms |

**Table C.9 (continued)**

| Byte number | 80 | 81 | 82 | 83 – 84 | 85 | 86 – 87 |
|---|---|---|---|---|---|---|
| Parameter | GNSS_info1 | GNSS_info2 | #solnSVs | V_latency | Angles position type | Heading GNSS |
| Length | 1 byte | 1 byte | 1 byte | 2 byte word | 1 byte | 2 byte word |
| *Note* | | | | s*1000 | | deg*100 |

**Table C.9 (continued)**

| Byte number | 88 – 89 | 90 – 91 | 92 – 93 | 94 – 95 | 96 – 99 | 100 |
|---|---|---|---|---|---|---|
| Parameter | Latency ms_head | Latency ms_pos | Latency ms_vel | P_bar | H_bar | New GPS |
| Length | 2 byte sword | 2 byte sword | 2 byte sword | 2 byte word | 4 byte integer | 1 byte |
| *Note* | ms | | | Pa/2 | M*100 | |

**Notes:**

1. Orientation, position, and velocity data can be presented in the form of instant or average values (see section 4.2.1, “Averaged Output Data” checkbox and INS ICD Appendix E.1 for details).
2. Gyros, accelerometers, and magnetometers data can be presented in the form of instant, average, or incremental values (see section 4.4).
3. Values of KG, KA are scale factors depending on gyro and accelerometer range (see Table C.4)
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 INS orientation relative to the carrier object axes is set by alignment angles (see “Appendix E. Variants of the Inertial Labs™ INS Mounting Relative to the Object Axes”).
5. g = 9.8106 m/s$^2$.
6. USW is unit status word (see Appendix D for details).
7. Vinp is input voltage of the INS.
8. Temper is averaged temperature in 3 gyros.
9. ms_gps are milliseconds from the beginning of the GPS reference week.
10. GNSS_info1, GNSS_info2 contain information about GNSS data (see Table C.5, Table C.6).
11. #SolnSVs is number of satellites used in navigation solution.
12. V_latency is latency in the velocity time tag in milliseconds.

13. Angles position type is GNSS position type at orientation calculation using dual GNSS antennas. If this value is less than 100, see its description in Table C.16. Otherwise subtract 100 from the "Angles position type" and refer again to Table C.16.
14. P_bar and H_bar are pressure and barometric height.
15. New_GPS is indicator of new update of GPS data (see Table C.7).
16. LSB is transmitted first.

**Table C.10. The INS message payload at the "INS OPVT2AW" (Orientation, Position, Velocity, Time, Dual-antenna receiver data, GPS Week) format**

| Byte number | 0 – 1 | 2 – 3 | 4 – 5 | 6 – 11 | 12 – 17 | 18 – 23 |
|---|---|---|---|---|---|---|
| Parameter | Heading | Pitch | Roll | GyroX, GyroY, GyroZ | AccX, AccY, AccZ | MagX, MagY, MagZ |
| Length | 2 byte word | 2 byte sword | 2 byte sword | 3×2 byte sword | 3×2 byte sword | 3×2 byte sword |
| *Note* | Orientation angles, deg*100 | | | Angular rates, deg/s*KG | Accelerations g*KA | Magnetic fields, nT/10 |

**Table C.10 (continued)**

| Byte number | 24 – 25 | 26 – 27 | 28 – 29 | 30 – 33 | 34 – 37 | 38 – 41 |
|---|---|---|---|---|---|---|
| Parameter | USW | Vinp | Temper | Latitude | Longitude | Altitude |
| Length | 2 byte word | 2 byte word | 2 byte sword | 4 byte integer | 4 byte integer | 4 byte integer |
| *Note* | | Supply voltage, VDC*100 | Temperature, °C*10 | deg *1.0e7 | deg *1.0e7 | m*100 |

**Table C.10 (continued)**

| Byte number | 42 – 45 | 46 – 49 | 50 – 53 | 54 – 57 | 58 – 61 |
|---|---|---|---|---|---|
| Parameter | East speed | North speed | Vertical speed | Latitude GNSS | Longitude GNSS |
| Length | 4 byte integer | 4 byte integer | 4 byte integer | 4 byte integer | 4 byte integer |
| *Note* | m/s*100 | m/s*100 | m/s*100 | deg *1.0e7 | deg *1.0e7 |

**Table C.10 (continued)**

| Byte number | 62 – 65 | 66 – 69 | 70 – 71 | 72 – 75 | 76 – 79 | 80 – 81 |
|---|---|---|---|---|---|---|
| Parameter | Altitude GNSS | Horizontal speed GNSS | Track over ground GNSS | Vertical speed GNSS | ms_gps | GPS week |
| Length | 4 byte integer | 4 byte integer | 2 byte word | 4 byte integer | 4 byte | 2 byte word |
| *Note* | m*100 | m/s*100 | deg*100 | m/s*100 | ms | |

**Table C.10 (continued)**

| Byte number | 82 | 83 | 84 | 85 | 86 | 87 |
|---|---|---|---|---|---|---|
| Parameter | GNSS_info1 | GNSS_info2 | #solnSVs | Latency ms_pos | Latency ms_vel | Angles position type |
| Length | 1 byte | 1 byte | 1 byte | 1 byte | 1 byte | 1 byte |
| *Note* | | | | ms | ms | |

**Table C.10 (continued)**

| Byte number | 88 – 89 | 90 – 91 | 92 – 93 | 94 – 95 | 96 – 97 | 98 – 101 | 102 |
|---|---|---|---|---|---|---|---|
| Parameter | Heading GNSS | Pitch GNSS | Heading STD GNSS | Pitch STD GNSS | P_bar | H_bar | New GPS |
| Length | 2 byte word | 2 byte sword | 2 byte word | 2 byte word | 2 byte word | 4 byte integer | 1 byte |
| *Note* | Orientation angles, deg*100 | | STD, deg*100 | | Pa/2 | m*100 | |

**Notes:**

1. Orientation, position, and velocity data can be presented in the form of instant or average values (see section 4.2.1, “Averaged Output Data” checkbox and INS ICD Appendix E.1 for details).
2. Gyros, accelerometers, and magnetometers data can be presented in the form of instant, average, or incremental values (see section 4.4).
3. Values of KG, KA are scale factors depending on gyro and accelerometer range(see Table C.4)
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 INS orientation relative to the carrier object axes is set by alignment angles (see “Appendix E. Variants of the Inertial Labs™ INS Mounting Relative to the Object Axes”).
5. g = 9.8106 m/s2.
6. USW is unit status word (see Appendix D for details).
7. Vinp is input voltage of the INS.
8. Temper is averaged temperature in 3 gyros.
9. ms_gps are milliseconds from the beginning of the GPS reference week.
10. GNSS_info1, GNSS_info2 contain information about GNSS data (see Table C.5, Table C.6).
11. #SolnSVs is number of satellites used in navigation solution.
12. V_latency is latency in the velocity time tag in milliseconds.
13. Angles position type is GNSS position type at orientation calculation using dual GNSS antennas. If this value is less than 100, see its description in Table C.16. Otherwise, subtract 100 from the “Angles position type” and refer again to Table C.16.
14. P_bar and H_bar are pressure and barometric height.
15. New_GPS is indicator of new update of GPS data (see Table C.7).
16. LSB is transmitted first.

**Table C.11. The INS message payload at the "INS OPVT2AHR" (Orientation, Position, Velocity, Time, Dual-antenna receiver data, with high resolution) data format**

| Byte number | 0 – 1 | 2 – 3 | 4 – 5 | 6 – 17 | 18 – 29 | 30 – 35 | 36 – 37 |
|---|---|---|---|---|---|---|---|
| Parameter | Heading | Pitch | Roll | GyroX, GyroY, GyroZ | AccX, AccY, AccZ | MagX, MagY, MagZ | USW |
| Length | 2 byte word | 2 byte sword | 2 byte sword | 3×4 byte integer | 3×4 byte integer | 3×2 byte sword | 2 byte word |
| *Note* | Orientation angles, deg*100 | | | Angular rates, deg/s*1.0e5 | Accelerations, g*1.0e6 | Magnetic fields, nT/10 | |

**Table C.11 (continued)**

| Byte number | 38 – 39 | 40 – 41 | 42 – 49 | 50 – 57 | 58 – 61 | 62 – 65 |
|---|---|---|---|---|---|---|
| Parameter | Vinp | Temper | Latitude | Longitude | Altitude | East speed |
| Length | 2 byte word | 2 byte sword | 8 byte integer | 8 byte integer | 4 byte integer | 4 byte integer |
| *Note* | Supply voltage, VDC*100 | Temperature, °C*10 | deg*1.0e9 | deg*1.0e9 | m*1000 | m/s*100 |

**Table C.11 (continued)**

| Byte number | 66 – 69 | 70 – 73 | 74 – 81 | 82 – 89 | 90 – 93 | 94 – 97 | 98 – 99 |
|---|---|---|---|---|---|---|---|
| Parameter | North speed | Vertical speed | Latitude GNSS | Longitude GNSS | Altitude GNSS | Horizontal speed GNSS | Track over ground GNSS |
| Length | 4 byte integer | 4 byte integer | 8 byte integer | 8 byte integer | 4 byte integer | 4 byte integer | 2 byte word |
| *Note* | m/s*100 | m/s*100 | deg*1.0e9 | deg*1.0e9 | m*1000 | m/s*100 | deg*100 |

**Table C.11 (continued)**

| Byte number | 100 – 103 | 104 – 107 | 108 | 109 | 110 | 111 – 112 | 113 |
|---|---|---|---|---|---|---|---|
| Parameter | Vertical speed GNSS | ms_gps | GNSS_info1 | GNSS_info2 | #solnSVs | V_latency | Angles position type |
| Length | 4 byte integer | 4 byte | 1 byte | 1 byte | 1 byte | 2 byte word | 1 byte |
| *Note* | m/s*100 | ms | | | | s*1000 | |

**Table C.11 (continued)**

| Byte number | 114 – 115 | 116 – 117 | 118 – 119 | 120 – 121 | 122 – 123 | 124 – 127 | 128 |
|---|---|---|---|---|---|---|---|
| Parameter | Heading GNSS | Latency ms_head | Latency ms_pos | Latency ms_vel | P_bar | H_bar | New GPS |
| Length | 2 byte word | 2 byte sword | 2 byte sword | 2 byte sword | 2 byte word | 4 byte integer | 1 byte |
| *Note* | deg*100 | ms | | | Pa/2 | m*100 | |

**Notes:**

1. Orientation, position, and velocity data can be presented in the form of instant or average values (see section 4.2.1, "Averaged Output Data" checkbox and INS ICD Appendix E.1 for details).
2. Gyros, accelerometers, and magnetometers data can be presented in the form of instant, average, or incremental values (see section 4.4).
3. 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 INS orientation relative to the carrier object axes is set by alignment angles (see "Appendix E. Variants of the Inertial Labs™ INS Mounting Relative to the Object Axes").
4. g = 9.8106 m/s$^2$.
5. USW is unit status word (see Appendix D for details).
6. Vinp is input voltage of the INS.
7. Temper is averaged temperature in 3 gyros.
8. ms_gps are milliseconds from the beginning of the GPS reference week.
9. GNSS_info1, GNSS_info2 contain information about GNSS data (see Table C.5, Table C.6).
10. #SolnSVs is number of satellites used in navigation solution.
11. V_latency is latency in the velocity time tag in milliseconds.
12. Latency ms_head, Latency ms_pos and Latency ms_vel are latencies of time stamps in GNSS receiver's heading, position, and velocity logs relative to INS time (ms_gps), in milliseconds.
13. Angles position type is GNSS position type at orientation calculation using dual GNSS antennas. If this value is less than 100, see its description in Table C.16. Otherwise, subtract 100 from the "Angles position type" and refer again to Table C.16.
14. P_bar and H_bar are pressure and barometric height.
15. New_GPS is indicator of new update of GPS data (see Table C.7).
16. LSB is transmitted first.

**Table C.12. The INS message payload at the "INS OPVTAD" data format**

| Byte number | 0 – 1 | 2 – 3 | 4 – 5 | 6 – 17 | 18 – 29 | 30 – 35 |
|---|---|---|---|---|---|---|
| Parameter | Heading | Pitch | Roll | GyroX, GyroY, GyroZ | AccX, AccY, AccZ | MagX, MagY, MagZ |
| Length | 2 byte word | 2 byte sword | 2 byte sword | 3×4 byte integer | 3×4 byte integer | 3×2 byte sword |
| *Note* | Orientation angles, deg*100 | | | Angular rates, deg/s*1.0e5 | Accelerations g*1.0e6 | Magnetic fields, nT/10 |

**Table C.12 (continued)**

| Byte number | 36 – 37 | 38 – 39 | 40 – 41 | 42 – 49 | 50 – 57 | 58 – 61 |
|---|---|---|---|---|---|---|
| Parameter | USW | Vinp | Temper | Latitude | Longitude | Altitude |
| Length | 2 byte word | 2 byte word | 2 byte sword | 8 byte integer | 8 byte integer | 4 byte integer |
| *Note* | | Supply voltage, VDC*1000 | Temperature, ºC*10 | deg *1.0e9 | deg *1.0e9 | m*1000 |

**Table C.12 (continued)**

| Byte number | 62 – 65 | 66 – 69 | 70 – 73 | 74 – 81 | 82 – 89 | 90 – 93 |
|---|---|---|---|---|---|---|
| Parameter | East speed | North speed | Vertical speed | Latitude GNSS | Longitude GNSS | Altitude GNSS |
| Length | 4 byte integer | 4 byte integer | 4 byte integer | 8 byte integer | 8 byte integer | 4 byte integer |
| *Note* | m/s*100 | m/s*100 | m/s*100 | deg *1.0e9 | deg *1.0e9 | m*1000 |

**Table C.12 (continued)**

| Byte number | 94 – 97 | 98 – 99 | 100 – 103 | 104 – 107 | 108 | 109 |
|---|---|---|---|---|---|---|
| Parameter | Horizontal speed GNSS | Track over ground GNSS | Vertical speed GNSS | ms_gps | GNSS_info 1 | GNSS_info 2 |
| Length | 4 byte integer | 2 byte word | 4 byte integer | 4 byte | 1 byte | 1 byte |
| *Note* | m/s*100 | deg*100 | m/s*100 | ms | | |

**Table C.12 (continued)**

| Byte number | 110 | 111 | 112 | 113 | 114 – 115 | 116 – 117 |
|---|---|---|---|---|---|---|
| Parameter | #solnSVs | Latency ms_pos | Latency ms_vel | Angles position type | Heading GNSS | Latency ms_head |
| Length | 1 byte | 1 byte | 1 byte | 1 byte | 2 byte word | 2 byte sword |
| *Note* | | ms | ms | | Orientation angles, deg*100 | ms |

**Table C.12 (continued)**

| Byte number | 118 – 119 | 120 – 123 | 124 | 125 – 128 | 129 – 130 | 131 – 132 |
|---|---|---|---|---|---|---|
| Parameter | P_bar | H_bar | New GPS | Odometer | Air speed | North wind |
| Length | 2 byte word | 4 byte integer | 1 byte | 4 byte integer | 2 byte sword | 2 byte sword |
| *Note* | Pa/2 | m*100 | | Distance, m*1000 | Speed, kt*100 | North wind, kt*100 |

**Table C.12 (continued)**

| Byte number | 133 – 134 | 135 – 136 | 137 – 138 | 139 – 142 | 143 – 146 |
|---|---|---|---|---|---|
| Parameter | East wind | North wind STD | East wind STD | Latitude external | Longitude external |
| Length | 2 byte sword | 2 byte word | 2 byte word | 4 byte integer | 4 byte integer |
| *Note* | East wind, kt*100 | STD, kt*100 | | deg *1.0e7 | |

**Table C.12 (continued)**

| Byte number | 147 – 150 | 151 – 152 | 153 – 154 | 155 – 156 | 157 – 158 | 159 – 162 |
|---|---|---|---|---|---|---|
| Parameter | Altitude external | Latitude external STD | Longitude external STD | Altitude external STD | External position latency | Locator latitude |
| Length | 4 byte integer | 2 byte word | 2 byte word | 2 byte word | 2 byte word | 4 byte integer |
| *Note* | m*1000 | m *100 | | | sec*1000 | deg *1.0e7 |

**Table C.12 (continued)**

| Byte number | 163 – 166 | 167 – 170 | 171 – 172 | 173 – 174 | 175 – 176 |
|---|---|---|---|---|---|
| Parameter | Locator longitude | Locator altitude | Doppler shift | Doppler shift STD | New aiding data |
| Length | 4 byte integer | 4 byte integer | 2 byte sword | 2 byte word | 2 byte word |
| *Note* | deg *1.0e7 | m*1000 | (m/s) *100 | | |

**Notes:**

1. Orientation, position, and velocity data can be presented in the form of instant or average values (see section 4.2.1, “Averaged output data” checkbox and INS ICD Appendix E.1 for details).
2. Gyros, accelerometers, and magnetometers data can be presented in the form of instant, average, or incremental values (see section 4.4).
3. 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 INS orientation relative to the carrier object axes is set by alignment angles (see “Appendix E. Variants of the Inertial Labs™ INS Mounting Relative to the Object Axes”).
4. g = 9.8106 m/s$^2$.
5. USW is unit status word.
6. Vinp is input voltage of the INS.
7. Temper is averaged temperature in 3 gyros.
8. ms_gps are milliseconds from the beginning of the GPS reference week.
9. GNSS_info1, GNSS_info2 contain information about GNSS data.
10. #SolnSVs is number of satellites used in navigation solution.
11. Latency ms_head, Latency ms_pos, and Latency ms_vel are latencies of heading, position, and velocity GNSS data in milliseconds.
12. Angles position type is GNSS position type at orientation calculation using dual GNSS antennas. If this value is less than 100,see its description in Table C.16.

Otherwise, subtract 100 from the "Angles position type" and refer again to Table C.16.

13. P_bar and H_bar are pressure and barometric height.
14. New_GPS is an indicator of new update of GPS data (see Table C.7).
15. New aiding data is an indicator of update of external sensors data (see Table C.13).
16. North and east wind are northward and eastward components of the ground speed of air mass motion.
17. LSB is transmitted first.

**Table C.13. New aiding data indicator**

| | Bit | Parameter | Description |
|---|---|---|---|
| Low byte | 0 | Odometer | 0 – data absent / 1 – data updated |
| | 1 | Air speed | 0 – data absent / 1 – data updated |
| | 2 | Wind data | 0 – data absent / 1 – data updated |
| | | North wind component<br>East wind component North wind STD<br>East wind STD | |
| | 3 | External position | 0 – data absent / 1 – data updated |
| | | Latitude external<br>Longitude external<br>Altitude external<br>Latitude external STD<br>Longitude external STD<br>Altitude external STD<br>External position latency | |
| | 4 | Doppler shift from locator | 0 – data absent / 1 – data updated |
| | | Locator latitude<br>Locator longitude<br>Locator altitude<br>Doppler shift<br>Doppler shift STD | |
| | 5 | Heading external | 0 – data absent / 1 – data updated |
| | | Heading external<br>Heading external STD<br>Heading external latency | |
| | 6 | DVL data | 0 – data absent / 1 – data updated |
| | | Lateral velocity<br>Forward velocity<br>Vertical velocity<br>Lateral velocity STD<br>Forward velocity STD<br>Vertical velocity STD<br>Velocity latency | |
| | 7 | Sensors bias external | 0 – data absent / 1 – data updated |
| High byte | 8 | Pitch and Roll external | 0 – data absent / 1 – data updated |
| | 9 | GNSS antennas position | 0 – data absent / 1 – data updated |
| | 10 | Ambient Air Data | 0 – data absent / 1 – data updated |
| | 11 | Altitude external | 0 – data absent / 1 – data updated |

| | | | |
|---|---|---|---|
| | 12 – 15 | Reserved | |

**Table C.14. The message payload at the "INS Sensors Data" format**

| Byte number | 0 – 1 | 2 – 3 | 4 – 5 | 6 – 23 | 24 – 25 | 26 – 27 |
|---|---|---|---|---|---|---|
| Parameter | Heading (AHRS) | Pitch (AHRS) | Roll (AHRS) | Ugyro, Uacc, Umag | Reserved | Reserved |
| Length | 2 byte word | 2 byte sword | 2 byte sword | 9×2 byte sword | 2 byte sword | 2 byte sword |
| *Note* | Orientation angles, deg*100 | | | Raw sensor data (gyros, accelerometers, magnetometers) | | |

**Table C.14 (continued)**

| Byte number | 28 – 29 | 30 – 31 | 32 – 33 | 34 – 37 | 38 – 41 | 42 – 45 | 46 – 47 |
|---|---|---|---|---|---|---|---|
| Parameter | USW | Vinp/Vdd | Utermo | Latitude GNSS | Longitude GNSS | Altitude GNSS | Latitude STD |
| Length | 2 byte word | 2 byte word | 2 byte sword | 4 byte integer | 4 byte integer | 4 byte integer | 2 byte word |
| *Note* | | Combined voltage | Temperature in each sensor | deg *1.0e7 | deg *1.0e7 | m*100 | m*1000 |

**Table C.14 (continued)**

| Byte number | 48 – 49 | 50 – 51 | 52 – 55 | 56 – 57 | 58 – 61 | 62 – 65 | 66 |
|---|---|---|---|---|---|---|---|
| Parameter | Longitude STD | Altitude STD | Horizontal speed GNSS | Track over ground GNSS | Vertical speed GNSS | ms_gps | TS_gps |
| Length | 2 byte word | 2 byte word | 4 byte integer | 2 byte word | 4 byte integer | 4 byte integer | 1 byte |
| *Note* | m*1000 | m*1000 | m/s*100 | deg*100 | m/s*100 | ms | |

**Table C.14 (continued)**

| Byte number | 67 | 68 | 69 | 70 | 71 | 72 | 73 |
|---|---|---|---|---|---|---|---|
| Parameter | sol_stat | pos_type | #SVs | #SolnSVs | #SolnL1SVs | #SolnMultiSVs | ext_sol_stat |
| Length | 1 byte | 1 byte | 1 byte | 1 byte | 1 byte | 1 byte | 1 byte |
| *Note* | | | | | | | |

**Table C.14 (continued)**

| Byte number | 74 | 75 | 76 | 77 | 78 – 79 | 80 – 81 | 82 | 83 |
|---|---|---|---|---|---|---|---|---|
| Parameter | Galileo and BeiDou | GPS and GLONASS | Latency ms_pos | Latency ms_vel | UP | UT | New GPS | Reserved |
| Length | 1 byte | 1 byte | 1 byte | 1 byte | 2 byte word | 2 byte word | 1 byte | 1 byte |
| *Note* | | | ms | ms | | | | |

**Notes:**

1. Orientation, position, and velocity data can be presented in the form of instant or average values (see section 4.2.1, "Averaged output data" checkbox and INS ICD Appendix E.1 for details).
2. Gyros, accelerometers, and magnetometers data can be presented in the form of instant, average, or incremental values (see section 4.4).
3. USW is unit status word (see Appendix D for details).
4. The following data are recorded in the field "Vdd" sequentially:
   - the INS input voltage, Vinp, VDC*100
   - stabilized voltage supplied to the INS sensors, Vdd, VDC*1000
5. In the "Utermo" field, ADC codes are recorded sequentially from seven temperature sensors inside gyros, accelerometers, and magnetometers.
6. ms_gps are milliseconds from the beginning of the GPS reference week.
7. TS_gps is time status, which indicates the quality of the GPS reference time (see Table C.5).
8. sol_stat is GNSS solution status (see Table C.15).
9. pos_type is GNSS position type (see Table C.16).
10. #SVs is number of satellites tracked.
11. #SolnSVs is number of satellites used in navigation solution.
12. #SolnL1SVs is number of satellites with L1/E1/B1 signals used in solution.
13. #SolnMultiSVs is number of satellites with multi-frequency signals used in solution.
14. ext_sol_stat is GNSS extended solution status (see Table C.17).
15. GPS and GLONASS is GPS and GLONASS signal-used mask (see Table C.18).
16. Galileo and BeiDou is Galileo and BeiDou signal-used mask (see Table C.19).
17. V_latency is latency in the velocity time tag in milliseconds.
18. UP and UT are raw data from the pressure sensor – pressure and temperature.
19. New_GPS is indicator of new update of GPS data (see Table C.7).
20. LSB is transmitted first.

**Table C.15. sol_stat – GNSS solution status**

| Value | Description |
|---|---|
| 0 | Solution computed |
| 1 | Insufficient observations |
| 2 | No convergence |
| 3 | Singularity at parameters matrix |
| 4 | Covariance trace exceeds maximum (trace > 1000 m) |
| 5 | Test distance exceeded (maximum of 3 rejections if distance > 10 km) |
| 6 | Not yet converged from cold start |
| 7 | Height or velocity limits exceeded (in accordance with export licensing restrictions) |
| 8 | Variance exceeds limits |
| 9 | Residuals are too large |
| 13 | Large residuals make position unreliable |
| 18 | When a FIX POSITION command is entered, the receiver computes its own position and determines if the fixed position is valid |
| 19 | The fixed position, entered using the FIX POSITION command, is not valid |
| 20 | Position type is unauthorized (HP or XP on a receiver not authorized) |

**Table C.16. pos_type – GNSS position or velocity type**

| Value | Description |
|---|---|
| 0 | No solution |
| 8 | Velocity computed using instantaneous Doppler |
| 16 | Single point position |
| 17 | Pseudorange differential solution |
| 18 | Solution calculated using corrections from an WAAS |
| 32 | Floating L1 ambiguity solution |
| 33 | Floating ionospheric-free ambiguity solution |
| 34 | Floating narrow-lane ambiguity solution |
| 48 | Integer L1 ambiguity solution |
| 50 | Integer narrow-lane ambiguity solution |
| 68 | PPP converging (Converging TerraStar-C, TerraStar-C PRO, TerraStar-X, or Oceanix solution) |
| 69 | PPP (Converged TerraStar-C, TerraStar-C PRO, TerraStar-X, or Oceanix solution) |
| 77 | PPP basic converging (Converging TerraStar-L solution) |
| 78 | PPP basic (Converged TerraStar-L solution) |

**Note:** PPP solution requires access to a suitable correction stream, delivered either through L-Band or the internet. For L-Band delivered TerraStar or Oceanix service and an appropriate receiver software model is required, along with a subscription to the desired service.

**Table C.17. ext_sol_stat – GNSS extended solution status**

| Bit | Mask | Description |
|---|---|---|
| 0 | 0x01 | If an RTK solution: NovAtel CORRECT solution has been verified.<br>If a PDP solution: solution is GLIDE.<br>Otherwise: Reserved. |
| 1 – 3 | 0x0E | Pseudorange Iono Correction<br>0 = Unknown or default Klobuchar model<br>1 = Klobuchar Broadcast<br>2 = SBAS Broadcast<br>3 = Multi-frequency Computed<br>4 = PSRDiff Correction<br>5 = NovAtel Blended Iono Value |
| 4 | 0x10 | Reserved |
| 5 | 0x20 | 0 = No antenna warning<br>1 = Antenna information is missing |
| 6 – 7 | 0xC0 | Reserved |

**Table C.18. GPS and GLONASS signal-used mask**

| Bit | Mask | Description |
|---|---|---|
| 0 | 0x01 | GPS L1 used in solution |
| 1 | 0x02 | GPS L2 used in solution |
| 2 | 0x04 | GPS L5 used in solution |
| 3 | 0x08 | Reserved |
| 4 | 0x10 | GLONASS L1 used in solution |
| 5 | 0x20 | GLONASS L2 used in solution |
| 6 – 7 | 0x40 – 0x80 | Reserved |

**Table C.19. Galileo and BeiDou signal-used mask**

| Bit | Mask | Description |
|---|---|---|
| 0 | 0x01 | Galileo E1 used in solution |
| 1 – 3 | 0x02 – 0x08 | Reserved |
| 4 | 0x10 | BeiDou B1 used in solution |
| 5 | 0x20 | BeiDou B2 used in solution |
| 6 – 7 | 0x40 – 0x80 | Reserved |

**Table C.20. The message payload at the "INS Minimal Data" format**

| Byte number | 0 – 1 | 2 – 3 | 4 – 5 | 6 – 7 | 8 – 9 |
|---|---|---|---|---|---|
| Parameter | Heading | Pitch | Roll | USW | Vinp |
| Length | 2 byte word | 2 byte sword | 2 byte sword | 2 byte word | 2 byte word |
| *Note* | Orientation angles, deg*100 | | | | Supply voltage, VDC*100 |

**Table C.20 (continued)**

| Byte number | 10 – 11 | 12 – 15 | 16 – 19 | 20 – 23 | 24 – 27 |
|---|---|---|---|---|---|
| Parameter | Temper | Latitude | Longitude | Altitude | East speed |
| Length | 2 byte sword | 4 byte integer | 4 byte integer | 4 byte integer | 4 byte integer |
| *Note* | Temperature, ºC*10 | deg *1.0e7 | deg *1.0e7 | m*100 | m/s*100 |

**Table C.20 (continued)**

| Byte number | 28 – 31 | 32 – 35 | 36 – 39 | 40 | 41 |
|---|---|---|---|---|---|
| Parameter | North speed | Vertical speed | ms_gps | GNSS_info1 | #SolnSVs |
| Length | 4 byte integer | 4 byte integer | 4 byte integer | 1 byte | 1 byte |
| *Note* | m/s*100 | m/s*100 | | | |

**Notes:**

1. Orientation, position, and velocity data can be presented in the form of instant or average values (see section 4.2.1, "Averaged output data" checkbox and INS ICD Appendix E.1 for details).
2. USW is unit status word (see Appendix D for details).
3. Vinp is input voltage of the INS.
4. Temper is averaged temperature in 3 gyros.

5. ms_gps are milliseconds from the beginning of the GPS reference week.
6. GNSS_info1 contains information about GNSS data (see Table C.5).
7. #SolnSVs is number of satellites used in navigation solution.
8. LSB is transmitted first.

**Table C.21. The message payload at the "INS OPVT & Raw IMU Data" format**

| Byte number | 0 – 7 | 8 – 15 | 16 – 27 | 28 – 39 | 40 – 41 | 42 – 45 | 46 – 49 | 50 – 53 |
|---|---|---|---|---|---|---|---|---|
| Parameter | GPS INS Time | GPS IMU Time | GyroX, GyroY, GyroZ | AccX, AccY, AccZ | USW | Heading | Pitch | Roll |
| Length | 8 byte unsigned integer | 8 byte unsigned integer | 3×4 byte integer | 3×4 byte integer | 2 byte word | 4 byte unsigned integer | 4 byte integer | 4 byte integer |
| *Note* | s*1.0e9 | s*1.0e9 | Angular rates, deg/s∗10000 | Accelerations, $m/s^2$∗10000 | | Orientation angles, deg*1000 | | |

**Table C.21 (continued)**

| Byte number | 54 – 61 | 62 – 69 | 70 – 73 | 74 – 77 | 78 – 81 |
|---|---|---|---|---|---|
| Parameter | Latitude | Longitude | Altitude | East speed | North speed |
| Length | 8 byte integer | 8 byte integer | 4 byte integer | 4 byte integer | 4 byte integer |
| *Note* | deg *1.0e9 | deg *1.0e9 | m*1000 | m/s*100 | m/s*100 |

**Table C.21 (continued)**

| Byte number | 82 – 85 | 86 | 87 | 88 | 89 |
|---|---|---|---|---|---|
| Parameter | Vertical speed | GNSS_info 1 | GNSS_info 2 | #solnSVs | New GPS |
| Length | 4 byte integer | 1 byte | 1 byte | 1 byte | 1 byte |
| *Note* | m/s*100 | | | | |

**Notes:**

1. Orientation, position, and velocity data can be presented in the form of instant or average values (see section 4.2.1, "Averaged output data" checkbox and INS ICD Appendix E.1 for details).
2. Gyros, accelerometers, and magnetometers data can be presented in the form of instant, average, or incremental values (see section 4.4).
3. GPS Time is time of INS navigation solution (orientation, position, velocity data), in nanoseconds from the beginning of the GPS reference week.
4. GPS IMU Time is time of getting IMU data (measurements from the gyros and accelerometers) in nanoseconds from the beginning of the GPS reference week.
5. USW is unit status word (see Appendix D for details).
6. GNSS_info1, GNSS_info2 contain information about GNSS data (see Table 6.5, Table 6.6).
7. #SolnSVs is number of satellites used in navigation solution.
8. New_GPS is indicator of new update of GPS data (see Table C.7).
9. LSB is transmitted first.

**Table C.22. The "SPAN rawimu" message structure**

| Byte number | 0 | 1 | 2 | 3 | 4 – 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Parameter | Sync1 | Sync2 | Sync3 | Header Length | Message ID | Message Type | Port Address |
| Length | 1 byte | 1 byte | 1 byte | 1 byte | 2 byte word | 1 byte | 1 byte |
| *Note* | 0xAA | 0x44 | 0x12 | 28 | 268 | 0x00 | |

**Table C.22 (continued)**

| Byte number | 8 – 9 | 10 – 11 | 12 | 13 | 14 – 15 | 16 – 19 | 20 – 23 | 24 – 25 |
|---|---|---|---|---|---|---|---|---|
| Parameter | Message Length | Sequence | Idle Time | Time Status | Week | GPS Time | Receiver Status | Reserved |
| Length | 2 byte word | 2 byte word | 1 byte | 1 byte | 2 byte word | 4 byte unsigned integer | 4 byte unsigned integer | 2 byte word |
| *Note* | 40 | 0x00 | | | | ms | | |

**Table C.22 (continued)**

| Byte number | 26 – 27 | 28 – 31 | 32 – 39 | 40 – 43 | 44 – 55 | 56 – 67 | 68 – 71 |
|---|---|---|---|---|---|---|---|
| Parameter | Receiver S/W Version | Week | GPS IMU Time | IMU Status | AccZ, -AccY, AccX | GyroZ, -GyroY, GyroX | 32-bit CRC |
| Length | 2 byte word | 4 byte unsigned integer | 8 byte double | 4 byte integer | 3×4 byte integer | 3×4 byte integer | 4 byte hex |
| *Note* | | | s | | $m/s*2^{31}/200$ | $deg*2^{31}/720$ | |

**Notes:**

1. Bytes 0 to 27 are header of the "SPAN rawimu" message.
2. Time Status indicates the quality of the GPS reference time (see Table C.23).
3. Week is the GPS week number.
4. GPS Time are milliseconds from the beginning of the GPS reference week.
5. Receiver Status is 32 bits representing the status of various hardware and software components of the GNSS receiver (see Table C.24).
6. Receiver S/W Version is a value (0 – 65535) representing the receiver software build number.
7. GPS IMU Time is time of receiving IMU data (measurements from the gyros and accelerometers) in seconds from the beginning of the GPS reference week.
8. IMU Status – see Table C.25.
9. AccZ, -AccY, AccX are accelerometers output along Z, Y, and X axes in the form of linear velocity increments in m/s. Note that -AccY has an opposite sign for velocity Y increment.
10. GyroZ, -GyroY, GyroX are gyros output around Z, Y, and X axes in the form of angle increments in degrees. Note that -GyroY has an opposite sign for angle Y increment.
11. Gyros, accelerometers, and magnetometers data can be presented in the form of instant, average, or incremental values (see section 4.4).

**Table C.23. GPS Reference Time Status**

| Value | Description |
|---|---|
| 20 | Time validity is unknown |
| 60 | Time is set approximately |
| 80 | Time is approaching coarse precision |
| 100 | Time is valid to coarse precision |
| 120 | Time is coarse set and is being steered |
| 130 | Position is lost and the range bias cannot be calculated |
| 140 | Time is adjusting to fine precision |
| 160 | Time has fine precision |
| 170 | Time is fine set and is being steered by the backup system |
| 180 | Time is fine set and is being steered |

**Table C.24. GNSS Receiver Status**

| Nibble | Bit | Mask | Description | Bit = 0 | Bit = 1 |
|---|---|---|---|---|---|
| N0 | 0 | 0x00000001 | Error flag | No error | Error |
| | 1 | 0x00000002 | Temperature status | Within specifications | Warning |
| | 2 | 0x00000004 | Voltage supply status | OK | Warning |
| | 3 | 0x00000008 | Antenna power status | Powered | Not powered |
| N1 | 4 | 0x00000010 | LNA Failure | OK | Failure |
| | 5 | 0x00000020 | Antenna open flag | OK | Open |
| | 6 | 0x00000040 | Antenna shorted flag | OK | Shorted |
| | 7 | 0x00000080 | CPU overload flag | No overload | Overload |
| N2 | 8 | 0x00000100 | COM1 buffer overrun flag | No overrun | Overrun |
| | 9 | 0x00000200 | COM2 buffer overrun flag | No overrun | Overrun |
| | 10 | 0x00000400 | COM3 buffer overrun flag | No overrun | Overrun |
| | 11 | 0x00000800 | Link overrun flag | No overrun | Overrun |
| N3 | 12 | 0x00001000 | Reserved | | |
| | 13 | 0x00002000 | Aux transmit overrun flag | No overrun | Overrun |
| | 14 | 0x00004000 | AGC out of range | OK | Out of range |
| | 15 | 0x00008000 | Reserved | | |
| N4 | 16 | 0x00010000 | INS Reset | No Reset | INS reset |
| | 17 | 0x00020000 | Reserved | | |
| | 18 | 0x00040000 | Almanac flag/UTC known | Valid | Invalid |
| | 19 | 0x00080000 | Position solution flag | Valid | Invalid |
| N5 | 20 | 0x00100000 | Position fixed flag | Not fixed | Fixed |
| | 21 | 0x00200000 | Clock steering status | Enabled | Disabled |
| | 22 | 0x00400000 | Clock model flag | Valid | Invalid |
| | 23 | 0x00800000 | External oscillator locked flag | Unlocked | Locked |
| N6 | 24 | 0x01000000 | Software resource | OK | Warning |
| | 25 | 0x02000000 | Reserved | | |
| | 26 | 0x04000000 | Reserved | | |
| | 27 | 0x08000000 | Reserved | | |
| N7 | 28 | 0x10000000 | Reserved | | |
| | 29 | 0x20000000 | Auxiliary 3 status event flag | No event | Event |
| | 30 | 0x40000000 | Auxiliary 2 status event flag | No event | Event |
| | 31 | 0x80000000 | Auxiliary 1 status event flag | No event | Event |

**Table C.25. IMU Status**

| Nibble | Bit | Mask | Description | Range Value |
|---|---|---|---|---|
| N0 | 0 | 0x00000001 | Alarm Status Flag | |
| | 1 | 0x00000002 | Reserved | |
| | 2 | 0x00000004 | Reserved | |
| | 3 | 0x00000008 | SPI Communication Error | 0 = Passed, 1 = Failed |
| N1 | 4 | 0x00000010 | Sensor Over-Range | 0 = Passed,<br>1 = One or more sensors over-ranged |
| | 5 | 0x00000020 | Initial Self-Test Failure | 0 = Passed, 1 = Failed |
| | 6 | 0x00000040 | Flash Memory Failure | 0 = Passed, 1 = Failed |
| | 7 | 0x00000080 | Processing Overrun | 0 = Passed, 1 = Failed |
| N2 | 8 | 0x00000100 | Self-Test Failure – X-axis gyro | 0 = Passed, 1 = Failed |
| | 9 | 0x00000200 | Self-Test Failure – Y-axis gyro | 0 = Passed, 1 = Failed |
| | 10 | 0x00000400 | Self-Test Failure – Z-axis gyro | 0 = Passed, 1 = Failed |
| | 11 | 0x00000800 | Self-Test Failure – X-axis accelerometer | 0 = Passed, 1 = Failed |
| N3 | 12 | 0x00001000 | Self-Test Failure – Y-axis accelerometer | 0 = Passed, 1 = Failed |
| | 13 | 0x00002000 | Self-Test Failure – Z-axis accelerometer | 0 = Passed, 1 = Failed |
| | 14 | 0x00004000 | Reserved | |
| | 15 | 0x00008000 | Reserved | |
| N4 | 16 | 0x00010000 | IMU temperature reading as follows:<br>Signed 2-byte value (SHORT)<br>25ºC = 0x0000<br>1 LSB = 0.00565ºC | |
| | 17 | 0x00020000 | | |
| | 18 | 0x00040000 | | |
| | 19 | 0x00080000 | | |
| N5 | 20 | 0x00100000 | | |
| | 21 | 0x00200000 | | |
| | 22 | 0x00400000 | | |
| | 23 | 0x00800000 | | |
| N6 | 24 | 0x01000000 | | |
| | 25 | 0x02000000 | | |
| | 26 | 0x04000000 | | |
| | 27 | 0x08000000 | | |
| N7 | 28 | 0x10000000 | | |
| | 29 | 0x20000000 | | |
| | 30 | 0x40000000 | | |
| | 31 | 0x80000000 | | |

**Table C.26. The INS message payload at the "INS OPVT GNSSext" data format**

| Byte number | 0 – 3 | 4 – 7 | 8 – 11 | 12 – 15 | 16 – 23 | 24 – 31 |
|---|---|---|---|---|---|---|
| Parameter | TOW | Heading | Pitch | Roll | Latitude | Longitude |
| Data format | 4 byte unsigned integer | 4 byte unsigned integer | 4 byte integer | 4 byte integer | 8 byte integer | 8 byte integer |
| *Note* | sec*$10^3$ | deg*$10^6$ | | | deg*$10^9$ | deg*$10^9$ |

**Table C.26 (continued)**

| Byte number | 32 – 35 | 36 – 39 | 40 – 43 | 44 – 47 | 48 – 59 | 60 – 71 |
|---|---|---|---|---|---|---|
| Parameter | Altitude | East speed | North speed | Vertical speed | GyroX, GyroY, GyroZ | AccX, AccY, AccZ |
| Data format | 4 byte integer | 4 byte integer | 4 byte integer | 4 byte integer | 3×4 byte integer | 3×4 byte integer |
| *Note* | m*1000 | m/s*$10^6$ | | | deg/s*$10^6$ | g*$10^6$ |

**Table C.26 (continued)**

| Byte number | 72 – 77 | 78 – 79 | 80 – 81 | 82 – 83 | 84 | 85 – 88 | 89 – 92 | 93 – 96 |
|---|---|---|---|---|---|---|---|---|
| Parameter | MagX, MagY, MagZ | P_bar | Temper | USW | Pos_type | GNSS ECEF X | GNSS ECEF Y | GNSS ECEF Z |
| Data format | 3×2 byte sword | 2 byte word | 2 byte sword | 2 byte word | 1 byte | 4 byte integer | 4 byte integer | 4 byte integer |
| *Note* | nT/10 | Pa/2 | ºC*$10^2$ | | | m*$10^2$ | | |

**Table C.26 (continued)**

| Byte number | 97 – 98 | 99 – 102 | 103 – 106 | 107 – 110 | 111 – 112 | 113 – 120 |
|---|---|---|---|---|---|---|
| Parameter | GNSS_PACC | GNSS ECEF VX | GNSS ECEF VY | GNSS ECEF VZ | GNSS_SACC | Latitude GNSS |
| Data format | 2 byte word | 4 byte integer | 4 byte integer | 4 byte integer | 2 byte word | 8 byte integer |
| *Note* | m*$10^2$ | m/s*$10^6$ | | | m/s*$10^2$ | deg*$10^9$ |

**Table C.26 (continued)**

| Byte number | 121 – 128 | 129 – 132 | 133 – 136 | 137 – 140 | 141 – 144 | 145 |
|---|---|---|---|---|---|---|
| Parameter | Longitude GNSS | Altitude GNSS | Horizontal speed GNSS | Track over ground GNSS | Vertical speed GNSS | Angles_ pos_type |
| Data format | 8 byte integer | 4 byte integer | 4 byte integer | 4 byte integer | 4 byte integer | 1 byte |
| *Note* | deg*$10^9$ | m*1000 | m/s*$10^6$ | deg*$10^6$ | m/s*$10^6$ | |

**Table C.26 (continued)**

| Byte number | 146 – 147 | 148 | 149 | 150 | 151 – 152 | 153 – 154 | 155 – 156 | 157 – 158 |
|---|---|---|---|---|---|---|---|---|
| Parameter | GNSS Heading | #solnSVs | GNSS_info1 | GNSS_info2 | GDOP | PDOP | HDOP | VDOP |
| Data format | 2 byte word | 1 byte | 1 byte | 1 byte | 2 byte word | 2 byte word | 2 byte word | 2 byte word |
| *Note* | deg*$10^2$ | | | | *$10^3$ | *$10^3$ | *$10^3$ | *$10^3$ |

**Table C.26 (continued)**

| Byte number | 159 – 160 | 161 – 162 | 163 | 164 | 165 | 166 – 167 | 168 | 169 |
|---|---|---|---|---|---|---|---|---|
| Parameter | TDOP | Diff_age | GPS Hours | GPS Minutes | GPS Seconds | GPS Decimal Seconds | Month | Day |
| Data format | 2 byte word | 2 byte word | 1 byte | 1 byte | 1 byte | 2 byte word | 1 byte | 1 byte |
| *Note* | $*10^3$ | sec*10 | | | | | | |

**Table C.26 (continued)**

| Byte number | 170 – 171 | 172 – 179 | 180 | 181 – 182 | 183 | 184 | 185 |
|---|---|---|---|---|---|---|---|
| Parameter | Year | UTC | Latency ECEF_time | V_latency | Latency pos_time | Latency vel_time | New GPS |
| Data format | 2 byte word | 8 byte integer | 1 byte | 2 byte sword | 1 byte | 1 byte | 1 byte |
| *Note* | | | msec | msec | msec | msec | |

**Notes:**

1. Orientation, position, and velocity data can be presented in the form of instant or average values (see section 4.2.1, “Averaged output data” checkbox and INS ICD Appendix E.1 for details).
2. Gyros, accelerometers, and magnetometers data can be presented in the form of instant, average, or incremental values (see section 4.4).
3. TOW (time of week) are seconds from the beginning of the GPS reference week.
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 INS orientation relative to the carrier object axes is set by alignment angles (see “Appendix E. Variants of the Inertial Labs™ INS Mounting Relative to the Object Axes”).
5. P_bar is pressure.
6. Temper is averaged temperature in 3 gyros.
7. USW is unit status word (see Appendix D for details).
8. pos_type is GNSS position type (see Table C.16).
9. GNSS_PACC is 3D position accuracy estimate (1 sigma).
10. GNSS_SACC is speed accuracy estimate (1 sigma).
11. #solnSVs is number of satellites used in navigation solution.
12. GNSS_info1, GNSS_info2 contain information about GNSS data (see Table C.5, Table C.6).
13. Diff_age is age of differential correction.
14. UTC is the absolute number of seconds since midnight, January 1, 1970, including leap seconds. A value of zero indicates that UTC is not available.
15. GPS Decimal Seconds are milliseconds part of the UTC time.
16. Latency ECEF_time, Latency pos_time, and Latency vel_time are latencies of time stamps in received BESTXYZ, BESTPOS, and BESTVEL logs relative to INS time synchronized to the receiver PPS.
17. V_latency is the latency in the velocity time tag.
18. New_GPS is indicator of new update of GPS data (see Table C.7).

**19.** LSB is transmitted first.

**Table C.27. Payload of the "User Defined Data"**

| Field | Offset in payload, bytes | Size, bytes | Value |
|---|---|---|---|
| Pckg Number | 0 | 1 | Number of data packages present in the payload (N) |
| Data List | 1 | N | List of data types, one per byte, refer to Table C.28 for values |
| Data #1 | N+1 | Variable, depends on data type. Refer to Table C.28 for sizes | Data according to structure shown in Table C.28 |
| Data #2 | Variable, depends on Data #1 size | Variable, depends on data type. Refer to Table C.28 for sizes | Data according to structure shown in Table C.28 |
| … | … | … | … |
| Data #N | Variable, depends on preceding data | Variable, depends on data type. Refer to Table C.28 for sizes | Data according to structure shown in Table C.28 |

**Table C.28. Detailed description of "User Defined Data" structure**

| Data type | Description | Size, bytes | Structure | *Note* |
|---|---|---|---|---|
| 0x00 | Reserved | TBD | TBD | |
| 0x01 | GPS INS Time (round) | 4 | unsigned integer | Time of INS solution, milliseconds from the beginning of the GPS reference week, rounded to 1000 / (output data rate) |
| 0x02 | GPS INS Time | 8 | unsigned integer | Time of INS solution, seconds*1.0e9 from the beginning of the GPS reference week |
| 0x03 | GPS IMU Time | 8 | unsigned integer | Time of INS IMU data, seconds*1.0e9 from the beginning of the GPS reference week |
| 0x04 | UTC | 9 | byte | UTC Hours |
| | | | byte | UTC Minutes |
| | | | byte | UTC Seconds |
| | | | word | UTC Decimal Seconds |
| | | | byte | UTC Month |
| | | | byte | UTC Day |
| | | | word | UTC Year |
| 0x05 – 0x06 | Reserved | TBD | TBD | |
| 0x07 | Orientation angles | 6 | word | Heading, deg*100 |
| | | | sword | Pitch, deg*100 |
| | | | sword | Roll, deg*100 |
| 0x08 | Orientation angles HR | 12 | unsigned integer | Heading, deg*1000 |
| | | | integer | Pitch, deg*1000 |
| | | | integer | Roll, deg*1000 |
| 0x09 | Quaternion of | 8 | sword | q0*10000 |

| | | | | |
|---|---|---|---|---|
| | orientation | | sword | q1*10000 |
| | | | sword | q2*10000 |
| | | | sword | q3*10000 |
| 0x0A – 0x0F | Reserved | TBD | TBD | |
| 0x10 | Position | 12 | integer | Latitude, deg*1.0e7 |
| | | | integer | Longitude, deg*1.0e7 |
| | | | integer | Altitude, m*100 |
| 0x11 | Position HR | 20 | integer (8 byte) | Latitude, deg*1.0e9 |
| | | | integer (8 byte) | Longitude, deg*1.0e9 |
| | | | integer | Altitude, m*1000 |
| 0x12 | Velocities | 12 | integer | East speed, m/s*100 |
| | | | integer | North speed, m/s*100 |
| | | | integer | Vertical speed, m/s*100 |
| 0x13 – 0x1A | Reserved | | | Data destined for other device |
| 0x1B | Velocities HR | 12 | integer | East speed, m/s*1.0e6 |
| | | | integer | North speed, m/s*1.0e6 |
| | | | integer | Vertical speed, m/s*1.0e6 |
| 0x1C – 0x1F | Reserved | TBD | TBD | |
| 0x20 | Gyro data | 6 | sword | Gyro X, deg/s*KG |
| | | | sword | Gyro Y, deg/s*KG |
| | | | sword | Gyro Z, deg/s*KG |
| 0x21 | Gyro data HR | 12 | integer | Gyro X, deg/s*1.0e5 |
| | | | integer | Gyro Y, deg/s*1.0e5 |
| | | | integer | Gyro Z, deg/s*1.0e5 |
| 0x22 | Accelerometer data | 6 | sword | Accelerometer X, g*KA |
| | | | sword | Accelerometer Y, g*KA |
| | | | sword | Accelerometer Z, g*KA |
| 0x23 | Accelerometer data HR | 12 | integer | Accelerometer X, g*1.0e6 |
| | | | integer | Accelerometer Y, g*1.0e6 |
| | | | integer | Accelerometer Z, g*1.0e6 |
| 0x24 | Magnetometer data | 6 | sword | Magnetometer X, nT/10 |
| | | | sword | Magnetometer Y, nT/10 |
| | | | sword | Magnetometer Z, nT/10 |
| 0x25 | Barometer data | 6 | word | Pressure, Pa/2 |
| | | | integer | Baro altitude, m*100 |
| 0x26 | Sensors bias | 7 | signed byte | Gyro bias X, deg/s*0.5*$10^4$ |
| | | | signed byte | Gyro bias Y, deg/s*0.5*$10^4$ |
| | | | signed byte | Gyro bias Z, deg/s*0.5*$10^4$ |
| | | | signed byte | Accel bias X, g*0.5*$10^5$ |
| | | | signed byte | Accel bias Y, g*0.5*$10^5$ |
| | | | signed byte | Accel bias Z, g*0.5*$10^5$ |
| | | | byte | Reserved |
| 0x27 | Accelerometer data | 12 | integer | Accelerometer X, m/$s^2$*1.0e5 |

| | | | | |
|---|---|---|---|---|
| | in PV measuring point (see note #14) | | integer | Accelerometer Y, m/s$^2$*1.0e5 |
| | | | integer | Accelerometer Z, m/s$^2$*1.0e5 |
| 0x29 | Gyro data filtered | 12 | integer | Gyro X filtered, deg/s*1.0e5 |
| | | | integer | Gyro Y filtered, deg/s*1.0e5 |
| | | | integer | Gyro Z filtered, deg/s*1.0e5 |
| 0x2A | HG4930 IMU status | 1 | byte | IMU status (only for Honeywell HG4930). See description in Table C.29 |
| 0x2B – 0x2F | Reserved | TBD | TBD | |
| 0x30 | GNSS Position | 12 | integer | GNSS Latitude, deg*1.0e7 |
| | | | integer | GNSS Longitude, deg*1.0e7 |
| | | | integer | GNSS Altitude, m*100 |
| 0x31 | GNSS Position HR | 20 | integer (8 byte) | GNSS Latitude, deg*1.0e9 |
| | | | integer (8 byte) | GNSS Longitude, deg*1.0e9 |
| | | | integer | GNSS Altitude, m*1000 |
| 0x32 | GNSS Velocity, Track over ground | 10 | integer | GNSS Horizontal speed, m/s*100 |
| | | | word | GNSS Track over ground, deg*100 |
| | | | integer | GNSS Vertical speed, m/s*100 |
| 0x33 | GNSS Heading, GNSS Pitch | 4 | word | GNSS Heading, deg*100 |
| | | | sword | GNSS Pitch, deg*100 |
| 0x34 | GNSS position STD | 6 | word | GNSS Latitude STD, m*1000 |
| | | | word | GNSS Longitude STD, *1000 |
| | | | word | GNSS Height STD, *1000 |
| 0x35 | GNSS Heading STD, GNSS Pitch STD | 4 | word | GNSS Heading STD, deg*100 |
| | | | word | GNSS Pitch STD, deg*100 |
| 0x36 | GNSS info short | 2 | byte | GNSS_info1 (Position type, pseudorange iono correction – see Table C.5) |
| | | | byte | GNSS_info2 (solution status, time status, GNSS constellations in use – see Table C.6) |
| 0x37 | Full satellites info | 8 | byte | #SVs (Number of satellites tracked) |
| | | | byte | #SolnSVs (Number of satellites used in solution) |
| | | | byte | #SolnL1SVs (Number of satellites with L1/E1/B1 signals used in solution) |
| | | | byte | #SolnMultiSVs (Number of satellites with multi-frequency signals used in solution) |
| | | | byte | Galileo and BeiDou signal-used mask (see Table C.19) |
| | | | byte | GPS and GLONASS signal-used mask (see Table C.18) |
| | | | byte | GPS time status (see Table C.23) |
| | | | byte | Extended solution status (Table C.17) |
| 0x38 | GNSS Solution status | 1 | byte | See Table C.15 |
| 0x39 | GNSS Position or | 1 | byte | See Table C.16 |

| | | | | |
|---|---|---|---|---|
| | Velocity type | | | |
| 0x3A | GNSS Angles position type | 1 | byte | Angles position type at calculation of GNSS angles (see Table C.16) |
| 0x3B | Number of satellites used in solution | 1 | byte | |
| 0x3C | GPS week | 2 | word | |
| 0x3D | GNSS Velocity Latency | 2 | word | ms |
| 0x3E | GNSS Position timestamp | 4 | unsigned integer | ms |
| 0x3F | GNSS Velocity timestamp | 4 | unsigned integer | ms |
| 0x40 | GNSS Heading timestamp | 4 | unsigned integer | ms |
| 0x41 | New GPS | 1 | byte | Indicator of new update of GPS data (see Table C.7) |
| 0x42 | Dilution of precision (DOP) | 10 | word | GDOP (Geometric dilution of precision), $*10^3$ |
| | | | word | PDOP (Position dilution of precision), $*10^3$ |
| | | | word | HDOP (Horizontal dilution of precision), $*10^3$ |
| | | | word | VDOP (Vertical dilution of precision), $*10^3$ |
| | | | word | TDOP (Time dilution of precision), $*10^3$ |
| 0x43 | GNSS Position and Speed accuracy | 4 | word | GNSS_PACC, m*100 |
| | | | word | GNSS_SACC, m/s*100 |
| 0x44 | GDOP, PDOP | 4 | word | GDOP (Geometric dilution of precision), $*10^3$ |
| | | | word | PDOP (Position dilution of precision), $*10^3$ |
| 0x45 | GNSS Track over ground | 2 | word | GNSS Track over ground, deg*100 |
| 0x46 | Reserved | | | |
| 0x47 | GNSS diff age | 2 | word | Age of differential correction, s*10 |
| 0x48 | GNSS ECEF Velocity STD | 6 | word | Standard deviation of GNSS ECEF velocity X, m/s*1000 |
| | | | word | Standard deviation of GNSS ECEF velocity Y, m/s*1000 |
| | | | word | Standard deviation of GNSS ECEF velocity Z, m/s*1000 |
| 0x49 | PPPSEED status (see note #15) | 2 | byte | APPLICATION status |
| | | | byte | STORE status |
| 0x4A – 0x4F | Reserved | TBD | TBD | |
| 0x50 | Supply voltage | 2 | word | VDC*100 |
| 0x51 | Stabilized voltage | 2 | word | VDC*1000 |
| 0x52 | Temperature | 2 | sword | °C*10 |
| 0x53 | Unit status word | 2 | word | USW (see Appendix D) |
| 0x54 | INS solution status | 1 | byte | See Table C.30 for details |
| 0x55 | KF position covariance | 3 | byte | Latitude STD, cm |
| | | | byte | Longitude STD, cm |

| | | | | |
|---|---|---|---|---|
| | | | byte | Altitude STD, cm |
| 0x56 | KF heading covariance | 1 | byte | Heading STD, deg*100 |
| 0x57 | KF position covariance HR | 6 | word | Latitude STD, mm |
| | | | word | Longitude STD, mm |
| | | | word | Altitude STD, mm |
| 0x58 | KF velocity covariance | 3 | byte | East speed STD, mm/s |
| | | | byte | North speed STD, mm/s |
| | | | byte | Vertical speed STD, mm/s |
| 0x59 | Calculation time | 4 | integer | Time of algorithm calculation, μs*1000 |
| 0x5A – 0x5F | Reserved | TBD | TBD | |
| 0x60 | Odometer | 4 | integer | Odometer distance, m*1000 |
| 0x61 | Air speed | 2 | sword | Air speed, kt*100 |
| 0x62 | Wind data | 8 | sword | North wind, kt*100 |
| | | | sword | East wind, kt*100 |
| | | | word | North wind STD, kt*100 |
| | | | word | East wind STD, kt*100 |
| 0x63 | External position | 20 | integer | Latitude external, deg*1.0e7 |
| | | | integer | Longitude external, deg*1.0e7 |
| | | | integer | Altitude external, m*1000 |
| | | | word | Latitude external STD, m*100 |
| | | | word | Longitude external STD, m*100 |
| | | | word | Altitude external STD, m*100 |
| | | | word | External position latency, sec*1000 |
| 0x64 | Doppler shift from locator | 16 | integer | Locator latitude, deg*1.0e7 |
| | | | integer | Locator longitude, deg*1.0e7 |
| | | | integer | Locator altitude, deg*1.0e7 |
| | | | sword | Doppler shift, m/s*100 |
| | | | word | Doppler shift STD, m/s*100 |
| 0x65 | New aiding data | 2 | word | Indicator of update of external sensors data (see Table C.13) |
| 0x66 | Heading external | 6 | word | Heading external, deg*100 |
| | | | word | Heading external STD, deg*100 |
| | | | word | Heading external latency, sec*1000 |
| 0x67 | DVL data (depends on reference frame, see note #13) | 24 | integer | Lateral velocity, 1000*m/sec |
| | | | integer | Forward velocity, 1000*m/sec |
| | | | integer | Vertical velocity, 1000*m/sec |
| | | | word | Lateral velocity STD, 1000*m/sec |
| | | | word | Forward velocity STD, 1000*m/sec |
| | | | word | Vertical velocity STD, 1000*m/s |
| | | | word | Velocity latency, msec |
| | | | integer | Reserved |
| 0x68 | Sensors bias external | 7 | signed byte | Gyro bias X, deg/s*0.5*$10^4$ |
| | | | signed byte | Gyro bias Y, deg/s*0.5*$10^4$ |
| | | | signed byte | Gyro bias Z, deg/s*0.5*$10^4$ |
| | | | signed byte | Accel bias X, g*0.5*$10^5$ |
| | | | signed byte | Accel bias Y, g*0.5*$10^5$ |

| | | | | |
|---|---|---|---|---|
| | | | signed byte | Accel bias Z, g*0.5*$10^5$ |
| | | | byte | Reserved |
| 0x69 | Pitch and Roll external | 4 | sword | Pitch external, deg*100 |
| | | | sword | Roll external, deg*100 |
| 0x6A | GNSS antennas position | 12 | sword | Primary antenna, Right , m*1000 |
| | | | sword | Primary antenna, Forward , m*1000 |
| | | | sword | Primary antenna, Up , m*1000 |
| | | | sword | Secondary antenna, Right , m*1000 |
| | | | sword | Secondary antenna, Forward , m*1000 |
| | | | sword | Secondary antenna, Up , m*1000 |
| 0x6B | Ambient Air Data | 8 | sword | Temperature, degC*10 |
| | | | integer | Altitude, m*100 |
| | | | word | Pressure, Pa/2 |
| 0x6C | Altitude external | 6 | integer | Altitude external in m*1000 |
| | | | word | Altitude external STD in m*100 |
| 0x6D – 0x89 | Reserved | TBD | TBD | |
| 0x8A | Wind speed (see note #17) | 2 | sword | East wind, m/s*100 |
| | | 2 | sword | North wind, m/s*100 |
| | | 2 | sword | Vertical wind, m/s*100 |
| 0x8B – 0x8F | Reserved | TBD | TBD | |

**Notes:**

1. Unit status word (USW) is the highly recommended choice to control INS unit state (see Appendix D for details).
2. If even one data type from the “GNSS data” group is chosen, then “New_GPS” data is the highly recommended choice. This is indicator of new update of GNSS data (see Table C.7 for details).
3. If even one data type from the “External aiding data” group is chosen, then “New aiding data” is the highly recommended choice. This is indicator of new update of aiding data (see Table C.13 for details).
4. Orientation, position, and velocity data can be presented in the form of instant or average values (see section 4.2.1, “Averaged output data” checkbox and INS ICD Appendix E.1 for details).
5. Gyros, accelerometers, and magnetometers data can be presented in form of instant, average, or incremental values (see section 4.4).
6. UTC Decimal Seconds are milliseconds of the UTC time.
7. Values of KG, KA are scale factors depending on gyro and accelerometer range (see Table C.4).
8. g = 9.8106 m/$s^2$.
9. 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 INS orientation relative to the carrier object axes is set by alignment angles (see “Appendix E. Variants of the Inertial Labs™ INS Mounting Relative to the Object Axes”).

10. Temper is averaged temperature in 3 gyros.
11. GNSS_PACC is 3D position accuracy estimate (1 sigma).
12. GNSS_SACC is speed accuracy estimate (1 sigma).
13. DVL (Doppler Velocity Log) data can be presented in the vehicle axes (in the right, forward, vertical directions) or in navigational frame (East, North, Up) depending on "DVL reference frame" value (see section 4.2.4.2).
14. INS can calculate accelerations for any measuring point set by its position relative to the accelerometer mass-center of the INS unit. See section 4.2.1 for details.
15. PPPSEED status logs are present only if PPP correction (TerraStar or Oceanix) is chosen for the NovAtel GNSS receiver; otherwise appropriate fields will be zeros (see section 10.2.1).
16. North and east wind are northward and eastward components of the ground speed of air mass motion.
17. Wind speed in three directions (eastward, northward and vertical) is estimated at available GNSS data and at receiving of external air speed otherwise these estimates are frozen. Also, wind speed accounts external wind data if they were received as aiding data (see section 4.2.4.2 and INS ICD, section "6.6.4. Aiding Data Input Through the Main COM-Port" for details).
18. LSB is transmitted first.

**Table C.29. The Honeywell HG4930 IMU status description**

| Size | Bit | Definition | Description |
|---|---|---|---|
| byte | 0 | Gyro Health | 0 – Successful<br>1 – Failed |
| | 1 | Start data flag | 0 – Sensor data<br>1 – 0x5555 data transmitted for synchronization |
| | 2 | Process Test | 0 – Successful<br>1 – Failed |
| | 3 | Memory Test | 0 – Successful<br>1 – Failed |
| | 4 | Electronics Test (ASIC) | 0 – Successful<br>1 – Failed |
| | 5 | Gyro Health | 0 – Successful<br>1 – Failed |
| | 6 | Accelerometer Health | 0 – Successful<br>1 – Failed |
| | 7 | Status flag | 0 |

**Table C.30. INS solution status (data type # 0x54)**

| Value | Description |
|---|---|
| 0 | INS solution is good. |
| 1 | INS solution is satisfactory, KF convergence is in progress. |
| 2 | INS started at absence of GNSS solution and it is still absent. |
| 3 | Heading correction did not yet start. This could be due to not high enough vehicle speed (at "GNSS track" or "Inertial" type of correction), or because the dual antenna position did not yet reach "Integer narrow-lane ambiguity solution" or "Integer L1 ambiguity solution" (at "Dual antenna GNSS" type of correction). |
| 4 | INS operates in autonomous mode (without GNSS or any other aiding data). |

| | |
|---|---|
| 5 | INS operates without GNSS data but with other external aiding data. |
| 6 | INS froze position and velocity calculation because time of INS autonomous operation exceeded set maximum time. |
| 7 | Zero velocity update (ZUPT) is applied to INS solution at detected stop. |
| 8 | INS solution is invalid. |

At the **"INS NMEA"** output, the INS 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 "NMEA Output" sentence is as follows:

**$PAPR,LLmm.mmmm,n,YYYmm.mmmm,x,AAAA.aa,B,RRRR.rr,PPP.pp,HHH.hh,tttttttt,TTT.t,VV.v,SSSS*CC<CR><LF>**

where **PAPR** is the identifier and other fields are listed below:

- **LLmm.mmmm** is unsigned latitude, where LL are degrees and mm.mmmm are minutes;
- **n** is N or S (north or south);
- **YYYmm.mmmm** is unsigned longitude, where YYY are degrees and mm.mmmm are minutes;
- **x** is E or W (East or West);
- **AAAA.aa** is altitude in meters;
- **B** denotes the kind of height data ('a' is altitude) that is defined by switch as "Barometric altitude" in the "Pressure sensor" tab of the "Devices Options" window (see section 10.3);
- **RRRR.rr** is roll in degrees;
- **PPP.pp** is pitch in degrees;
- **HHH.hh** is heading in degrees;
- **tttttttt** is timestamp (milliseconds from the beginning of the GPS reference week);
- **TTT.t** is temperature inside the INS (averaged value for 3 gyros);
- **VV.v** is input voltage of the INS;
- **SSSS** is unit status word, USW (see Appendix D for details). It is hex written with ASCII;
- **CC** is check sum that consists of a "*" and two hex digits representing XOR of all characters between, but not including, "$" and "*".

**Note:** Orientation, position, and velocity data can be presented in the form of instant or average values (see section 4.2.1, "Averaged output data" checkbox and INS ICD Appendix E.1 for details).

The **"INS Sensors NMEA output"** data have a structure similar to the "INS NMEA", with the addition of gyros and accelerometers data. So, at the **"INS Sensors NMEA output"**, the INS 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 "INS Sensors NMEA output" sentence is as follows:

**$PAPS,LLmm.mmmm,n,YYYmm.mmmm,x,AAAA.aa,B,RRRR.rr,PPP.pp,HHH.hh,GGGG.xx,GGGG.yy,GGGG.zz,AA.xxxx,AA.yyyy,AA.zzzz,tttttttt,TTT.t,VV.v,SSSS*CC<CR><LF>**

where **PAPS** is the identifier and other fields are listed below:

- **LLmm.mmmm** is unsigned latitude, where LL are degrees and mm.mmmm are minutes;
- **n** is N or S (North or South);
- **YYYmm.mmmm** is unsigned longitude, where YYY are degrees and mm.mmmm are minutes;
- **x** is E or W (East or West);
- **AAAA.aa** is altitude in meters;
- **B** denotes the kind of height data ('a' is altitude) that is defined by switch as "Barometric altitude" in the "Pressure sensor" tab of the "Devices Options" window (see section 10.3);
- **RRRR.rr** is roll in degrees;
- **PPP.pp** is pitch in degrees;
- **HHH.hh** is heading in degrees;
- **GGGG.xx** is gyro X data in degrees/s;
- **GGGG.yy** is gyro Y data in degrees/s;
- **GGGG.zz** is gyro Z data in degrees/s;
- **AA.xxxx** is accelerometer X data in g;
- **AA.yyyy** is accelerometer Y data in g;
- **AA.zzzz** is accelerometer Z data in g;
- **tttttttt** is timestamp (milliseconds from the beginning of the GPS reference week);
- **TTT.t** is temperature inside the INS (averaged value for 3 gyros);

- **VV.v** is input voltage of the INS;
- **SSSS** is unit status word, USW (see Appendix D for details). It is hex written with ASCII;
- **CC** is check sum that consists of a "*" and two hex digits representing XOR of all characters between, but not including, "$" and "*".

**Notes:**

1. Orientation, position, and velocity data can be presented in the form of instant or average values (see section 4.2.1, "Averaged output data" checkbox and INS ICD Appendix E.1 for details).
2. Gyros, accelerometers, and magnetometers data can be presented in form of instant, average, or incremental values (see section 4.4).

For the **"Cobham UAV 200 Satcom"**, the INS data are transmitted as AT-commands in the form of sentences with printable ASCII characters. Each sentence starts with an "AT_ITINS=" text 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 "Cobham UAV 200 Satcom" sentence is as follows, with fields listed and described in Table C.31:

**AT_ITINS=<lat>,<lon>,<alt>,<height>,<utc>,<ns_vel>,<ew_vel>,<gnd_spd>,<track_ angle>,<roll>,<pitch>,<heading>,<mag_heading>,<roll_rate>,<pitch_rate>,<heading_rate><CR><LF>**

**Table C.31. Structure of the "Cobham UAV 200 Satcom" sentence**

| Parameter | Description | Units/Format | Positive Sense | Range min | Range max |
|---|---|---|---|---|---|
| AT_ITINS= | AT-Command | - | - | - | - |
| <lat> | Latitude | decimal degrees | North | -90 | 90 |
| <long> | Longitude | decimal degrees | East | -180 | 180 |
| <alt> | Altitude (pressure) | meters | Up | -500 | 25000 |
| <height> | Height | meters | Up | -500 | 25000 |
| <utc> | Time | <year>.<month>.<day>-<hour>:<minute>:<second> | | 13-12-1901 | 19-01-2038 |
| <ns_vel> | North-South velocity | m/s | North | -500 | 500 |
| <ew_ve/> | East-West velocity | m/s | East | -500 | 500 |
| <gnd_spd> | Ground speed | m/s | | 0 | 500 |
| <track_angle> | Track angle – true | degrees | Clockwise from North | -180 | 360 |
| <roll> | Roll angle | degrees | Right | -180 | 360 |
| <pitch> | Pitch angle | degrees | Nose up | -180 | 360 |

| | | | | | |
|---|---|---|---|---|---|
| <heading> | True Heading | degrees | Clockwise from North | -180 | 360 |
| <mag_heading> | Magnetic Heading | degrees | Clockwise from North | -180 | 360 |
| <roll_rate> | Roll rate | degrees/second | Right | -90 | 90 |
| <pitch_rate> | Pitch rate | degrees/second | Nose up | -90 | 90 |
| <heading_rate> | Yaw rate | degrees/second | Clockwise | -90 | 90 |
| <CR> | Carriage return | | | | |
| <LF> | Line feed | | | | |

**Table C.32. The "NAV440" message structure**

| Byte number | 0 – 1 | 2 – 3 | 4 | 5 – 6 | 7 – 8 | 9 – 10 |
|---|---|---|---|---|---|---|
| Parameter | Preamble | Packet Type | Length | rollAngle | pitchAngle | yawAngleTrue |
| Length | 2 byte | 2 byte | 1 byte | 2 byte sword | 2 byte sword | 2 byte sword |
| *Note* | 0x5555 | 0x4E30 | 0x20 | 2*pi/2^16, radians [360°/2^16, deg] | 2*pi/2^16, Radians [360°/2^16, deg] | 2*pi/2^16, Radians [360°/2^16, deg] |

**Table C.32 (continued)**

| Byte number | 11 – 12 | 13 – 14 | 15 – 16 | 17 – 18 | 19 – 20 | 21 – 22 |
|---|---|---|---|---|---|---|
| Parameter | xRateCorrected | yRateCorrected | zRateCorrected | nVel | eVel | dVel |
| Length | 2 byte sword | 2 byte sword | 2 byte sword | 2 byte sword | 2 byte sword | 2 byte sword |
| *Note* | 7*pi/2^16, rad/s [1260°/2^16, deg/s] | 7*pi/2^16, rad/s [1260°/2^16, deg/s] | 7*pi/2^16, rad/s [1260°/2^16, deg/s] | 512/2^16, m/s | 512/2^16, m/s | 512/2^16, m/s |

**Table C.32 (continued)**

| Byte number | 23 – 26 | 27 – 30 | 31 – 32 | 33 – 34 | 35 – 36 | 37 – 38 |
|---|---|---|---|---|---|---|
| Parameter | longitudeGPS | latitudeGPS | altitudeGPS | GPSITOW | BITstatus | Check sum |
| Length | 4 byte integer | 4 byte integer | 2 byte sword | 2 byte word | 2 byte word | 2 byte word |
| *Note* | 2*pi/2^32, Radians [360°/2^32, deg] | 2*pi/2^32, Radians [360°/2^32, deg] | (2^14/2^16) – 100, m | lower 2 bytes of GPS TOW, ms | | CRC-16 check sum |

**Notes:**

1. rollAngle, pitchAngle, and yawAngleTrue are orientation angles: roll, pitch, and yaw (true north), in radians. Angles: scaled to a range of [-pi, +pi] or [-180 deg to +180 deg].

2. xRateCorrected, yRateCorrected, and zRateCorrected are corrected angular rate around X, Y, and Z axes, in rad/s.
3. nVel, eVel, and dVel are North, East, and Down velocity, respectively, in m/s.
4. longitudeGPS, latitudeGPS, altitudeGPS are GPS Longitude in radians, GPS Latitude in radians, and GPS altitude in meters (range is from -100 to 16284 meters).
5. GPSITOW is GPS Integer Time of Week (lower 2 bytes of GPS Time), in milliseconds.
6. BITstatus is Master BIT and Status (see Table C.33).
7. All multiple byte values are transmitted Big Endian (most significant byte first).
8. All communication packets end with a single word, CRC (2 bytes). CRCs are calculated on all packet bytes excluding the preamble and CRC itself. Input packets with incorrect CRCs will be ignored. This 16-bit CRC-CCITT standard is maintained by the International Telecommunication Union (ITU). The highlights are:
    - Width = 16 bits
    - Polynomial 0x1021
    - Initial value = 0xFFFF
    - No XOR performed on the final value

**Table C.33. NAV440 Default BIT Status Definitions**

| BITstatus Field | Bits | Meaning | Category |
|---|---|---|---|
| masterFail (1) | 0 | 0 = normal, 1 = fatal error has occurred | BIT |
| HardwareError (2) | 1 | 0 = normal, 1 = internal hardware error | BIT |
| comError | 2 | 0 = normal, 1 = communication error | BIT |
| softwareError (3) | 3 | 0 = normal,1 = internal software error | BIT |
| Reserved | 4 – 7 | N/A | |
| masterStatus (4) | 8 | 0 = nominal, 1 = one or more status alert | Status |
| hardwareStatus | 9 | 0 = nominal,<br>1 = internal GPS unlocked or 1PPS invalid | Status |
| comStatus | 10 | Disabled | Status |
| softwareStatus | 11 | 0 = nominal, 1 = algorithm initialization | Status |
| sensorStatus (5) | 12 | 0 = nominal, 1 = sensor over-range | Status |
| Reserved | 13 – 15 | N/A | |

**Notes:**

1. masterFail equals 1 when there is an error with one of the bits in BIT Category; otherwise, value equals 0.
2. HardwareError equals 1 when there is an error with: IMU data correctness, Gyroscope Unit, Accelerometer Unit, Magnetometer Unit, Electronics, or GNSS receiver; otherwise, value equals 0 when there are no errors.
3. softwareError equals 1 when Initial Alignment has failed; otherwise, value equals 0 when there are no errors.
4. masterStatus equals 1 when there is an error with one of the bits in Status Category; otherwise, value equals 0.
5. sensorStatus equals 1 when there is an error with: Incorrect Power Supply, Angular Rate Exceeding Detect, Large Magnetic Field Detect, or Environmental Temperature; otherwise, value equals 0 when there are no errors.

## INS Sensors

P11 Test report Date\Time 15.07.2015 11:53:00, GPS reference week number 1853

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 278.01 | 0.30 | -1.35 | -31 | 25 | -48 | 51 | -137 | 4164 | -5112 | -418 | -7308 | 0 | 0 | 8525 | 12.2 |
| 278.00 | 0.29 | -1.34 | -30 | 14 | -52 | 52 | -142 | 4166 | -5110 | -396 | -7308 | 0 | 0 | 9401 | 5.01 |

(continuation)

| USW (L/H) | Latitude | Longitude | Height | LatRMS | LonRMS | HgtRMS | hor_spd | trk_gnd | ver_spd | ms_Pos | TS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0000000 00000000 | 39.0492073 | -77.3909065 | 121.63 | 3.959 | -7.62 | 11.776 | 0.02 | 71.80 | 0.02 | 291206400 | 180 |
| 0000000 00000000 | 39.0492073 | -77.3909065 | 121.63 | 3.959 | -7.62 | 11.776 | 0.02 | 71.80 | 0.02 | 291206400 | 180 |

(continuation)

| sol_stat | pos_type | #SVs | #solnSVs | L1SVs | Multi | ext_sol | Gal_Bei | GPS_GLO | latency | UP | UT | New_GPS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 16 | 4 | 4 | 4 | 0 | 2 | 0 | 1 | 0.150 | 41350 | 28309 | 3 |
| 0 | 16 | 4 | 4 | 4 | 0 | 2 | 0 | 1 | 0.150 | 41350 | 28309 | 0 |

***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 | ADC code | – | – | ADC code | VDC |

(continuation)

| USW (L/H) | Latitude | Longitude | Height | LatRMS | LonRMS | HgtRMS | hor_spd | trk_gnd | ver_spd | ms_Pos | TS | sol_stat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| – – | deg | deg | m | m | m | m | m/s | deg | m/s | ms | – | – |

(continuation)

| pos_type | #SVs | #solnSVs | L1SVs | Multi | ext_sol | Gal_Bei | GPS_GLO | latency | UP | UT | New_GPS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| – | – | – | – | – | – | – | – | s | ADC code | ADC code | – |

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

## INS OPVT Output

P13 Test report Date\Time 15.07.2015 11:54:00, GPS reference week number 1853

| Heading | Pitch | Roll | Gyro_X | Gyro_Y | Gyro_Z | Acc_X | Acc_Y | Acc_Z | Magn_X | Magn_Y | Magn_Z | Temperature | Vdd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 277.97 | 0.32 | -1.43 | 0.02 | -0.020 | 0.020 | 0.025 | 0.006 | 1.005 | 21880 | 70 | -38050 | 36.1 | 12.16 |
| 278.07 | 0.32 | -1.43 | -0.02 | 0.060 | -0.020 | 0.024 | 0.006 | 1.007 | 21900 | 50 | -38060 | 36.1 | 12.19 |

(continuation)

| USW (L/H) | Latitude | Longitude | Height | V_East | V_North | V_Up | Lat_GNSS | Long_GNSS | Height_GNSS | Hor_spd |
|---|---|---|---|---|---|---|---|---|---|---|
| 0000000 00000000 | 39.0492073 | -77.3909065 | 120.42 | 0.00 | 0.00 | 0.00 | 39.0492073 | -77.3909065 | 120.67 | 0.04 |
| 0000000 00000000 | 39.0492073 | -77.3909065 | 120.42 | 0.00 | 0.00 | 0.00 | 39.0492073 | -77.3909065 | 120.67 | 0.04 |

(continuation)

| Trk_gnd | Ver_spd | ms_Pos | GNSS_info_1 | GNSS_info_2 | #solnSVs | latency | P_Bar | H_Bar | New_GPS |
|---|---|---|---|---|---|---|---|---|---|
| 89.77 | 0.25 | 291267650 | 00010000 | 00011100 | 4 | 0.150 | 99792 | 120.42 | 3 |
| 89.77 | 0.25 | 291267650 | 00010000 | 00011100 | 4 | 0.150 | 99790 | 120.51 | 0 |

***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 | deg/s | deg/s | deg/s | g | g | g | nT | nT | nT | – | – | deg C | VDC |

(continuation)

| USW (L/H) | Latitude | Longitude | Height | V_East | V_North | V_Up | Lat_GNSS | Long_GNSS | Height_GNSS | Hor_spd |
|---|---|---|---|---|---|---|---|---|---|---|
| – – | deg | deg | m | m/s | m/s | m/s | deg | deg | m | m/s |

(continuation)

| Trk_gnd | Ver_spd | ms_Pos | GNSS_info_1 | GNSS_info_2 | #solnSVs | latency | P_Bar | H_Bar | New_GPS |
|---|---|---|---|---|---|---|---|---|---|
| deg | m/s | ms | – | – | – | s | Pa | m | – |

USW (Unit Status Word) is in binary form with low and high bytes listed in two columns. Each bit of the USW is specified in the Appendix D.

## INS QPVT Output

P24 Test report Date\Time 15.07.2015 11:54:00, GPS reference week number 1853

| Lk0 | Lk1 | Lk2 | Lk3 | Gyro_X | Gyro_Y | Gyro_Z | Acc_X | Acc_Y | Acc_Z | Magn_X | Magn_Y | Magn_Z | Temperature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.6128 | -0.0099 | 0.0056 | 0.7902 | 0.02 | -0.020 | 0.020 | 0.025 | 0.006 | 1.005 | 21880 | 70 | -38050 | 36.1 |
| 0.6128 | -0.0099 | 0.0056 | 0.7902 | -0.02 | 0.060 | -0.020 | 0.024 | 0.006 | 1.007 | 21900 | 50 | -38060 | 36.1 |

(continuation)

| Vdd | USW (L/H) | Latitude | Longitude | Height | V_East | V_North | V_Up | Lat_GNSS | Long_GNSS | Height_GNSS |
|---|---|---|---|---|---|---|---|---|---|---|
| 12.16 | 0000000 00000000 | 39.0492073 | -77.3909065 | 120.42 | 0.00 | 0.00 | 0.00 | 39.0492073 | -77.3909065 | 120.67 |
| 12.19 | 0000000 00000000 | 39.0492073 | -77.3909065 | 120.42 | 0.00 | 0.00 | 0.00 | 39.0492073 | -77.3909065 | 120.67 |

(continuation)

| Hor_spd | Trk_gnd | Ver_spd | ms_Pos | GNSS_info_1 | GNSS_info_2 | #solnSVs | latency | P_Bar | H_Bar | New_GPS |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.04 | 89.77 | 0.25 | 291267650 | 00010000 | 00011100 | 4 | 0.150 | 99792 | 120.42 | 3 |
| 0.04 | 89.77 | 0.25 | 291267650 | 00010000 | 00011100 | 4 | 0.150 | 99790 | 120.51 | 0 |

***Note:*** saved data units

| Lk0 | Lk1 | Lk2 | Lk3 | Gyro_X | Gyro_Y | Gyro_Z | Acc_X | Acc_Y | Acc_Z | Magn_X | Magn_Y | Magn_Z | Reserv1 | Reserv2 | Temperature |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| – | – | – | – | deg/s | deg/s | deg/s | g | g | g | nT | nT | nT | – | – | deg C |

(continuation)

| Vdd | USW (L/H) | Latitude | Longitude | Height | V_East | V_North | V_Up | Lat_GNSS | Long_GNSS | Height_GNSS |
|---|---|---|---|---|---|---|---|---|---|---|
| VDC | – – | deg | deg | m | m/s | m/s | m/s | deg | deg | m |

(continuation)

| Hor_spd | Trk_gnd | Ver_spd | ms_Pos | GNSS_info_1 | GNSS_info_2 | #solnSVs | latency | P_Bar | H_Bar | New_GPS |
|---|---|---|---|---|---|---|---|---|---|---|
| m/s | deg | m/s | ms | – | – | – | s | Pa | m | – |

USW (Unit Status Word) is in binary form with low and high bytes listed in two columns. Each bit of the USW is specified in the Appendix D.

## INS OPVT2A Output

P29 Test report Date\Time 15.07.2015 11:54:00. GPS reference week number 1853

| Heading | Pitch | Roll | Gyro_X | Gyro_Y | Gyro_Z | Acc_X | Acc_Y | Acc_Z | Magn_X | Magn_Y | Magn_Z | Temperature | Vdd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 277.97 | 0.32 | -1.43 | 0.02 | -0.020 | 0.020 | 0.025 | 0.006 | 1.005 | 21880 | 70 | -38050 | 36.1 | 12.16 |
| 278.07 | 0.32 | -1.43 | -0.02 | 0.060 | -0.020 | 0.024 | 0.006 | 1.007 | 21900 | 50 | -38060 | 36.1 | 12.19 |

(continuation)

| USW (L/H) | Latitude | Longitude | Height | V_East | V_North | V_Up | Lat_GNSS | Long_GNSS | Height_GNSS | Hor_spd |
|---|---|---|---|---|---|---|---|---|---|---|
| 0000000 00000000 | 39.0492073 | -77.3909065 | 120.42 | 0.00 | 0.00 | 0.00 | 39.0492073 | -77.3909065 | 120.67 | 0.04 |
| 0000000 00000000 | 39.0492073 | -77.3909065 | 120.42 | 0.00 | 0.00 | 0.00 | 39.0492073 | -77.3909065 | 120.67 | 0.04 |

(continuation)

| Trk_gnd | Ver_spd | ms_Pos | GNSS_info_1 | GNSS_info_2 | #solnSVs | latency | anglesPosType | Heading_GNSS | Pitch_GNSS |
|---|---|---|---|---|---|---|---|---|---|
| 89.77 | 0.25 | 291267650 | 00010000 | 00011100 | 4 | 0.150 | 50 | 277.95 | 0.31 |
| 89.77 | 0.25 | 291267650 | 00010000 | 00011100 | 4 | 0.150 | 50 | 277.95 | 0.31 |

(continuation)

| Heading_STD_GNSS | Pitch_STD_GNSS | P_Bar | H_Bar | New_GPS |
|---|---|---|---|---|
| 0.16 | 0.38 | 99792 | 120.42 | 3 |
| 0.16 | 0.38 | 99790 | 120.51 | 0 |

***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 | deg/s | deg/s | deg/s | g | g | g | nT | nT | nT | – | – | deg C | VDC |

(continuation)

| USW (L/H) | Latitude | Longitude | Height | V_East | V_North | V_Up | Lat_GNSS | Long_GNSS | Height_GNSS | Hor_spd |
|---|---|---|---|---|---|---|---|---|---|---|
| – – | deg | deg | m | m/s | m/s | m/s | deg | deg | m | m/s |

(continuation)

| Trk_gnd | Ver_spd | ms_Pos | GNSS_info_1 | GNSS_info_2 | #solnSVs | latency | anglesPosType | Heading_GNSS | Pitch_GNSS |
|---|---|---|---|---|---|---|---|---|---|
| deg | m/s | ms | – | – | – | s | – | deg | deg |

(continuation)

| Heading_STD_GNSS | Pitch_STD_GNSS | P_Bar | H_Bar | New_GPS |
|---|---|---|---|---|
| deg | deg | Pa | m | – |

USW (Unit Status Word) is in binary form with low and high bytes listed in two columns. Each bit of the USW is specified in the Appendix D.

## INS OPVT2AW Output

P31 Test report Date\Time 15.09.2016 11:54:00, GPS reference week number 1853

| Heading | Pitch | Roll | Gyro_X | Gyro_Y | Gyro_Z | Acc_X | Acc_Y | Acc_Z | Magn_X | Magn_Y | Magn_Z | Temperature | Vdd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 277.97 | 0.32 | -1.43 | 0.02 | -0.020 | 0.020 | 0.025 | 0.006 | 1.005 | 21880 | 70 | -38050 | 36.1 | 12.16 |
| 278.07 | 0.32 | -1.43 | -0.02 | 0.060 | -0.020 | 0.024 | 0.006 | 1.007 | 21900 | 50 | -38060 | 36.1 | 12.19 |

(continuation)

| USW (L/H) | | Latitude | Longitude | Height | V_East | V_North | V_Up | Lat_GNSS | Long_GNSS | Height_GNSS | Hor_spd |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0000000 | 00000000 | 39.04 | -77.39 | 120.42 | 0.00 | 0.00 | 0.00 | 39.04 | -77.39 | 120.67 | 0.04 |
| 0000000 | 00000000 | 39.04 | -77.39 | 120.42 | 0.00 | 0.00 | 0.00 | 39.04 | -77.39 | 120.67 | 0.04 |

(continuation)

| Trk_gnd | Ver_spd | ms_gps | GPS_Week | GNSS_info1 | GNSS_info2 | #solnSVs | latency | anglesPosType | Heading_ GNSS | Pitch_ GNSS |
|---|---|---|---|---|---|---|---|---|---|---|
| 89.77 | 0.25 | 291267650 | 180 | 00010000 | 00001100 | 4 | 0.150 | 50 | 277.95 | 0.31 |
| 89.77 | 0.25 | 291267650 | 180 | 00010000 | 00001100 | 4 | 0.150 | 50 | 277.95 | 0.31 |

(continuation)

| Heading_STD_GNSS | Pitch_STD_GNSS | P_Bar | H_Bar | New_GPS |
|---|---|---|---|---|
| 0.16 | 0.38 | 99792 | 120.42 | 3 |
| 0.16 | 0.38 | 99790 | 120.51 | 0 |

***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 | deg/s | deg/s | deg/s | deg/s$^2$ | deg/s$^2$ | deg/s$^2$ | T | T | T | – | – | deg C | VDC |

(continuation)

| USW (L/H) | Latitude | Longitude | Height | V_East | V_North | V_Up | Lat_GNSS | Long_GNSS | Height_GNSS | Hor_spd |
|---|---|---|---|---|---|---|---|---|---|---|
| – – | deg | deg | m | m/s | m/s | m/s | deg | deg | m | m/s |

(continuation)

| Trk_gnd | Ver_spd | ms_gps | GNSS_info1 | GNSS_info2 | #solnSVs | latency | anglesPosType | Heading_GNSS | Pitch_GNSS |
|---|---|---|---|---|---|---|---|---|---|
| deg | m/s | ms | – | – | – | s | – | deg | deg |

(continuation)

| Heading_STD_GNSS | Pitch_STD_GNSS | P_Bar | H_Bar | New_GPS |
|---|---|---|---|---|
| deg | deg | Pa | m | – |

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 D.

## INS OPVT2Ahr Output

P30 Test report Date\Time 15.07.2015 11:54:00, GPS reference week number 1853

| Heading | Pitch | Roll | Gyro_X | Gyro_Y | Gyro_Z | Acc_X | Acc_Y | Acc_Z | Magn_X | Magn_Y | Magn_Z | Temperature | Vdd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 277.97 | 0.32 | -1.43 | 0.02345 | -0.02098 | 0.01838 | 0.025112 | 0.006391 | 1.005762 | 21880.0 | 70.0 | -38050.0 | 36.1 | 12.16 |
| 278.07 | 0.32 | -1.43 | -0.01342 | 0.06523 | -0.02711 | 0.024321 | 0.006302 | 1.007171 | 21900.0 | 50.0 | -38060.0 | 36.1 | 12.19 |

(continuation)

| USW (L/H) | Latitude | Longitude | Height | V_East | V_North | V_Up | Lat_GNSS | Long_GNSS | Height_GNSS | Hor_spd |
|---|---|---|---|---|---|---|---|---|---|---|
| 0000000 00000000 | 39.049207321 | -77.390906543 | 120.424 | 0.00 | 0.00 | 0.00 | 39.049207318 | -77.390906531 | 120.675 | 0.04 |
| 0000000 00000000 | 39.049207375 | -77.390906511 | 120.421 | 0.00 | 0.00 | 0.00 | 39.049207392 | -77.390906513 | 120.671 | 0.04 |

(continuation)

| Trk_gnd | Ver_spd | ms_Pos | GNSS_info_1 | GNSS_info_2 | #solnSVs | latency | anglesPosType | Heading_GNSS | Pitch_GNSS |
|---|---|---|---|---|---|---|---|---|---|
| 89.77 | 0.25 | 291267650 | 00010000 | 00011100 | 4 | 0.150 | 50 | 277.95 | 0.31 |
| 89.77 | 0.25 | 291267650 | 00010000 | 00011100 | 4 | 0.150 | 50 | 277.95 | 0.31 |

(continuation)

| Heading_STD_GNSS | Pitch_STD_GNSS | P_Bar | H_Bar | New_GPS |
|---|---|---|---|---|
| 0.16 | 0.38 | 99792 | 120.42 | 3 |
| 0.16 | 0.38 | 99790 | 120.51 | 0 |

***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 | deg/s | deg/s | deg/s | g | g | g | nT | nT | nT | – | – | deg C | VDC |

(continuation)

| USW (L/H) | Latitude | Longitude | Height | V_East | V_North | V_Up | Lat_GNSS | Long_GNSS | Height_GNSS | Hor_spd |
|---|---|---|---|---|---|---|---|---|---|---|
| – – | deg | deg | m | m/s | m/s | m/s | deg | deg | m | m/s |

(continuation)

| Trk_gnd | Ver_spd | ms_Pos | GNSS_info_1 | GNSS_info_2 | #solnSVs | latency | anglesPosType | Heading_GNSS | Pitch_GNSS |
|---|---|---|---|---|---|---|---|---|---|
| deg | m/s | ms | – | – | – | s | – | deg | deg |

(continuation)

| Heading_STD_GNSS | Pitch_STD_GNSS | P_Bar | H_Bar | New_GPS |
|---|---|---|---|---|
| deg | deg | Pa | m | – |

USW (Unit Status Word) is in binary form with low and high bytes listed in two columns. Each bit of the USW is specified in the Appendix D.

## INS OPVTAD Output

P36 Test report Date\Time 26.10.2017 17:47:29, GPS reference week number 1972

| Heading | Pitch | Roll | Gyro_X | Gyro_Y | Gyro_Z | Acc_X | Acc_Y | Acc_Z | Magn_X | Magn_Y | Magn_Z | Temper |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 136.43 | 1.34 | -1.00 | -0.00689 | -0.00930 | 0.01128 | 0.017418 | 0.023471 | 0.998453 | -15210.0 | -23250.0 | -45440.0 | 32.2 |
| 136.43 | 1.34 | -0.99 | -0.00443 | 0.04429 | 0.02326 | 0.017829 | 0.023891 | 0.999761 | -15170.0 | -23230.0 | -45470.0 | 32.2 |

(continuation)

| Vdd | USW (L/H) | | Latitude | Longitude | Altitude | V_East | V_North | V_Up | Lat_GNSS | Long_GNSS |
|---|---|---|---|---|---|---|---|---|---|---|
| 11.93 | 00000000 | 00000000 | 39.149048140 | -77.619228650 | 140.2100000 | 0.00 | 0.00 | 0.02 | 39.149048074 | -77.619228595 |
| 11.63 | 00000000 | 00000000 | 39.149048074 | -77.619228595 | 140.2100000 | 0.00 | 0.00 | - 0.02 | 39.149048074 | -77.619228595 |

(continuation)

| Height_GNSS | Hor_spd | Trk_gnd | Ver_spd | ms_gps | GNSS_info_1 | GNSS_info_2 | #solnSVs | Latency_ms_pos | Latency_ms_vel |
|---|---|---|---|---|---|---|---|---|---|
| 140.2210000 | 0.00 | 48.95 | -0.02 | 424075040 | 00110010 | 00011100 | 8 | 25 | 30 |
| 140.2210000 | 0.00 | 48.95 | -0.02 | 424075060 | 00110010 | 00011100 | 8 | 25 | 30 |

(continuation)

| anglesPosType | Heading_GNSS | Latency_ms_head | P_Bar | H_Bar | New_GPS | Odometer | Air_Speed | N_Wind | E_Wind |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00 | 0.00 | 99364 | 140.17 | 11 | 0.000 | 0.00 | 0.00 | 0.00 |
| 0 | 0.00 | 0.00 | 99364 | 140.16 | 0 | 0.000 | 0.00 | 0.00 | 0.00 |

(continuation)

| N_Wind_STD | E_Wind_STD | Ext_Lat | Ext_Long | Ext_Alt | Ext_Lat_STD | Ext_Long_STD | Ext_Alt_STD | Latency | Loc_Lat |
|---|---|---|---|---|---|---|---|---|---|
| 0.00 | 0.00 | 0. 0000000 | 0. 0000000 | 0. 000 | 0.00 | 0.00 | 0.00 | 0.000 | 0. 0000000 |
| 0.00 | 0.00 | 0. 0000000 | 0000000 | 0. 000 | 0.00 | 0.00 | 0.00 | 0.000 | 0. 0000000 |

(continuation)

| Loc_Long | Loc_Alt | Dopp_Shift | Dopp_Shift_STD | New_Aiding_Data |
|---|---|---|---|---|
| 0. 0000000 | 0.000 | 0. 00 | 0. 00 | 0000000000000000 |
| 0. 0000000 | 0.000 | 0. 00 | 0.00 | 0000000000000000 |

***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 | Temper |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| deg | deg | deg | deg/s | deg/s | deg/s | g | g | g | nT | nT | nT | °C |

(continuation)

| Vdd | USW (L/H) | Latitude | Longitude | Altitude | V_East | V_North | V_Up | Lat_GNSS | Long_GNSS |
|---|---|---|---|---|---|---|---|---|---|
| VDC | – – | deg | deg | m | m/s | m/s | m/s | deg | deg |

(continuation)

| Height_GNSS | Hor_spd | Trk_gnd | Ver_spd | ms_gps | GNSS_info_1 | GNSS_info_2 | #solnSVs | Latency_ms_pos | Latency_ms_vel |
|---|---|---|---|---|---|---|---|---|---|
| m | m/s | deg | m/s | ms | – | – | – | ms | ms |

(continuation)

| anglesPosType | Heading_GNSS | Latency_ms_head | P_Bar | H_Bar | New_GPS | Odometer | Air_Speed | N_Wind | E_Wind |
|---|---|---|---|---|---|---|---|---|---|
| – | deg | ms | Pa/2 | m | – | m | kt | kt | kt |

(continuation)

| N_Wind_STD | E_Wind_STD | Ext_Lat | Ext_Long | Ext_Alt | Ext_Lat_STD | Ext_Long_STD | Ext_Alt_STD | Latency | Loc_Lat |
|---|---|---|---|---|---|---|---|---|---|
| kt | kt | deg | deg | m | m | m | m | sec | deg |

(continuation)

| Loc_Long | Loc_Alt | Dopp_Shift | Dopp_Shift_STD | New_Aiding_Data |
|---|---|---|---|---|
| deg | m | m/s | m/s | – |

USW (Unit Status Word) is in binary form with low and high bytes listed in two columns. Each bit of the USW is specified in Appendix D.

## INS Minimal Data

| P14 Test report Date\Time 15.07.2015 11:54:27, GPS reference week number 1853 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Heading | Pitch | Roll | Temperature | Vdd | USW (L/H) | Latitude | Longitude | Height | V_East | V_North | V_Up |
| 277.98 | 0.34 | -1.47 | 36.1 | 12.16 | 0000000 00000000 | 39.0492073 | -77.3909065 | 120.42 | 0.00 | 0.00 | 0.00 |
| 277.98 | 0.35 | -1.47 | 36.1 | 12.19 | 0000000 00000000 | 39.0492073 | -77.3909065 | 120.42 | 0.00 | 0.00 | 0.00 |

(continuation)

| ms_Pos | GNSS_info_1 | #solnSVs |
|---|---|---|
| 291267650 | 00010000 | 4 |
| 291267650 | 00010000 | 4 |

***Note:*** saved data units

| Heading | Pitch | Roll | Temperature | Vdd | USW (L/H) | Latitude | Longitude | Height | V_East | V_North | V_Up |
|---|---|---|---|---|---|---|---|---|---|---|---|
| deg | deg | deg | deg C | VDC | – – | deg | deg | m | m/s | m/s | m/s |

(continuation)

| ms_Pos | GNSS_info_1 | #solnSVs |
|---|---|---|
| ms | – | – |

USW (Unit Status Word) is in binary form with low and high bytes listed in two columns. Each bit of the USW is specified in the Appendix D.

## INS OPVT Raw IMU output

P42 Test report Date\Time 10.01.2018 15:12:25, GPS reference week number 1972

| GpsTime | Gps_IMU_Time | Gyro_X | Gyro_Y | Gyro_Z | Acc_X | Acc_Y | Acc_Z |
|---|---|---|---|---|---|---|---|
| 2445.390000000 | 2445.385008200 | 0.0068 | 0.0066 | 0.0060 | 0.1602 | -1.2066 | 9.7249 |
| 2445.410000000 | 2445.405009688 | -0.0217 | -0.0182 | 0.0604 | 0.1588 | -1.2068 | 9.7320 |

(continuation)

| USW (L/H) | Heading | Pitch | Roll | Latitude | Longitude | Altitude | V_East |
|---|---|---|---|---|---|---|---|
| 00000000 00000000 | 0.000 | -7.066 | -0.940 | 39.040000915 | -77.389999389 | 140.2100000 | 0.00 |
| 00000000 00000000 | 0.000 | -7.067 | -0.940 | 39.040000915 | -77.389999389 | 140.2100000 | 0.00 |

(continuation)

| V_North | V_Up | GNSS_info_1 | GNSS_info_2 | #solnSVs | New_GPS |
|---|---|---|---|---|---|
| 0.00 | 0.00 | 00000110 | 00000001 | 0 | 3 |
| 0.00 | 0.00 | 00000110 | 00000001 | 0 | 0 |

***Note:*** saved data units

| GpsTime | Gps_IMU_Time | Gyro_X | Gyro_Y | Gyro_Z | Acc_X | Acc_Y | Acc_Z |
|---|---|---|---|---|---|---|---|
| s | s | deg/s | deg/s | deg/s | $m/s^2$ | $m/s^2$ | $m/s^2$ |

(continuation)

| USW (L/H) | Heading | Pitch | Roll | Latitude | Longitude | Altitude | V_East |
|---|---|---|---|---|---|---|---|
| – – | deg | deg | deg | deg | deg | m | m/s |

(continuation)

| V_North | V_Up | GNSS_info_1 | GNSS_info_2 | #solnSVs | New_GPS |
|---|---|---|---|---|---|
| m/s | m/s | – | – | – | – |

## INS GNSSext Output

P43 Test report Date\Time 11.06.2018 13:07:47, GPS reference week number 2005

| TOW | Heading | Pitch | Roll | Latitude | Longitude | Heave | V_East | V_North | V_Up |
|---|---|---|---|---|---|---|---|---|---|
| 148092.020 | 112.789764 | 1.386544 | -2.376833 | 39.149027603 | -77.619190124 | 138.863 | -0.000309 | -0.000078 | -0.017401 |
| 148092.025 | 112.789764 | 1.386710 | -2.375940 | 39.149027574 | -77.619190120 | 138.884 | -0.007513 | -0.018581 | -0.055799 |

(continuation)

| Gyro_X | Gyro_Y | Gyro_Z | Acc_X | Acc_Y | Acc_Z | Magn_X | Magn_Y | Magn_Z | P_Bar | Temperature |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.004223 | 0.019322 | 0 .005419 | 0.041721 | 0.024155 | 0.997718 | -19630.0 | -12680.0 | -47520.0 | 99888 | 35.20 |
| 0.031722 | 0.058148 | 0.016968 | 0 .041596 | 0.024433 | 0.998005 | -19520.0 | -12650.0 | -47520.0 | 99888 | 35.20 |

(continuation)

| USW (L/H) | Pos_type | GNSS_ECEF_X | GNSS_ECEF_Y | GNSS_ECEF_Z | GNSS_PACC | GNSS_ECEF_VX |
|---|---|---|---|---|---|---|
| 00000000 00000000 | 18 | 1061964.12 | -4837820.90 | 4005249.92 | 7.73 | 0.021820 |
| 00000000 00000000 | 18 | 1061964.12 | -4837820.90 | 4005249.92 | 7.73 | 0.021820 |

(continuation)

| GNSS_ECEF_VY | GNSS_ECEF_VZ | GNSS_SACC | Lat_GNSS | Long_GNSS | Height_GNSS | Hor_spd | Trk_gnd |
|---|---|---|---|---|---|---|---|
| -0.048715 | 0.032701 | 0.92 | 39.149032863 | -77.619204227 | 140.079 | 0.013281 | 125.086447 |
| -0.048715 | 0.032701 | 0.92 | 39.149032863 | -77.619204227 | 140.079 | 0.021463 | 204.021473 |

(continuation)

| Ver_spd | anglesPosType | Heading_GNSS | #solnSVs | GNSS_info_1 | GNSS_info_2 | GDOP | PDOP | HDOP | VDOP |
|---|---|---|---|---|---|---|---|---|---|
| 0.061174 | 0 | 0.00 | 6 | 00110010 | 00011100 | 0.000 | 6.585 | 1.855 | 6.842 |
| -0.056540 | 0 | 0.00 | 6 | 00110010 | 00011100 | 0.000 | 6.585 | 1.855 | 6.842 |

(continuation)

| TDOP | Diff_age | GPS_Hours | GPS_Minutes | GPS_Seconds | GPS_DSeconds | GPS_Month | GPS_Day | GPS_Year |
|---|---|---|---|---|---|---|---|---|
| 5.364 | 4.9 | 17 | 8 | 12 | 22 | 6 | 11 | 2018 |
| 5.364 | 4.9 | 17 | 8 | 12 | 29 | 6 | 11 | 2018 |

(continuation)

| UTC | LatencyECEF_Time | V_latency | Latency_pos_time | Latency_vel_time | New_GPS |
|---|---|---|---|---|---|
| 1528736892 | 5 | 0 | 10 | 0 | 27 |
| 1528736892 | 5 | 0 | 10 | 15 | 2 |

***Note:*** saved data units

| TOW | Heading | Pitch | Roll | Latitude | Longitude | Heave | V_East | V_North | V_Up |
|---|---|---|---|---|---|---|---|---|---|
| sec | deg | deg | deg | deg | deg | m | m/s | m/s | m/s |

(continuation)

| Gyro_X | Gyro_Y | Gyro_Z | Acc_X | Acc_Y | Acc_Z | Magn_X | Magn_Y | Magn_Z | P_Bar | Temperature |
|---|---|---|---|---|---|---|---|---|---|---|
| deg/s | deg/s | deg/s | $m/s^2$ | $m/s^2$ | $m/s^2$ | nT | nT | nT | Pa | °C |

(continuation)

| USW (L/H) | Pos_type | GNSS_ECEF_X | GNSS_ECEF_Y | GNSS_ECEF_Z | GNSS_PACC | GNSS_ECEF_VX |
|---|---|---|---|---|---|---|
| – – | – | m | m | m | m | m/s |

(continuation)

| GNSS_ECEF_VY | GNSS_ECEF_VZ | GNSS_SACC | Lat_GNSS | Long_GNSS | Height_GNSS | Hor_spd | Trk_gnd |
|---|---|---|---|---|---|---|---|
| m/s | m/s | m/s | deg | deg | m | m/s | deg |

(continuation)

| Ver_spd | anglesPosType | Heading_GNSS | #solnSVs | GNSS_info_1 | GNSS_info_2 | GDOP | PDOP | HDOP | VDOP |
|---|---|---|---|---|---|---|---|---|---|
| m/s | – | deg | – | – | – | – | – | – | – |

(continuation)

| TDOP | Diff_age | GPS_Hours | GPS_Minutes | GPS_Seconds | GPS_DSeconds | GPS_Month | GPS_Day | GPS_Year |
|---|---|---|---|---|---|---|---|---|
| – | sec | – | – | – | – | – | – | – |

(continuation)

| UTC | LatencyECEF_Time | V_latency | Latency_pos_time | Latency_vel_time | New_GPS |
|---|---|---|---|---|---|
| – | msec | msec | msec | msec | – |

USW (Unit Status Word) is in binary form with low and high bytes listed in two columns. Each bit of the USW is specified in Appendix D.

**SPAN Raw IMU**

P45 Test report Date\Time 10.01.2018 14:48:25, GPS reference week number 1972

| TimeStatus | GpsTime | Week | Gps_IMU_Time | IMUStatus | AccZ | AccY | AccX | GyroZ | GyroY | GyroX |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 1004586 | 1972 | 1004.586398544 | 01110111 | 0.0486378 | 0.0059171 | 0.0007602 | -0.00002795 | -0.00002692 | 0.00000515 |
| 20 | 1004606 | 1972 | 1004.606400033 | 01110111 | 0.0485928 | 0.0059106 | 0.0007580 | 0.00007485 | -0.00010543 | 0.00012638 |

***Note:*** saved data units

| TimeStatus | GpsTime | Week | Gps_IMU_Time | IMUStatus | AccZ | AccY | AccX | GyroZ | GyroY | GyroX |
|---|---|---|---|---|---|---|---|---|---|---|
| – | ms | – | s | – | m/s | m/s | m/s | deg | deg | deg |

## INS NMEA Output

**Example of the INS message in NMEA format:**

```
$PAPR,3902.4227,N,07723.4368,W,0120.12,b,-001.48,000.35,277.94,036.1,12.1,0000*6C
$PAPR,3902.4227,N,07723.4368,W,0120.12,b,-001.48,000.35,277.95,036.1,12.1,0000*6D
```

See **APPENDIX C. Description of data files** for details of the INS message in INS NMEA Output format

**NMEA** data messages can be saved 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 INS NMEA format:**

P20 Test report Date\Time 15.07.2015 11:54:53, GPS reference week number 1853

| Latitude | Longitude | Height | B | Heading | Pitch | Roll | Temperature | Vinp | USW (L/H) |
|---|---|---|---|---|---|---|---|---|---|
| 39.0492073 | -77.3909065 | 120.12 | 0 | 277.93 | 0.34 | -1.47 | 36.1 | 12.09 | 0000000 00000000 |
| 39.0492073 | -77.3909065 | 120.12 | 0 | 277.94 | 0.34 | -1.47 | 36.1 | 12.09 | 0000000 00000000 |

***Note:*** saved data units

| Latitude | Longitude | Height | B | Heading | Pitch | Roll | Temperature | Vinp | USW (L/H) |
|---|---|---|---|---|---|---|---|---|---|
| deg | deg | m | – | deg | deg | deg | deg C | VDC | – – |

USW (Unit Status Word) is in binary form with low and high bytes listed in two columns. Each bit of the USW is specified in the Appendix D.

## INS Sensors NMEA Output

**Example of the INS message in Sensors NMEA format:**

```
$PAPS,3902.4357,N,07723.4422,W,0000.00,h,0001.21,-00.18,255.30,0000.00,0000.28,-000.02,-0.0210,-0.0031,00.9999,483805170,040.9,12.1,0000*63
$PAPS,3902.4357,N,07723.4422,W,0000.00,h,0001.22,-00.18,255.30,0000.01,0000.19,-000.02,-0.0215,-0.0032,00.9988,483805190,040.9,12.2,0000*68
```

See **APPENDIX C. Description of data files** for details of the INS message in INS Sensors NMEA Output format

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

**Example of the text form of INS Sensors NMEA format:**

P20 Test report Date\Time 15.07.2015 11:54:53, GPS reference week number 1853

| Latitude | Longitude | Height | B | Heading | Pitch | Roll | Gyro_X | Gyro_Y | Gyro_Z |
|---|---|---|---|---|---|---|---|---|---|
| 39.0492073 | -77.3909065 | 120.12 | 0 | 255.30 | -0.18 | 1.21 | 0.00 | 0.28 | -0.02 |
| 39.0492073 | -77.3909065 | 120.12 | 0 | 255.30 | -0.18 | 1.21 | 0.01 | 0.19 | -0.02 |

(continuation)

| Acc_X | Acc_Y | Acc_Z | Timestamp | Temperature | Vinp | USW (L/H) |
|---|---|---|---|---|---|---|
| -0.0210 | -0.0031 | 0.9999 | 483805170 | 40.9 | 12.10 | 0000000 00000000 |
| -0.0215 | -0.0032 | 0.9998 | 483805190 | 40.9 | 12.20 | 0000000 00000000 |

***Note:*** saved data units

| Latitude | Longitude | Height | B | Heading | Pitch | Roll | Gyro_X | Gyro_Y | Gyro_Z |
|---|---|---|---|---|---|---|---|---|---|
| deg | deg | m | – | deg | deg | deg | | | |

(continuation)

| Acc_X | Acc_Y | Acc_Z | Timestamp | Temperature | Vinp | USW (L/H) |
|---|---|---|---|---|---|---|
| g | g | g | ms | deg C | VDC | – – |

USW (Unit Status Word) is in binary form with low and high bytes listed in two columns. Each bit of the USW is specified in the Appendix D.

# APPENDIX D.
# The Unit Status Word Definition

The Unit Status Word (USW) provides information about the state of the INS. The low byte (bits 0 – 7) of USW indicates failure of the INS. If this byte is 0, the INS operates correctly, if it is not 0, see Table D.1 for type of failure. The high byte (bits 8 – 15) contains a warning or information for the user. Status of each bit of the USW warning byte is specified in Table D.1, below.

**Table D.1. The Unit Status Word description**

| | Bit | Parameter | Performance |
|---|---|---|---|
| Low (failure) byte | 0 | Initial Alignment | 0 – Successful initial alignment<br>1 – Unsuccessful initial alignment due to INS moving or large change of outer magnetic field |
| | 1 | Software Status | 0 – Correct operation<br>1 – Incorrect data appeared at calculations |
| | 2 | Gyroscope Unit | 0 – No failure<br>1 – Failure is detected |
| | 3 | Accelerometer Unit | 0 – No failure<br>1 – Failure is detected |
| | 4 | Magnetometer Unit | 0 – No failure<br>1 – Failure is detected |
| | 5 | Electronics | 0 – No failure<br>1 – Failure is detected |
| | 6 | GNSS Receiver | 0 – No failure<br>1 – Failure is detected |
| | 7 | On-the-fly Calibration | 1 – during data accumulation and calculation<br>0 – otherwise |
| High (warning) byte | 8 | Incorrect Power Supply | 0 – Supply voltage is not less than minimum level<br>1 – Low supply voltage is detected |
| | 9 | | 0 – Supply voltage is not more than maximum level<br>1 – High supply voltage is detected |
| | 10 | Angular rate exceeding detect | 0 – X-angular rate is within the range<br>1 – X-angular rate is out of range |
| | 11 | | 0 – Y-angular rate is within the range<br>1 – Y-angular rate is out of range |
| | 12 | | 0 – Z-angular rate is within the range<br>1 – Z-angular rate is out of range |
| | 13 | Large magnetic field detect | 0 – Total magnetic field is within the range<br>1 – Total magnetic field limit is exceeded |
| | 14 | Environmental Temperature | 0 – Temperature is within the operating range<br>1 – Temperature is out of the operating range |
| | 15 | On-the-fly calibration | 0 – No on-the-fly calibration<br>1 – Successfully calibrated during current run |

**Note:** If hardware error occurred, then all USW bits become equal to 1. If so, before running the device again it should be power cycled. Also, hardware error can be detected with LED indicator when it blinking red (hard fault) or yellow (non-maskable interrupt) without stop.

# APPENDIX E.
# Variants of the Inertial Labs™ INS Mounting Relative to Object Axes

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

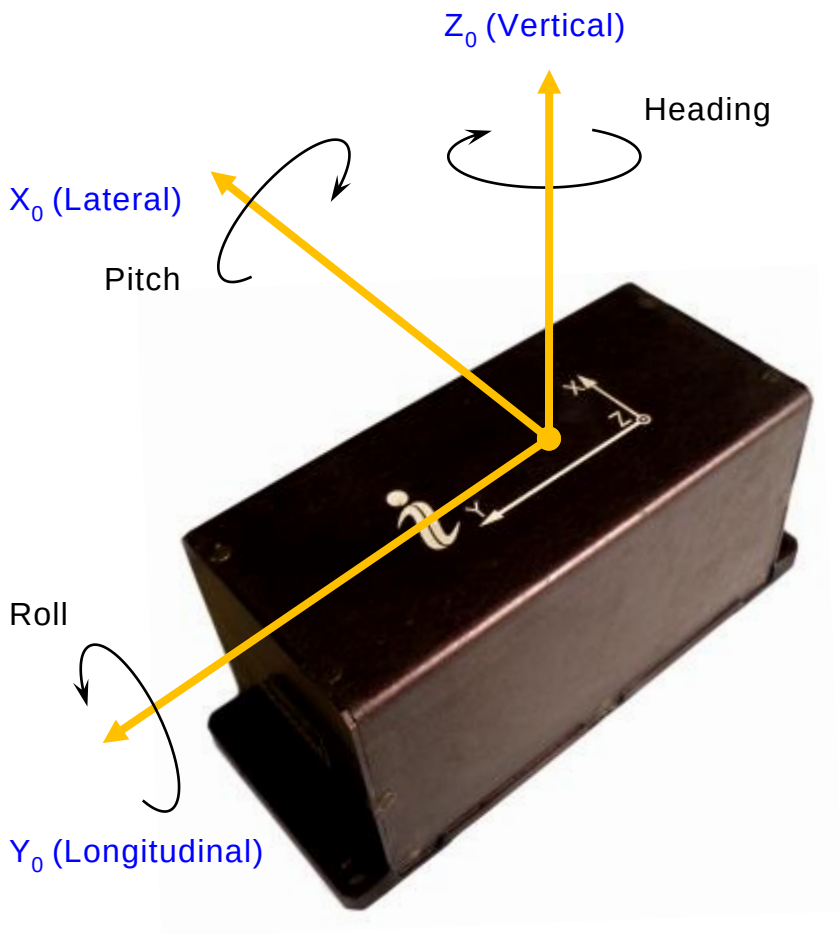



**Fig. E.1. Coordinate system of the Inertial Labs™ INS**

However, the Inertial Labs™ INS can be mounted on the object in any known position (up to upside-down, upright, etc.) relative to the object axes. Such mounting does not change the correct calculation of the object orientation if angles of the INS mounting are correctly stored in the INS nonvolatile memory.

To set these angles, select item **"Devices options"** from the "Options" menu. In opened window (shown in Fig. 4.2) angles of the INS mounting appear in the **"Alignment angles"** section.

The INS alignment angles are set in the following order (as in the heading, pitch, and roll settings):

- First alignment angle sets position of the INS 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 inclination angle of the INS 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 INS lateral axis X measured around the INS's longitudinal axis. Positive rotation is X axis moving down.

All angles are set in degrees.

- Some examples of the Inertial Labs™ INS mounting relative to the object are shown in Fig. E.2.

To check correctness of the alignment angles, please run the INS using the Inertial Labs™ INS GUI.

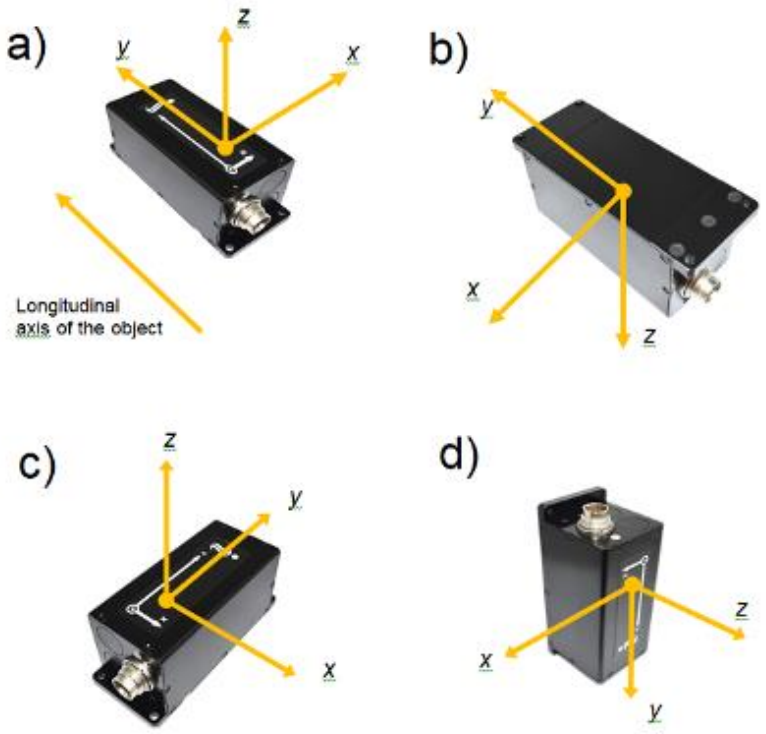



**Fig. E.2. Examples of the Inertial Labs™ INS mounting on the carrier object**

| | | | | |
|---|---|---|---|---|
| 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) |

# APPENDIX F.
# Installation of the GNSS Antennas

## F.1. Installation of Single GNSS Antenna

The INS unit and GNSS antenna are usually installed in different locations on the carrier object. Moreover, placement of the antenna close to the INS unit is not desirable because of the antenna's impact on the INS magnetometers.

While the best place for the INS unit is the center of gravity of the carrier object, the GNSS antenna must be placed with a clear view of the sky with a sufficient ground plane.

After installation of the INS unit and GNSS antenna on the carrier object, it is necessary to measure the antenna position relative to the accelerometer mass-center of the INS unit (see Fig. F.1, Fig. F.2, and Fig. F.3) in the object axes – right, forward, and up. It is then necessary to set these coordinates in the appropriate fields in the IMU tab (see section 4.2.1) and store them in the INS nonvolatile memory.

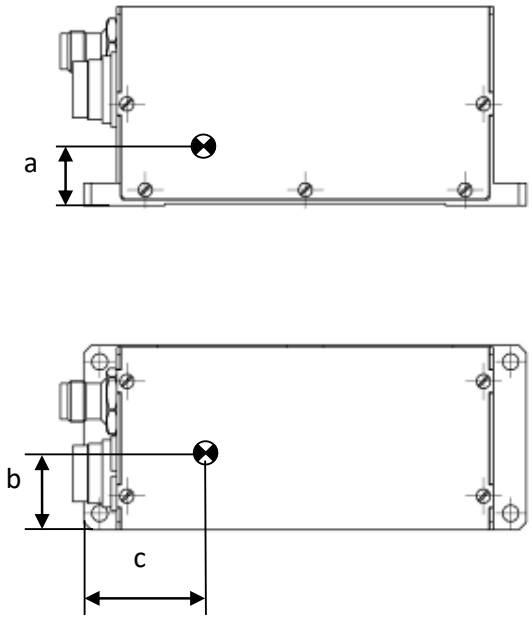



**Fig. F.1. Position of the accelerometer mass-center in housed Inertial Labs™ INS unit**

| Dimensions, mm | a | b | c |
|---|---|---|---|
| Variant 1 | 10 | 20 | 29 |
| Variant 2 | 15 | 27 | 58 |

**Notes:**

**Variant 1** includes INS-P and INS-B units with serial numbers up to F1710189 and INS-D units with serial numbers up to F1691036.

**Variant 2** includes all other INS units.

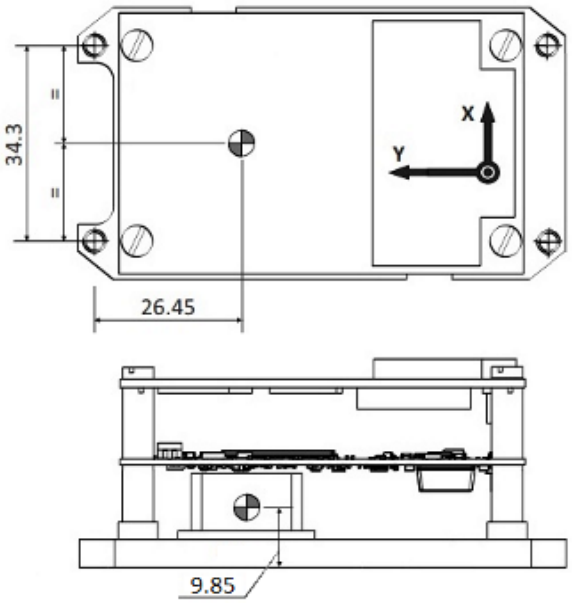



**Fig. F.2. Position of the accelerometer mass-center in Inertial Labs™ INS-OEM unit (in millimeters)**

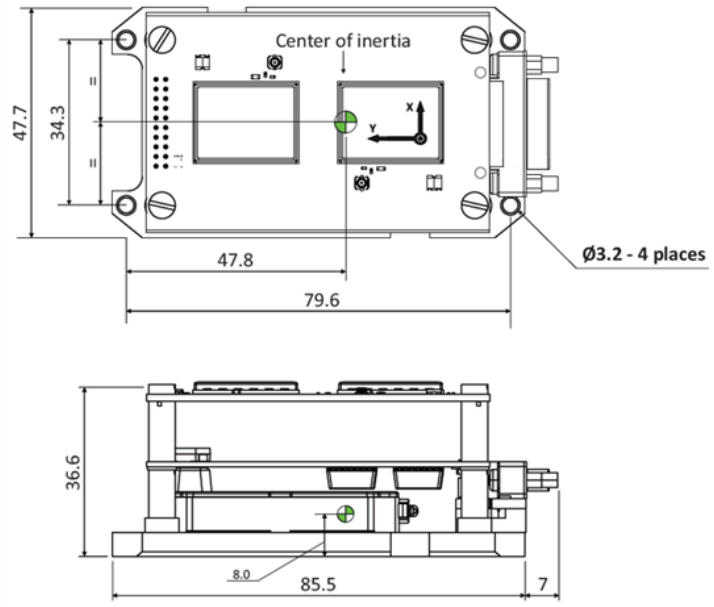



**Fig. F.3. Position of the accelerometer mass-center in Inertial Labs™ INS-DU-OEM unit (in millimeters)**

Fig. F.4 shows positive right, forward, and up directions of the antenna position relative to the INS unit.

**Important notes:**

1. If, after mounting the INS, its axes (see Fig. E.1) are parallel to the carrier object axes, then the antenna coordinates should be measured in the directions of the X, Y, and Z axes.
2. On the other hand, the INS unit can be mounted on the object in any known position (up to upside-down, upright, etc. (see “Appendix E. Variants of the Inertial Labs™ INS Mounting Relative to the Object Axes”). In this case, please set the GNSS antenna coordinates only in the object axes (right, forward, and up directions), but not in the INS axes.

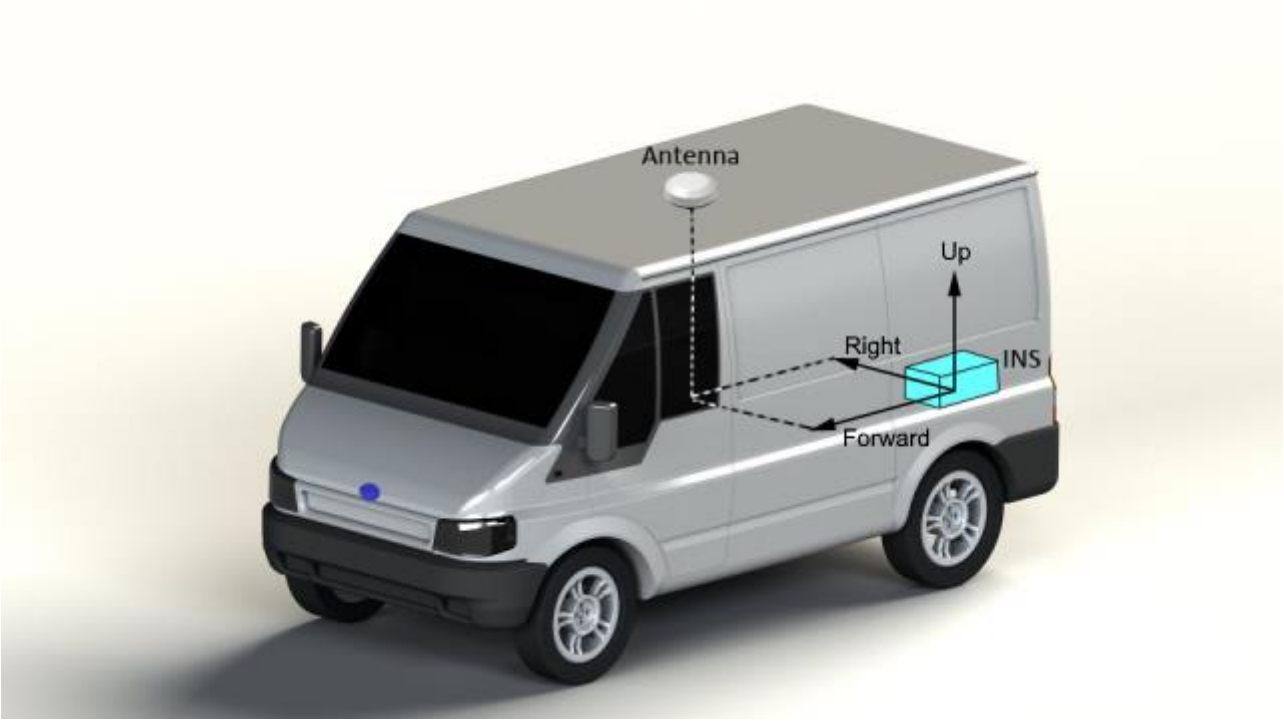



**Fig. F.4. Determination of the GNSS antenna position relative to the INS unit (positive directions)**

## F.2. Installation of Two GNSS Antennas for INS-D Operation

The Inertial Labs™ INS-D uses heading calculated by a dual-antenna GNSS receiver for the INS correction. Two antennas should be installed in parallel to the longitudinal axis of the carrier object to allow the GNSS receiver to measure object heading accurately. The secondary antenna should be installed ahead of the primary antenna, so direction from the primary to the secondary antenna is forward for the carrier object (see Fig. F.5). Requirements for the primary antenna installation are the same as described in "Appendix F.1. Installation of Single GNSS Antenna". Position of the primary and secondary antennas relative to the accelerometer mass-center of the INS unit must be measured and stored to the INS nonvolatile memory.

Since firmware version 2.9.1.7, the INS-D algorithm has the feature of the secondary antenna installation in arbitrary (but known) position relative to the INS-D unit and the primary antenna. It is possible to set the secondary antenna location in two ways: by specifying its position in meters relative to the accelerometer mass-center of the IMU in the "Secondary antenna position relative to the IMU (m)" fields or by specifying the antenna's baseline orientation in degrees in the "Antennas baseline orientation (deg)" fields (section 4.2.1).

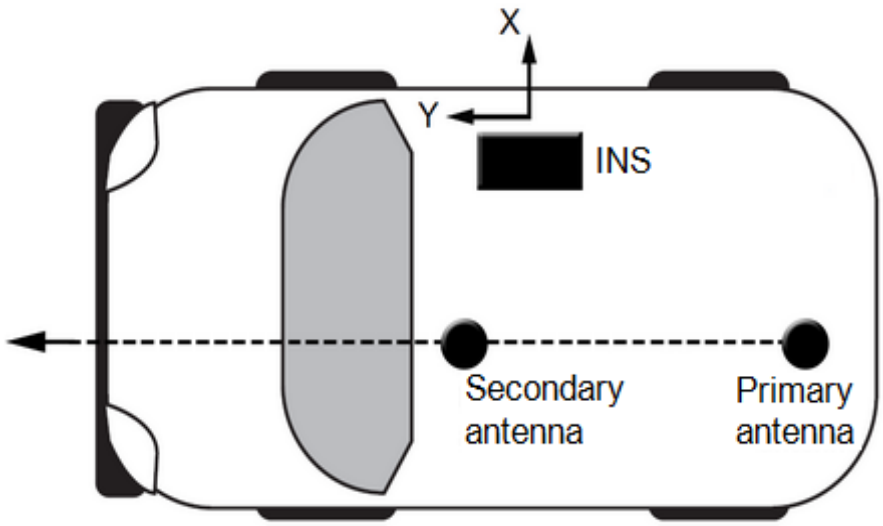



**Fig. F.5. Installation of the primary and secondary GNSS antennas on carrier object**

Fig. F.6 shows Alpha and Beta angles of the antenna's baseline orientation relative to the INS unit. Alpha angle is measured in horizontal plane of the object, with clockwise direction positive. Beta angle is measured in vertical plane of the object, with up positive. Note that in Fig. F.6 there are positive Alpha and negative Beta angles.

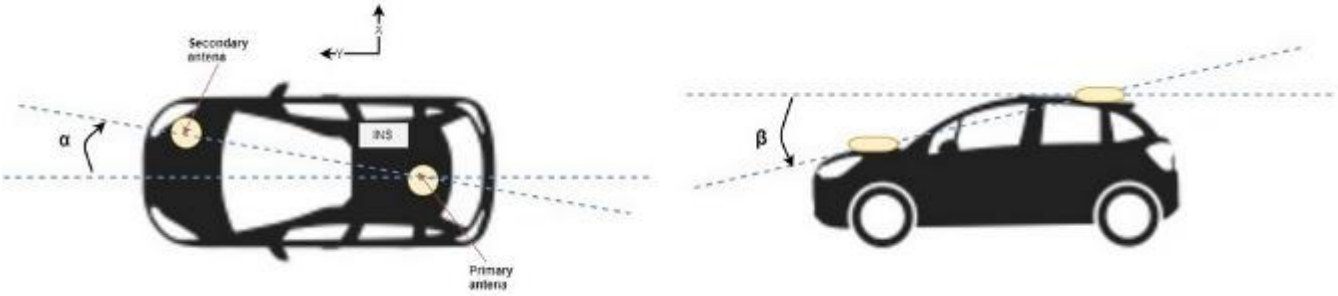



**Fig. F.6. Angles of baseline of two GNSS antennas installation on carrier object**

# APPENDIX G.
# Use of the STRSVR Tool

To receive the observation data of a remote base station at the INS (rover receiver) and to get RTK solution, the user can use the STRSVR tool from the RTKLIB package.

**Note:** RTKLIB is an open source program package for GNSS positioning. RTKLIB can be downloaded via the following link: http://www.rtklib.com/. The STRSVR tool is provided by Inertial Labs™, along with the software and documentation.

Fig. G.1. shows the scheme of the STRSVR use for receiving RTK solution from the base station at the receiver of the INS.

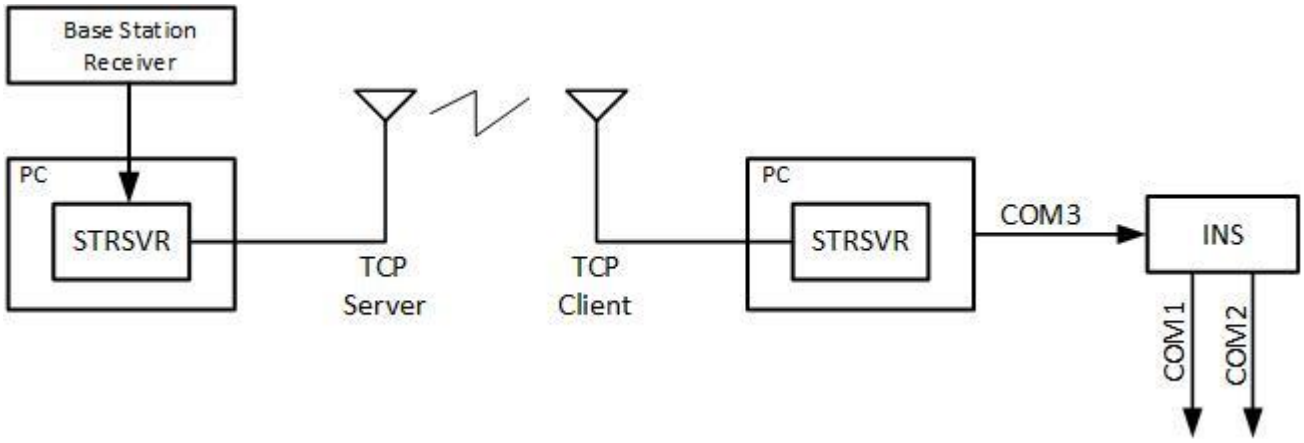



**Fig. G.1. Connection for RTK solution receiving by using STRSVR tool**

The main window of the STRSVR tool is shown in Fig. G.2.

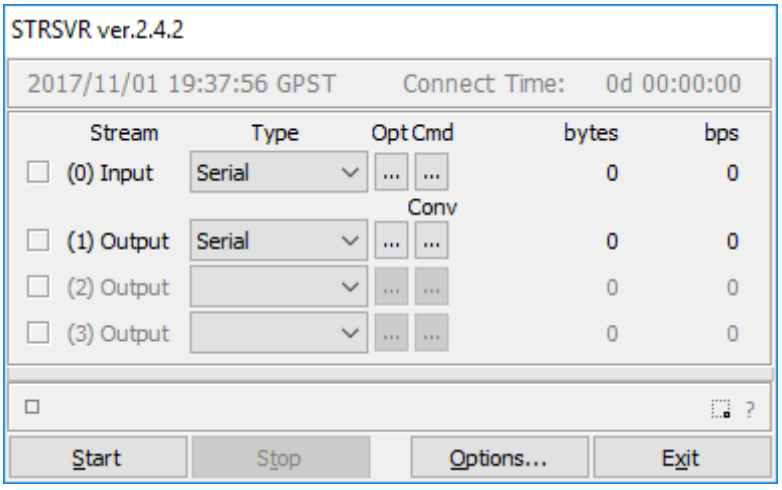



**Fig. G.2. Main window of the SVRSTR tool**

To configure the input stream, select the stream type from the drop-down list at **"(0) Input"**. Selectable stream types are as follows:

- Serial
- TCP Client
- TCP Server
- NTRIP Client
- File
- FTP or HTTP

To configure the output streams, select the stream type from the drop-down list at **"(1) Output"**, **"(2) Output"**, or **"(3) Output"**.

After input and output streams are specified, press the **"Start"** button to start communication. For details on STRSVR use, please see the RTKLIB Manual at the following website: http://www.rtklib.com/rtklib_document.htm.

# APPENDIX H.
# Using Ethernet Port for Communication with the Inertial Labs™ INS

This Appendix describes the basics of communication with INS units that have a built-in Ethernet port. Such an INS unit is equipped with USR-TCP232-ED2 module made by USR-IOT. This Appendix refers to the website of USR-IOT as the location of required software tools and datasheets: https://www.pusr.com/products/ethernet-modules

**Note:** If the INS unit is equipped by an internal datalogger, then it automatically excludes utilizing Ethernet for data / command transfer. In such cases, the Ethernet can be used for datalogger configuration only. For an explanation of how to operate and set up the datalogger, see "Appendix I. Using the Internal Datalogger"; otherwise continue to read this Appendix.

## H.1. Connection Overview

The Inertial Labs™ INS is delivered to a customer with a multi-conductor cable. One side of the cable should be connected to the connector on the rear wall of the device. The other side of the cable is attached to the breakout board with numerous connectors on it (see Fig. H.1 and Fig. H.2). The connectors needed for Ethernet communication are XS6 (used for data) and XS7 (used for power). The INS with Ethernet retains the communication via a serial port as well. So XS3 can also be used as an RS232 port if necessary.

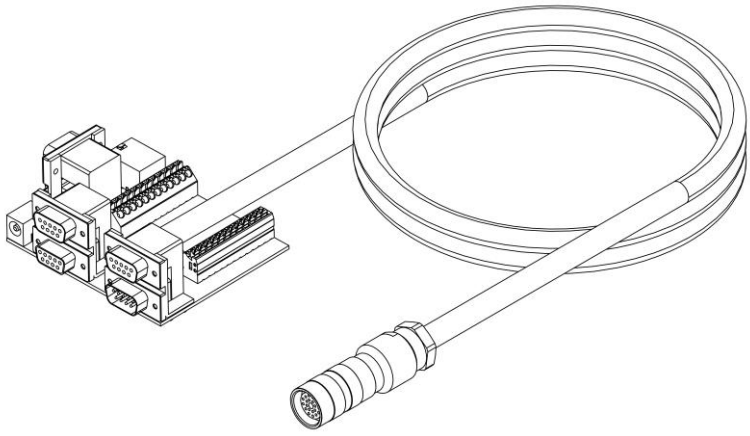


**Fig. H.1.**

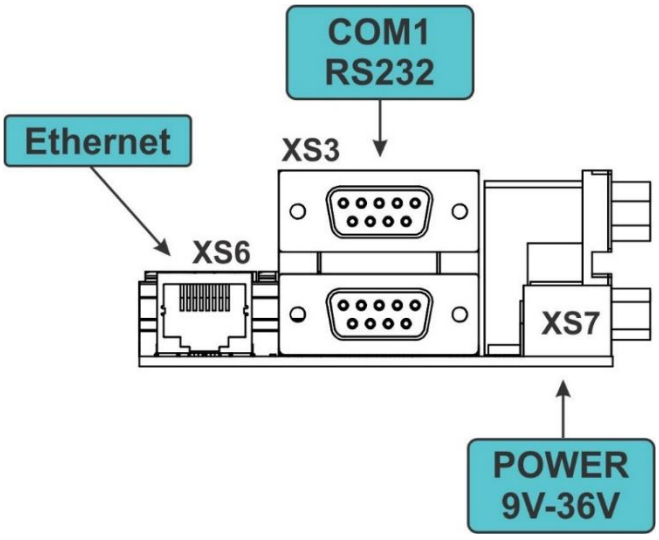



**Fig. H.2.**

By a specific request the device can be equipped with the cable assembly that provides Ethernet and power via a single RJ45 connector. For the testing purposes the PoE adapter (so called PoE injector) is also supplied. The example of this cable is shown on the picture below (see Fig. H.3).

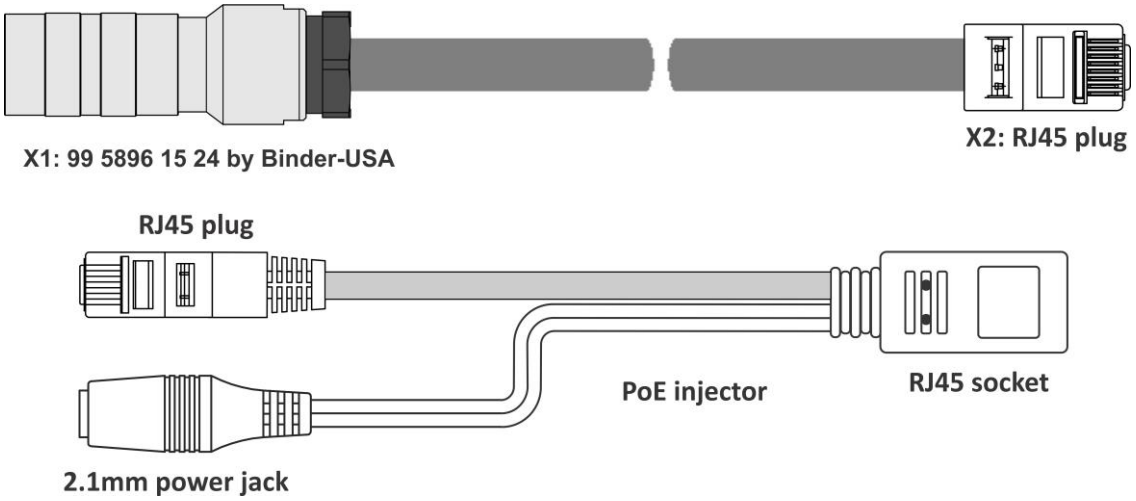



**Fig. H.3. Single port cable and PoE injector**

## H.2. Connection Steps

1. Attach the cable to the Binder connector of the INS unit.
2. Connect the breakout board to your local network via the XS6 socket using Ethernet patch cord, or connect the RJ45 plug of the PoE injector to your local network.
3. Connect the barrel power plug to the XS7 socket on the breakout board, or to the barrel socket on the PoE injector. The LED on the device should light up yellow and then turn to red. This signifies that the device is ready to operate.

## H.3. Networking Details

The Ethernet module inside the INS unit is preconfigured for obtaining an IP address automatically. In most cases the IP address is assigned immediately after the device is powered and connected to the LAN. To troubleshoot please access your router console and find the “DHCP” page. Make sure the DHCP server is ON with the MAC address filtering feature OFF; or add the MAC address of INS to the list of “known devices”. Then locate the DHCP Client tab and check the list of connected devices for the IP that was assigned to the INS.

**Note:** For the INS s/n **F1760080** the MAC address is **D8:B0:4C:B6:24:F5.**

## H.4. Checking the Connection to the Network

After the INS has obtained the IP address, it becomes accessible via the local network. To check the accessibility and re-configure the Ethernet module (if needed) please install the USR-VCOM software to the PC connected to the same network.

The USR-VCOM is developed by USR-IOT for configuring the Ethernet module and checking its accessibility via the local network. It can also create a virtual serial port on the PC connected to the same network as the INS. This can be downloaded from the following website: https://www.pusr.com/support/downloads/usr-vcom-setup-software.html

Run the software and select Tools –> Search –> USR-TCP232-E45. You'll see the device in the "Search List", as shown on Fig. H.4. You can assign fixed network parameters like Static IP, Subnet Mask, and Gateway using this tool. Do so, or leave all settings as is.

**Notes:**

1. USR-VCOM uses broadcast messages when scanning the network for the Ethernet Module. Please make sure the broadcast messages are not blocked in your LAN.
2. Unless otherwise is requested, the device is supplied to the customer pre-configured to obtain the IP address dynamically and with the Port 0 configured as TCP Server, i.e. ready for the Virtual Serial Port. No configuration is required.

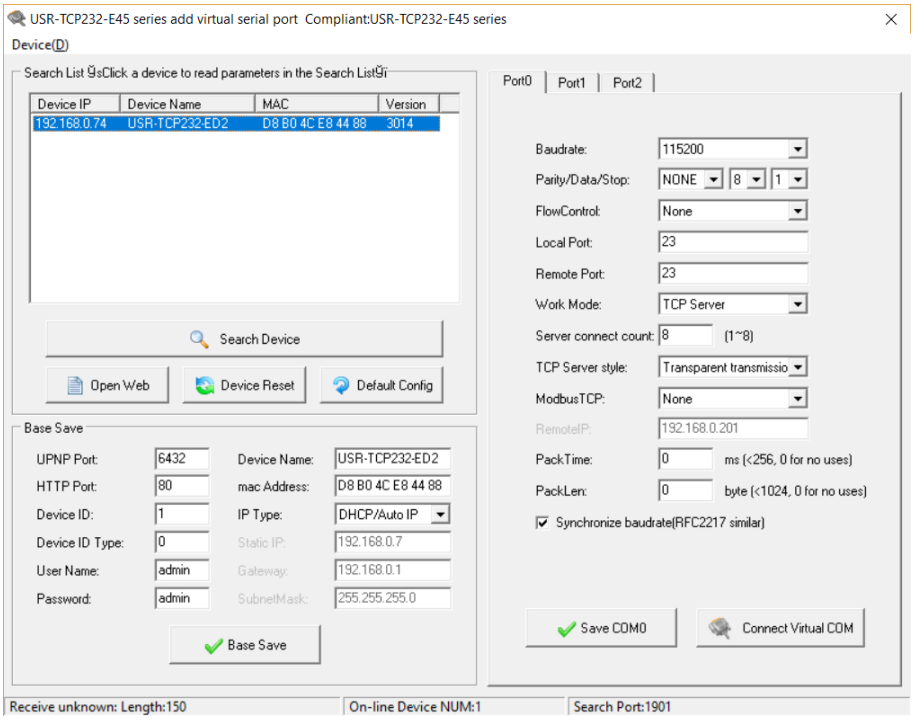



**Fig. H.4. The USR-VCOM search window shows an Ethernet device found in the LAN**

## H.5. Communication VIA Ethernet USING a Virtual Serial Port

It is possible to communicate with the device using the virtual serial port. In order to create a virtual serial port, please go to the USR-VCOM search window as directed in the previous clause; then choose the desired module in the Search List Window (see Fig. H.4.). Then click Connect Virtual COM on the bottom of the Port0 tab. In the new window choose the serial port number (can be any number not occupied by another hardware on your PC) and add the optional description of the port. Leave the other fields as shown of the Fig. H.4 and Fig. H.5. Press "OK" button and you will see the main window of USR-VCOM with the VSP created (see Fig. H.6).

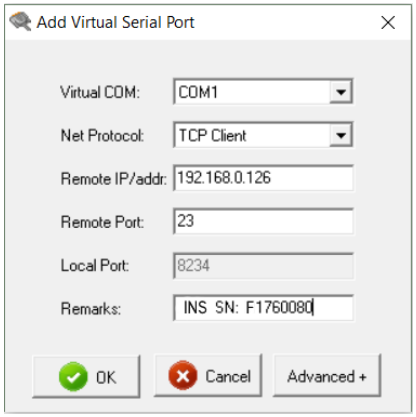



**Fig. H.5. Add Virtual Serial Port (VSP) window**

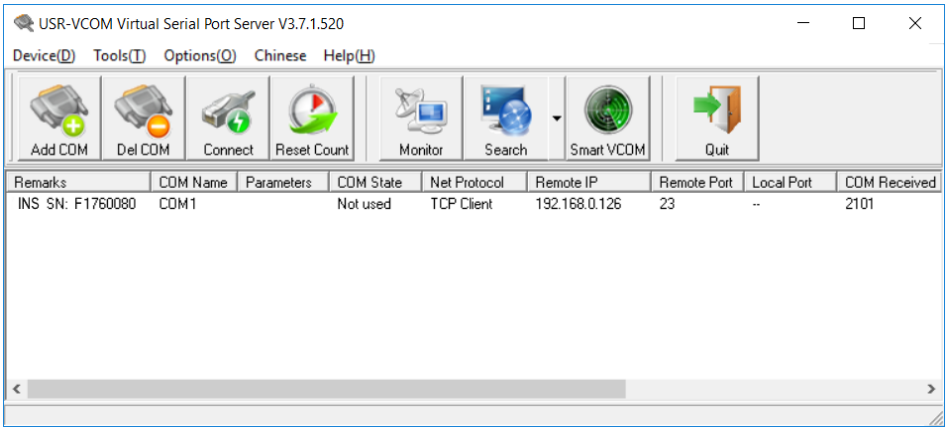



**Fig. H.6. Virtual Serial Port COM1 is created for the Port0 of the 192.168.0.126**

Now you can use this virtual port for communication with the INS as you would do with a regular serial port. Please refer to section "4.1. Test Options" for further steps of communication with the INS via a serial port.

## H.6. Communication OVER the Ethernet in TCP/IP MODE

It is possible to communicate with the device via the Ethernet directly without using any software from Inertial Labs. To establish the connection and send commands to the devise it is necessary to perform the following steps:

Step 1.

Use the USR-VCOM software to inquire the IP address and the number of the Local Port. On the example below the IP address is static and equals to 192.168.0.7, Local Port number is 23, see the Fig. H.7.

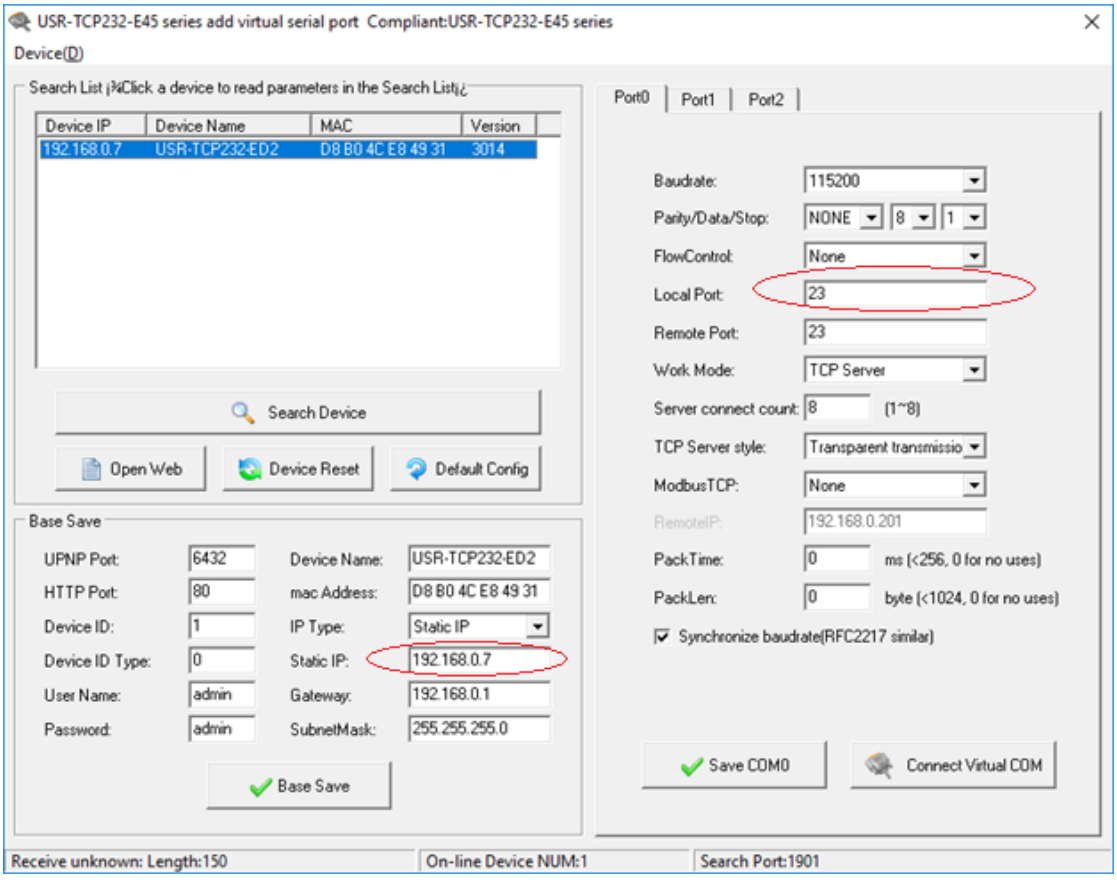



**Fig. H.7. The USR-VCOM search window shows an Ethernet device found in the LAN.**

Please note, that Baudrate value in the Port0 tab should match the Baudrate of the main port of the device. If the value is different - please correct and press Save COM0. (see Fig. H.7).

**Note:** In order to find out the current baudrate of the INS: create the VSP, run the corresponding GUI software, go to the “Test options” menu, choose the port and press Auto (see Fig. 4.1). This will perform the scan on all available baudrates and report the current one.

Step 2.

To send commands through the Ethernet any TCP terminal can be used. This document uses the RealTerm tool as an example. In the “Port” tab of the RealTerm it is necessary to set the IP address and Local port number obtained on the Step 1 in the following format: **ip_adress:port_number** (please see the Fig. H.8). After the IP address and Local port number are set please click “Open” button.

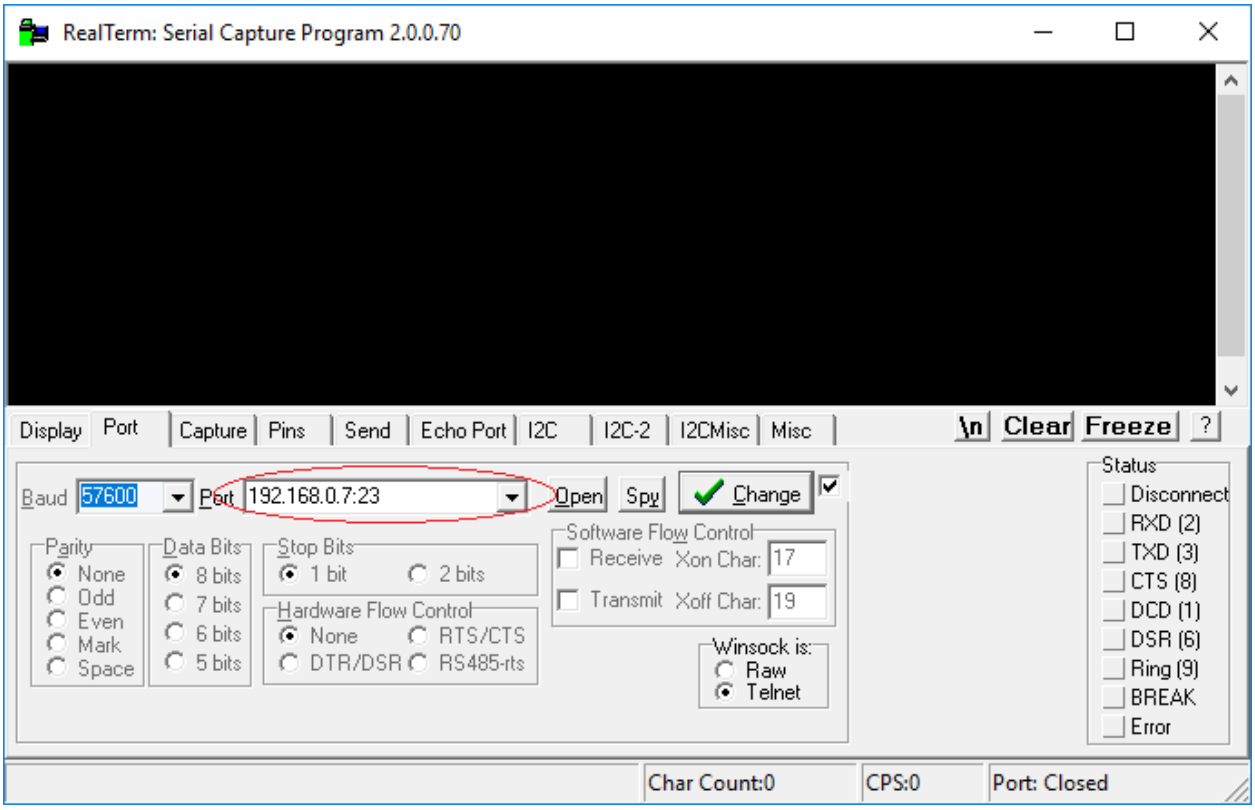



**Fig. H.8. The RealTerm tool, port settings.**

Step 3.

This example demonstrates how to pull a data message by message.

On the “Send” tab enter the command in hexadecimal format and then press “Send numbers” button. On Fig. H.9 the request to Inertial Labs DTS to return the Euler angles is shown as an example. The requested data appears on the window each time the “Send numbers” button is pressed.

**Note:** For the INS, see description of all available data formats and corresponding commands in the Interface Control Documents (ICD).

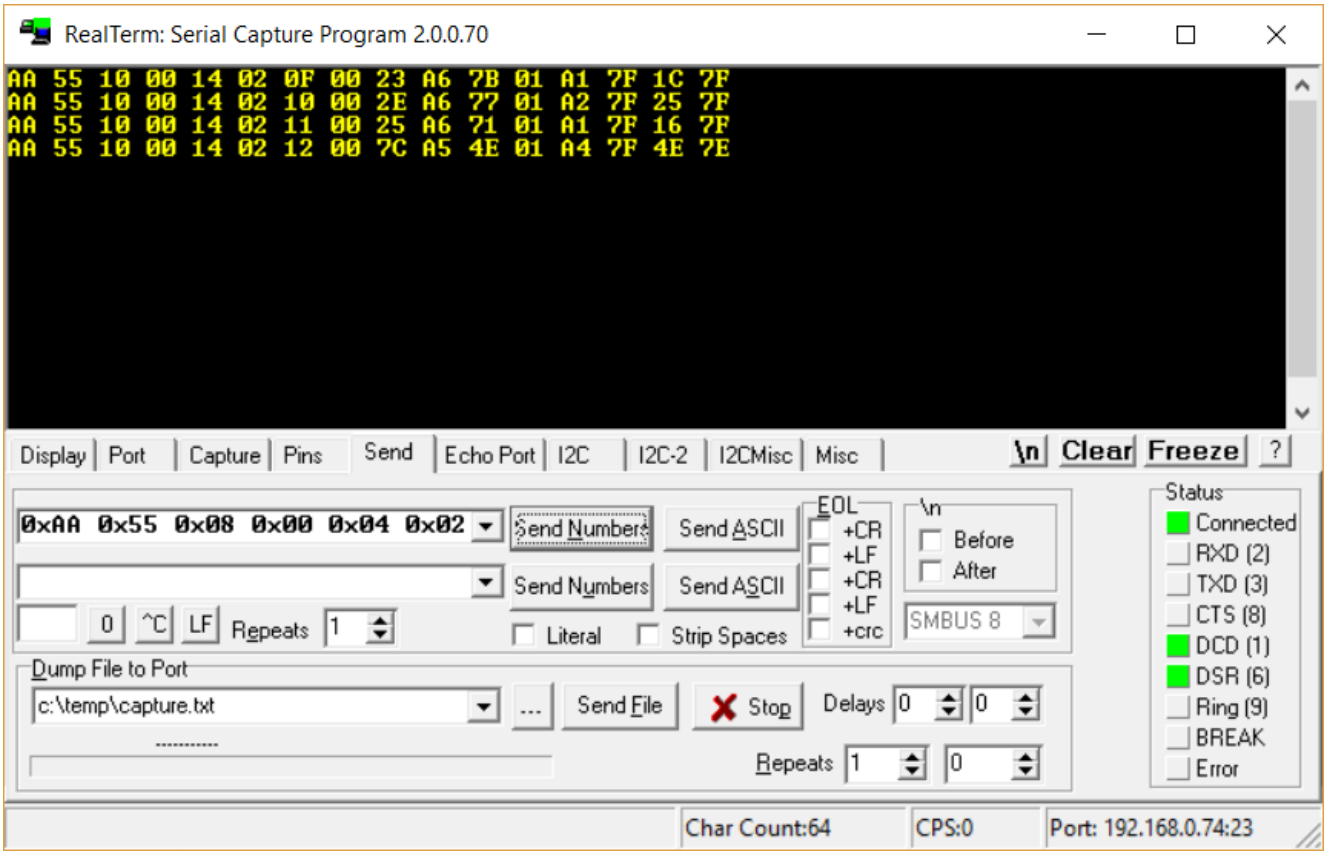



**Fig. H.9. The Euler angles requested and returned from DTS.**

The next example demonstrates how to start the data stream from a device.

In order to start the data stream, it is necessary to send the required command to the device.

**Note:** For the INS, see description of all available data formats and corresponding commands in the Interface Control Documents (ICD).

Enter the message in the hexadecimal format to the “Send” tab of the RealTerm tool (see Fig. H.10). Then click “Send Numbers” button. When the command is received by the device it may start the initial alignment process. After the initial alignment procedure is over, the device outputs the initial alignment block and starts transmitting data. If the initial alignment time is set to 0, then the initial alignment procedure is skipped and device starts the data output without any pause. As an example, the Fig. H.10 shows the device started to output messages.

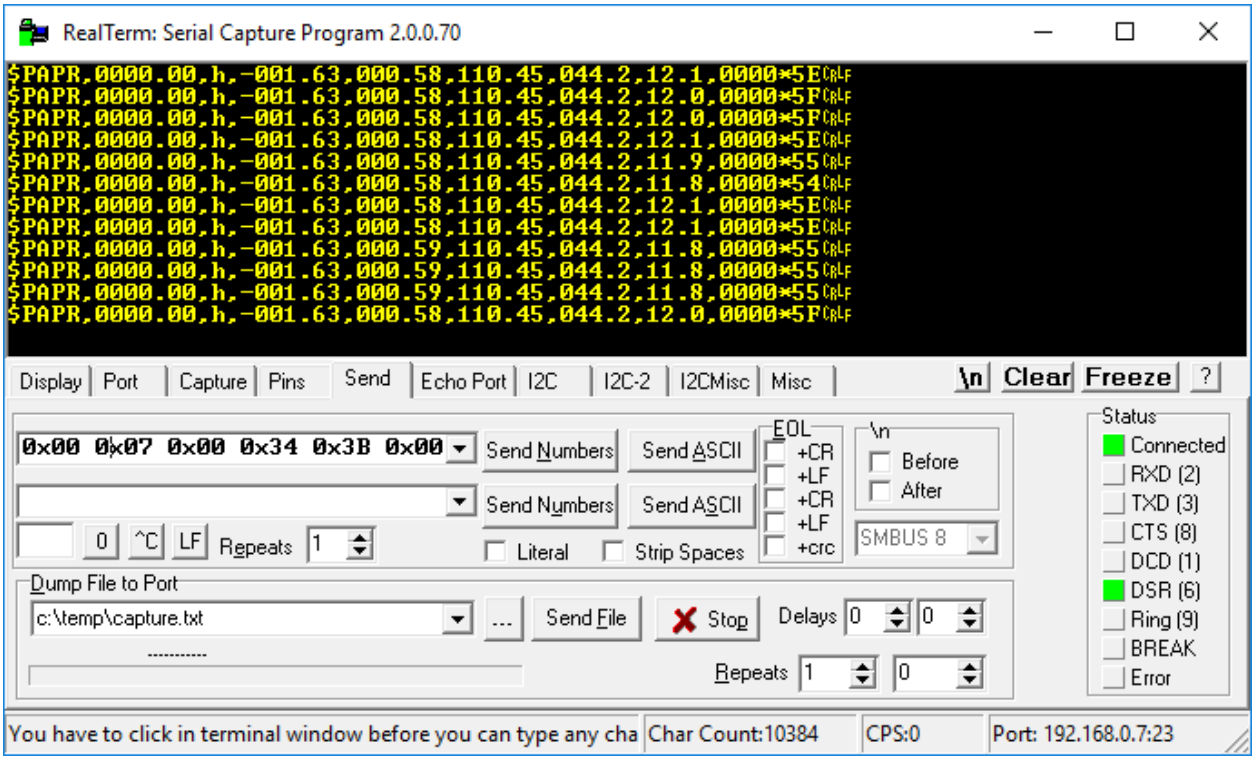



**Fig. H.10. MRU outputs NMEA messages.**

Step 4.

To stop the data stream, the Stop command should be sent to the device in the same way as described in Step 3.

## H.7. Communication OVER the Ethernet in Auto Start Mode

When the device is configured to output data after power up without any commands from the host computer (Auto start mode) the Ethernet should be configured to work in the UDP mode. For this purpose, please perform the following steps:

Step 1.

Please configure the device to Auto start mode (for details please refer to the INS ICD and/or see section 10.6 of INS User Manual). The main settings of auto start mode are the baudrate of the serial port to which COM1 of the device is connected, output data rate, and output format.

Step 2.

Open the USR-VCOM tool and go to Tools –> Search –> USR-TCP232-E45. Click on the device that appeared in the “Search List” as shown on Fig. H.4.

Step 3.

In the field 'Baudrate' please set the value that corresponds to the baudrate set on the Step 1. Please note that maximum possible baudrate is 230400 bps. Please set the 'Work Mode' parameter to 'UDP' and specify the IP address of the data receiver in the 'Remote IP' field (see Fig. H.11). Click 'Save COM0' button to save the settings.

Step 4.

Power-cycle the device to start automatic data output via the Ethernet port.

Step 5.

To stop data stream power off the device.

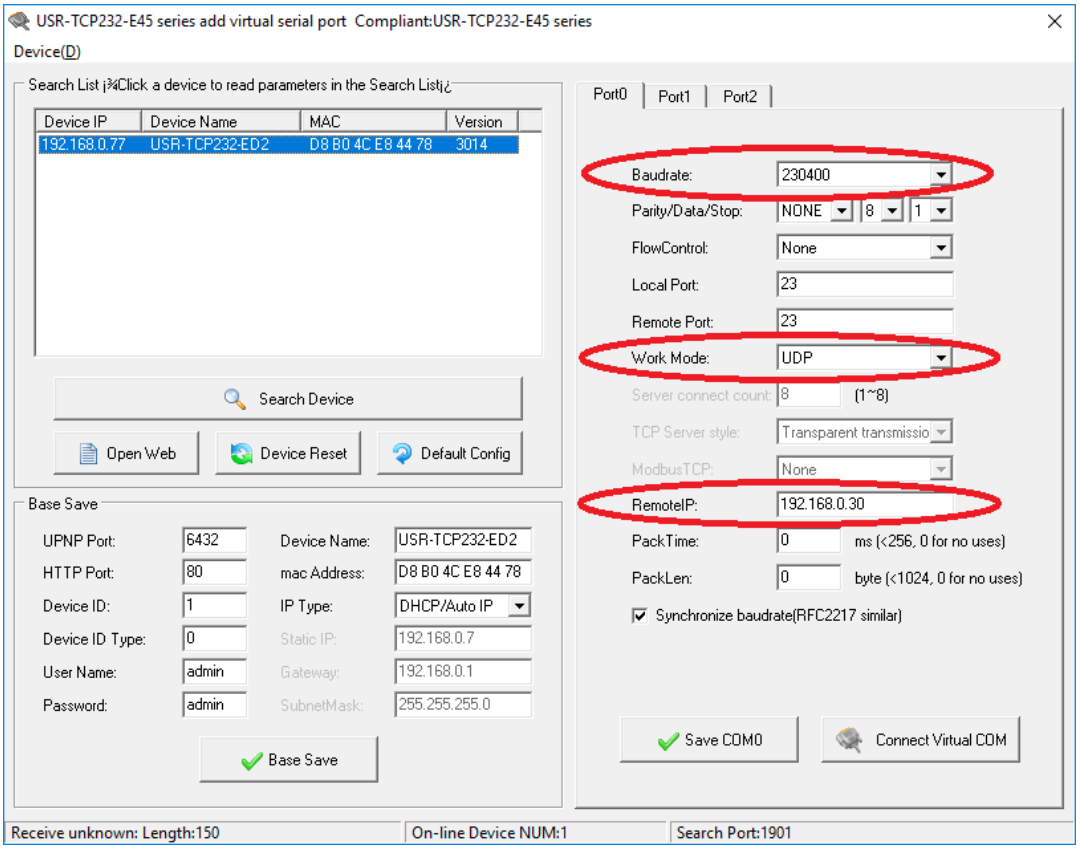



**Fig. H.11. Configuring the Ethernet module to UDP mode.**

## UDP messages logging/monitoring

When Ethernet is configured to work in the UDP mode there is a possibility to check data availability by monitoring transferred data in the network. For this purpose, it is easy to use Wireshark software. Wireshark is a widely-used network protocol analyzer. To download and learn more - visit the Wireshark`s developers site, https://www.wireshark.org/#download

For this purpose, please perform the following steps:

Step 1.

Open Wireshark and set up parameters of the capturing filter correspondingly to your configuration, please see Fig. H.12.

Step 2.

Start monitoring packets coming through the Ethernet. The packets correspond to the configured output format of the unit. An example is shown in Fig. H.13.

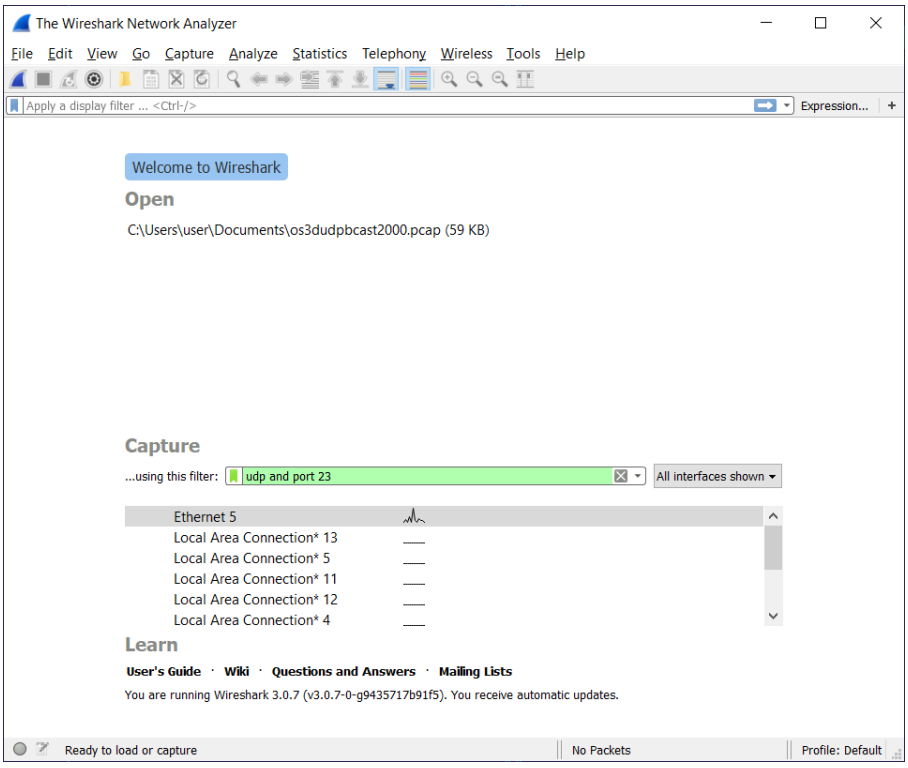



**Fig. H.12. Setting of the capturing filter**

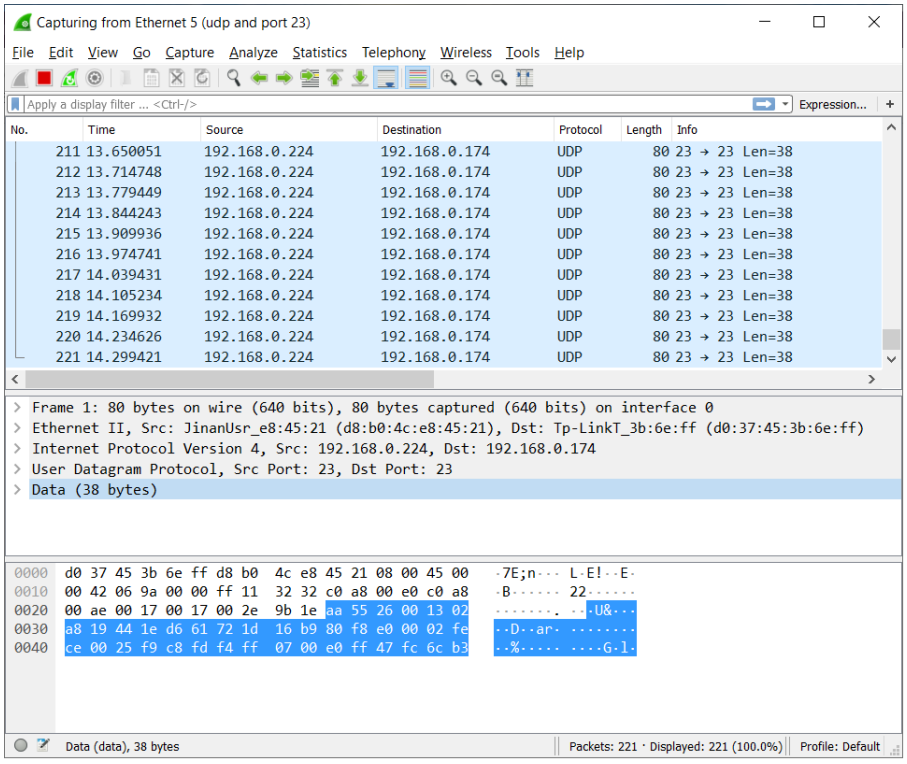



**Fig. H.13. Device outputs data packages**

# APPENDIX I.
# Using the Internal Datalogger

The purpose of this section is to explain the uses and functionality of the INS internal datalogger. It is important to note that this option is only available upon request for any of the INS models that are produced by Inertial Labs™. The capacity of the internal data logger is 8GB or 64GB.

A INS unit with internal datalogger is configured to log data once loaded with parameters in the web interface. The internal datalogger can store all data formats listed in section 4.1.

## I.1 Preparing INS for Operation with Datalogger

These steps will walk you through the setup process to begin recording data using the internal datalogger.

- Begin by setting up all required connections.
- Connect device to the included service cable.
- Plug the power supply into the multiport development kit.
- Connect Ethernet cable from source (router, etc.) to multiport development kit.

Data logging can then be started and stopped manually using an Ethernet connection to the INS and the logger's web-based interface as described below.

## I.2 Description of Web Based Internal Datalogger Interface

This section will guide you through web-based internal datalogger interface as well as how to export this data to a local host computer.

In order to access datalogger interface for turning logging on / off, or for viewing/exporting files on the internal datalogger, please open a web browser of your choice (Edge, Chrome, Firefox, etc.) and in the web address bar, type in the word "ins-" followed by the unit's serial number or the IP Address that your local network assigns to your unit. As an example, you should type in something similar to:

ins-######## or 192.168.0.92

**Note:** ######## represents the unit's assigned serial number (e.g., W2001065). Also, the IP address is shown as an example. Your network may assign a different number.

The main opened window will look similar to Fig. I.1 depending on whether the unit has been configured to output data or not. Regardless, there are three different main menu items that the user can choose from:

- Status: This menu item allows the user to view data output of the INS in real time and change the data output type.
  - In the "Logger control" section, the user can toggle on and off data logging using the "Start logging to ___" or "Stop logging to ___" button.
  - In the "Device output" section, the user has the ability to start and stop the device using the "Stop device" or "Start device" button. Additionally, located in this section, is a drop-down menu that contains the available output data formats that are selectable for the unit. This menu is only available if the device has been stopped. The "Status" window can be seen below in Fig. I.1.

**Note:** Please not that in order to change the device output data type, you must first click the "Stop logging to ___" button, then the "Stop device" button. At this point you can now change the output data format.

- Storage: This window allows the user to view, monitor and delete storage on the device. The menu item looks similar to Fig. I.2.

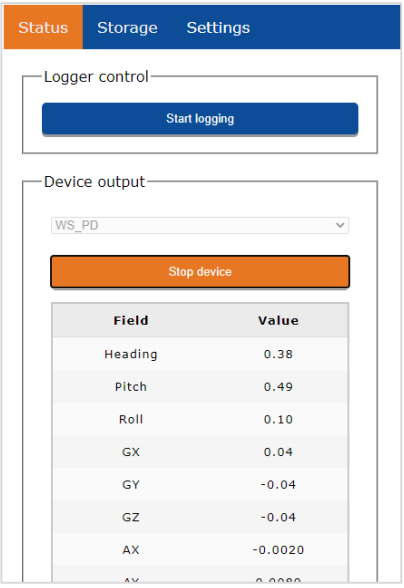



**Fig. I.1.**

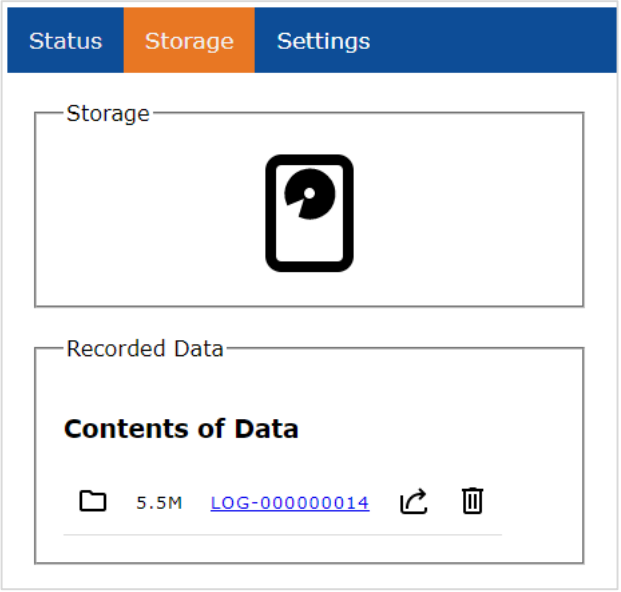



**Fig. I.2.**

- Storage: The indicator shown in the “Storage” section of the screen will be green if storage is within normal range. It will turn yellow when storage is at 75% max capacity and turn red when it is at 95% max capacity, as shown in Fig. I.3.

  If there are logs already on the device after power up, they will be contained in the “Recorded Data” section, where they will be labeled as “LOG-_XXXXXXXXX”, with XXXXXXXXX sequentially incrementing.
- Recorded Data: The user has the ability to select and download individual data files / folders and explore the internal storage of the datalogger. The two actions associated with recorded data allow the user to download the file / folder (Fig. I.4) or delete the file / folder (Fig. I.5).

**Fig. I.3.**

**Fig. I.4.**

**Fig. I.5.**

- Settings: This drop-down menu allows the user to control different settings pertaining to the device communication rates, automatic logging functionality, and network settings.
  - Device: The “Device” tab from the Settings drop-down menu gives the user the ability to configure the following settings: The **Baud rate** that the unit communicates with; the data format that is output by the device if it is configured in **Auto start**; and the **Data rate** for which the user can select the rate at which data packets are being output by the device. This window can be seen in Fig. I.6.

**Note:** Before changing settings in this menu, make sure to terminate logging in the “Logger control” section of the “Status” window. Changing any of these settings will result in the termination of data logging. Additionally, saved changes to the **Auto start** data format will not be applied until the next power up of the device.

  - Logger: The “Logger” tab from the Settings drop-down menu gives the user the ability to toggle on or off “Automatic logging”. This window can be seen in Fig. I.7.

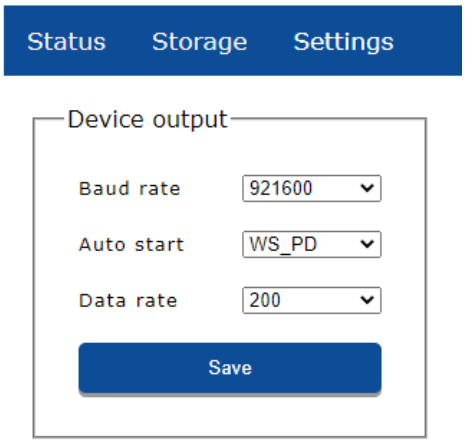



**Fig. I.6.**

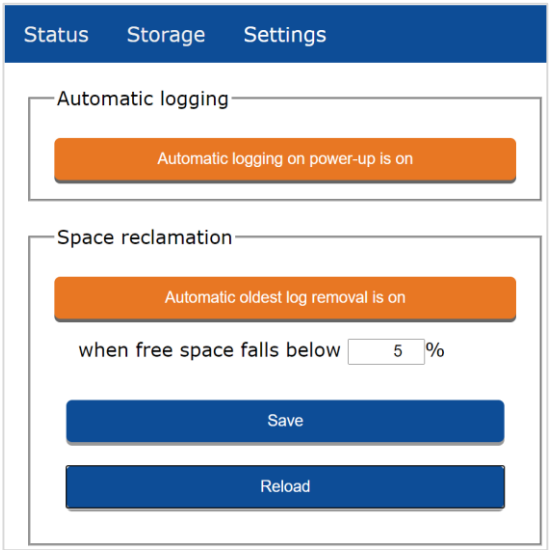



**Fig. I.7.**

- <u>Space reclamation:</u> Additionally, the "Space reclamation" section gives the user the ability to decide how data is recycled. Toggle on and off the button labeled "Automatic oldest log removal is…" in order to turn on and off data recycling. If this feature is turned **"off"** then the device will stop logging when the devices storage is full. However, if it is turned **"on"** then the user can select when the device will begin recycling data once it reaches its storage limit (which is configurable by the user as a percentage). This feature ensures that the logger continues to store data files from the current trial without stopping. Adjust the when this process begins by setting the field labeled "when free space falls below: __%" to set when data should begin to get recycled.

  When adjusting settings make sure to click the "Save" button to load settings to the device.

**Note:** When settings have been changed, the "Save" button will change to the color red to indicate to the user that the settings have not yet been saved to the device.

- <u>Network:</u> The "Network" tab from the Settings drop-down menu gives the user the ability to set up and configure the different COM ports for the device to output data packets with to select locations (in the "Interfaces" section) as well as configure the "Network address" settings. This window can be seen in Fig. I.8. Working with TCP settings will require you to follow instructions detailed in Appendix H, where you can set up the Ethernet connection as a virtual communication port and view data in real-time through a virtual serial connection.

- Interfaces: The current protocol settings allow for UDP or TCP protocols – alternatively the protocol can be configured to the “Off” position. After changing settings, the user must click the “Save” button to load the changes to the device. Please note that if you would like to use COM2 and COM3 in this manner you will have to direct this traffic to Ethernet in the GUI. See section “4.2.2. “GNSS Receiver” Tab of “Devices Options” Window” for more details.

  In the event where the user has made changes (that have not been saved) and would like to revert back to the original configuration, click the “Reload configuration” button.
- Network address: In the “Network address” section the user has the ability to configure the IP address type between a DHCP server or using a Static IP Address. If the user chooses the DHCP option, they should follow directions outlined in section J.6 of this User Manual. If the user selects a Static IP address, they can manually configure the Address, Netmask, and Gateway they would like to use. These options can be seen below in Fig. I.9.
- Firmware: The “Firmware” tab in the Settings drop down window enables the user to update the datalogger’s firmware. To load the latest firmware, click on the “Load logger firmware update button” and navigate to the distributive.

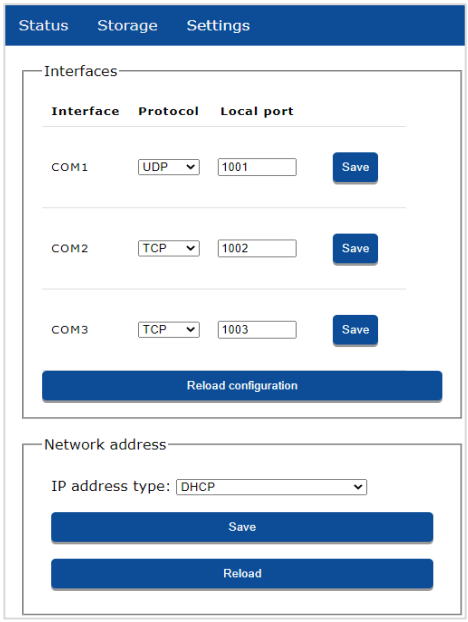



Fig. I.8.

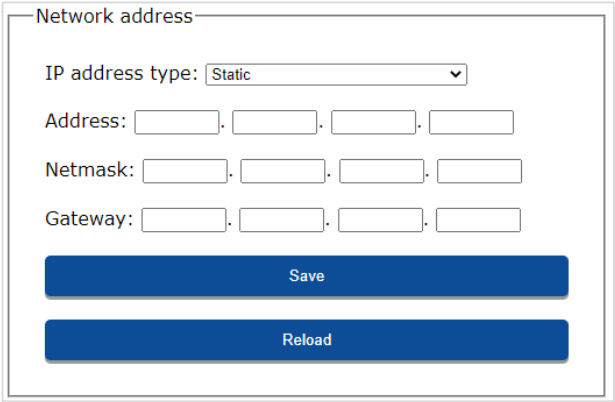



Fig. I.9.

## I.3 Automatic Logging and Recycling

The automatic logging feature is designed for unattended logging. For example, if there is no way to connect to the device and request logging, but every run of the INS should be logged. Only the most recent logs are important; logs are periodically downloaded if they need to be archived. The period may depend on the capacity of the logger and the amount of data logged. This is where automatic logging and recycling can be beneficial.

To configure automatic logging, click on **"Settings"** and then select the **"Logger"** tab shown in the main menu. Then proceed to toggle the button labeled "Automatic logging on power-up is on" which is shown in Fig. I.7.

The settings chosen will be applied next time the unit is powered up. After the next power up, the unit automatically will begin to log data with the configured format and rate that it was configured for from the "Device" tab in the "Setting" drop-down menu.

As stated previously, the unit has the ability to recycle data if the unit's storage limit has passed the set threshold. These settings can be adjusted using the parameters shown in Fig. I.6.

After recycling and archiving, the new log folder is created and logging is started whenever the INS starts generating data.

For user convenience, automatic logging files are generated with limits of 1 GB. Once the 1 GB limit is reached, a new log file begins to be populated. This was done such that when automatic recycling is used, the system will delete individual files instead of one large file containing all the recorded data.

# I.4 Converting Outputted Data to *.txt File

In order to use outputted data, which comes in *.zip files, conversion of the data files must be performed. The *.zip archive contains four useful files. Begin the conversion to *.txt by performing the following steps:

Step 1.

Open the INS GUI, click on **"Convert"**, and then click on **"Convert Log Data to Bin File"** (shown in Fig. I.10). The user will be prompted to first select the *.prm file (or *flash file), which is located in the outputted data folder, and then to select the data log file.

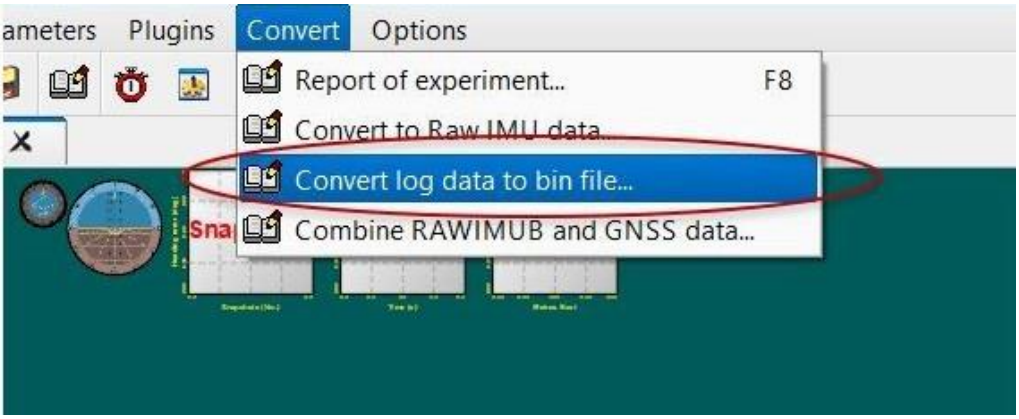



**Fig. I.10.**

Step 2.

Return to **"Convert"**, and then select **"Report of Experiment"** (Fig. I.11). User will be prompted to open the *.bin file just created, and then the GUI will now output a *.txt file on which it is possible to view all data.

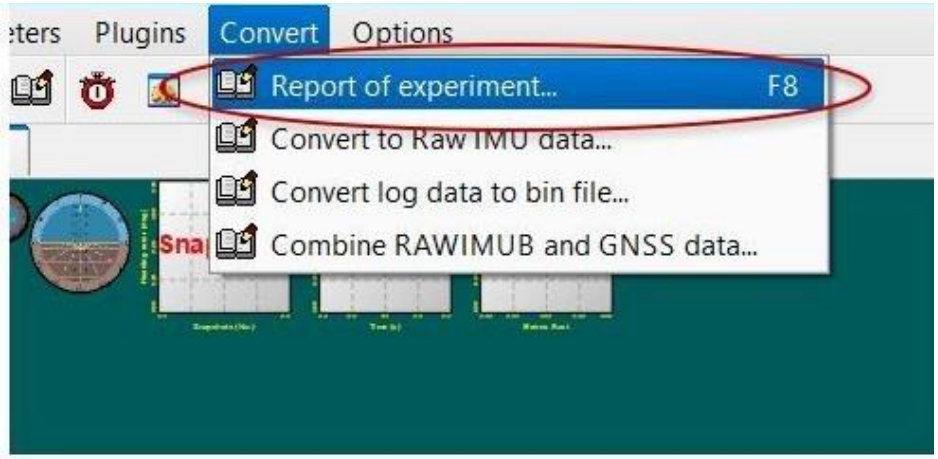



**Fig. I.11.**

## I.5 Notes on Applications of Internal Datalogger

1. The internal datalogger will reach its max storage capacity at slightly over 6GBs (or 62 for a 64 GB datalogger). Once the internal storage is full, the device will no longer record data. You must erase old data manually before being able to log data again.

   **Note:** This does not mean that functionality of the INS will suffer. If max storage limit is reached, the INS will continue to be operational but will no longer store any data internally.

   Automatic logging with automatic recycling allows the system to reclaim space on every power up of the INS. However, long unattended runs may still fill up storage. For example, if a single power up of the INS logs 1.2 GB of data, then the fifth and each subsequent power up will fill storage to the point where logging stops. It is therefore recommended to limit the data rate if prolonged non-stop logging is desired, to maintain a single power up log shorter than 1.2 GB.

2. Currently, to download data from the device, it must be connected via Ethernet.

3. To generate accurate time stamp of recorded data, at least one of the GNSS receiver ports (COM2 or COM3) should be routed to Ethernet in INS Devices options.

4. Parsing of data for real-time monitoring over web interface is currently supported for all data formats except: SPAN RawIMU, NMEA formats, and Cobham UAV200 Satcom. Those formats are only displayed as being output, without displaying the data contained.

## I.6 Setting up a DHCP Server to Use the Internal Datalogger

This method of connecting to the internal datalogger is convenient for users who do not have the ability to wire directly to a router or internet source. With this method, users can connect the INS directly to a host computer over an Ethernet port to access the internal datalogger. The following steps will ensure connectivity to the datalogger:

Step 1.

Download Tftpd64 by the Ph. Jounin application onto your PC. To do this use the link:

https://bitbucket.org/phjounin/tftpd64/downloads/Tftpd64-4.64-setup.exe

Step 2.

Install the Tftpd64 application by running file with *.exe extension and follow the steps.

Step 3.

Connect the INS to the Ethernet port on the host computer. It will be displayed in the **"Network Connections"** window as shown in Fig. I.12. Right-click each network connection, other than "Ethernet", and temporarily disable it.

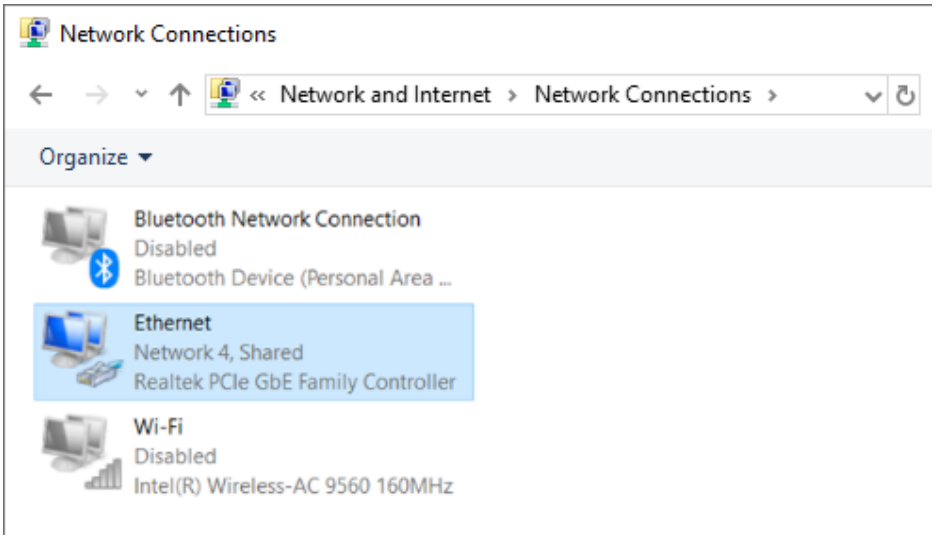



**Fig. I.12.**

Step 4.

Right-click **"Ethernet"** (highlighted in Fig. I.12) and select **"Properties"**.

Step 5.

Click on **"Internet Protocol Version 4 (TCP/IPv4)**" and select **"Properties"**, as highlighted in Fig. I.13.

Step 6.

Use Fig. I.14 and configure settings in the same fashion. Note that if the user normally uses an Ethernet connection for internet, it is necessary to go back and select **"Obtain...automatically"** to do so once the user is finished using the datalogger on the INS.

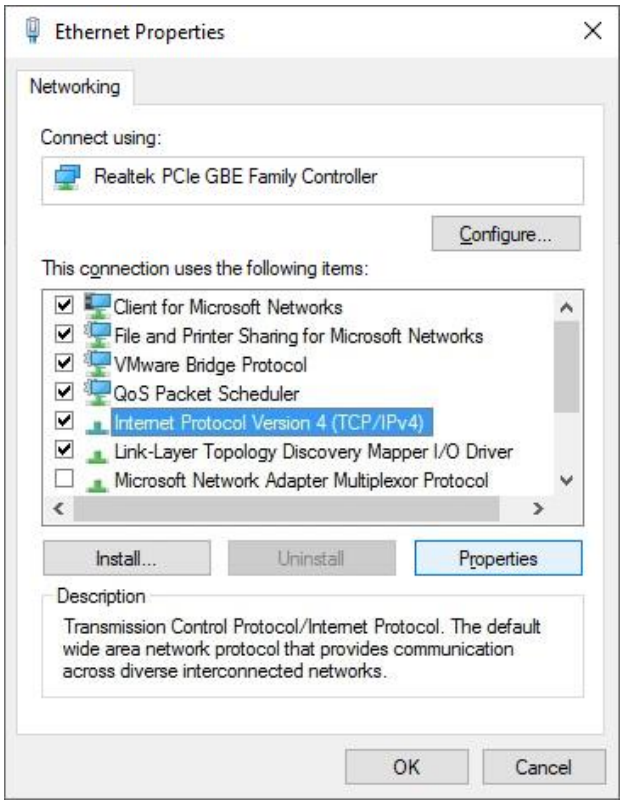



**Fig. I.13.**

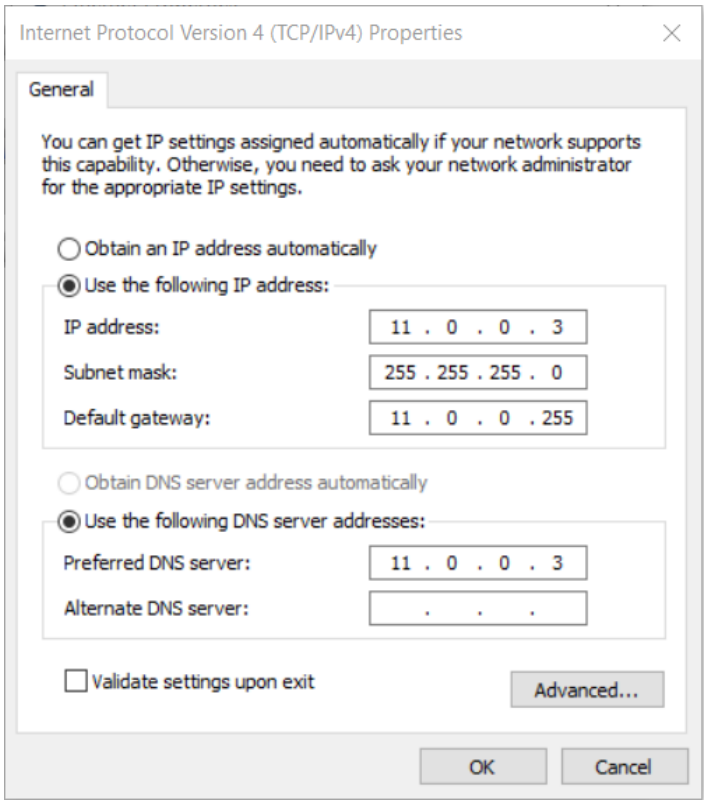



**Fig. I.14.**

Step 7.

Click "OK" and then open the Tftpd64 application; click on the **"DHCP server"** tab. The window will look like that in Fig. I.15. The **"Server Interfaces"** will have an option for a device that has the same IP Address as what you entered in Step 6, and this is the Ethernet connection.

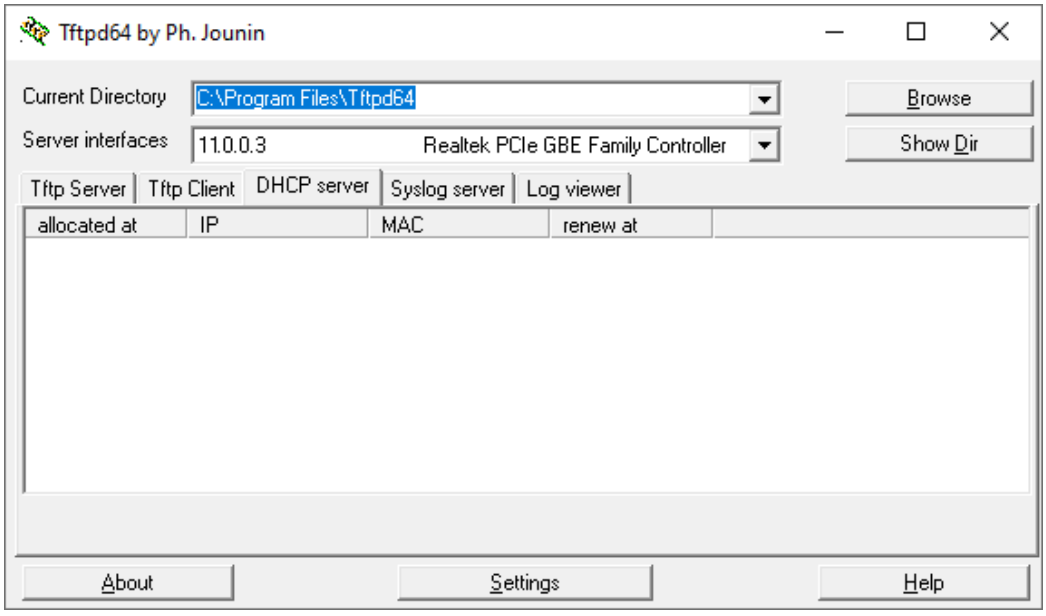



**Fig. I.15.**

Step 8.

Click **"Settings"** at the bottom of the window, and enter in the settings as seen in Fig. I.16 in the tab labeled **"DHCP server"**.

Step 9.

Click "OK", exit out of Tftpd64, and re-open the program. Within a minute or two, the INS will display under the DHCP server similarly as to what is seen in Fig. I.17.

Step 10.

At this point, the user may proceed to the internet explorer software of choice and type into the web browser (http://11.0.0.10/).

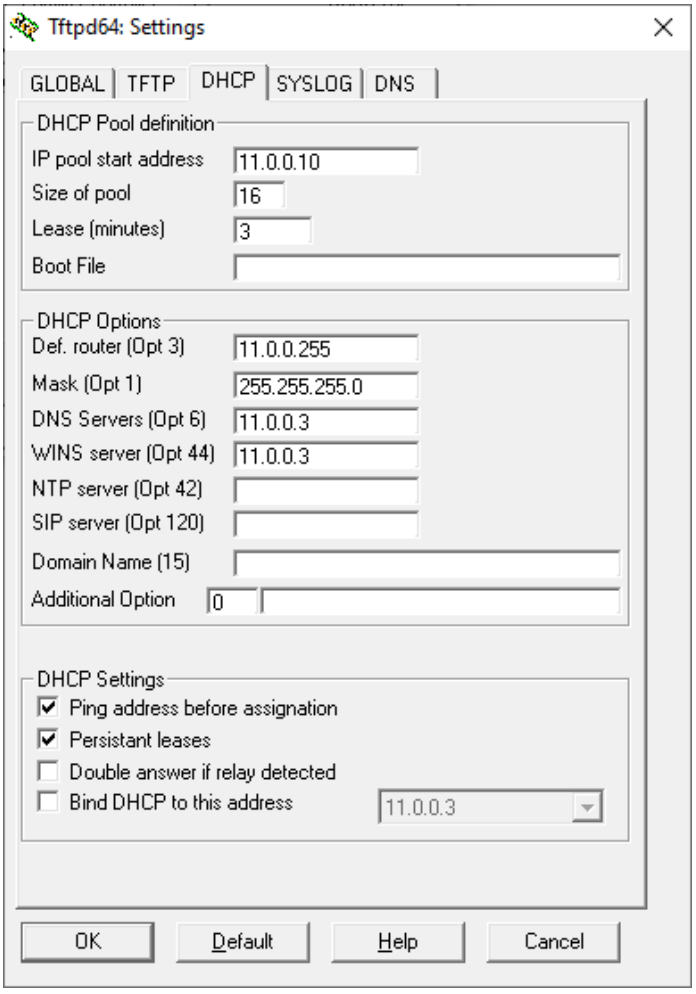



**Fig. I.16.**

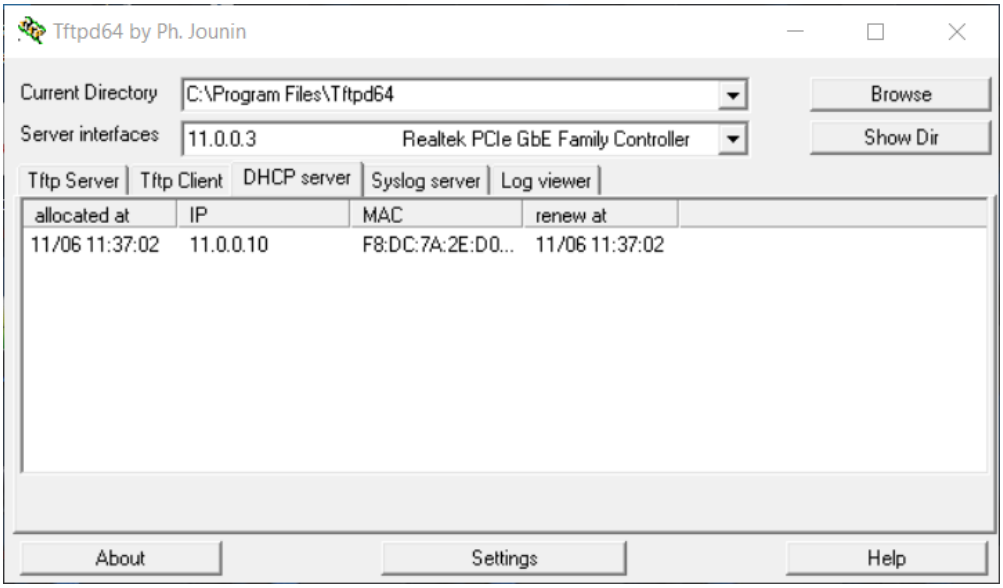



**Fig. I.17.**

## I.7 The Procedure of the Datalogger Updating

To update the internal datalogger follow these instructions:

### For Logger Versions Prior to 3.0.0

Step 1.

Make sure the unit is connected to the internet, and record its **ip address**.

Step 2.

Download the given distributive and unzip the .zip distributive.

Step 3.

Make sure to read the readme.txt file located in the update distributive to ensure you are aware of any known limitations or potential areas of fault.

Step 4.

Please download ALL data from the datalogger prior to updating the logger firmware. Any files left on the logger during installation of the update will be DELETED.

Step 5.

Double-click on “install_logger_update_X.X.X.cmd” to run the update from the command line. A window shown in Fig. I.18 will be displayed.

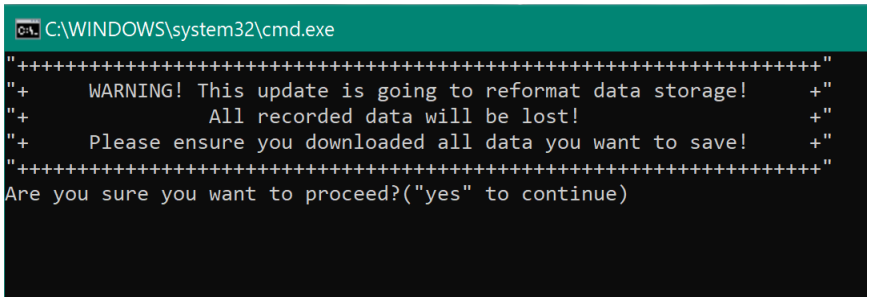



**Fig. I.18.**

Step 6.

Type “yes” to continue, and click “enter”. Then proceed to type in the IP address of the unit as prompted in the next step. This is shown in Fig. I.19.

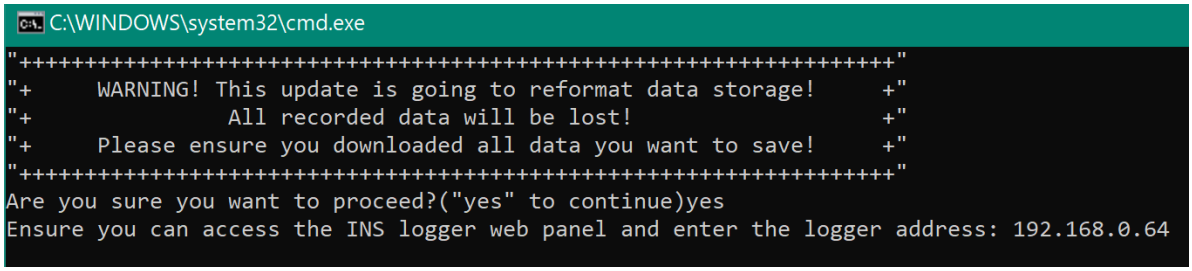



**Fig. I.19.**

Step 7.

Wait for a few moments as the logger begins updating. After approximately 1-3 minutes a message will be displayed indicating “Success”. A line will be generated immediately after this “Success” notification however this is expected and should not be of any concern to the user.

Step 8.

Your device has now been successfully updated to logger version 3.0.0 (or above). You may have to refresh your web browser to remove cached webpage information to refresh the usage of the datalogger interface.

## For Logger Versions After 3.0.0

For users that require a FW update for the data logger and are currently using a Logger version of 3.0.0 and above, the follow steps should be followed to successfully update the data logger interface.

Step 1.

Begin by connecting the device to the internet and open up the data logger interface in your web browser using methods as discussed in I.2 Description of Web Based Internal Datalogger Interface.

Step 2.

Make sure to read the readme.txt file located in the update distributive to ensure you are aware of any known limitations or potential areas of fault.

Step 3.

Please download ALL data from the datalogger prior to updating the logger firmware. Any files left on the logger during installation of the update will be DELETED.

Step 4.

Given that you have received a logger distributive from the Inertial Labs team, unzip the packaged .zip distributive to your local drive in a place that is convenient.

Step 5.

After the unit is connected to the internet, the distributive is in a known location, and you have gained access to the logger web interface - navigate to “Settings” in the web-based data logger interface and click on the tab option from the drop-down menu labeled “Firmware”.

Step 6.

In this window select the button labeled “Upload logger firmware update”, as shown in Fig. I.20

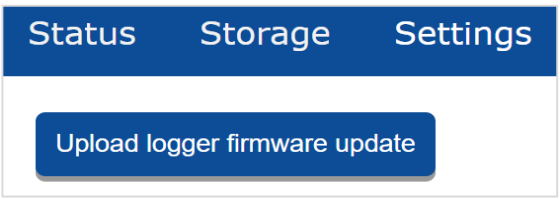



**Fig. I.20.**

Step 7.

A generic Windows “Open” window will appear prompting for the user to select a file. Go to the location of the unzipped update distributive and select the file labeled “logger_update_X.X.X.tar” and click “Ok”.

Step 8.

At this point the logger firmware will be updated and the web-page will automatically refresh in approximately 1-3 minutes depending on the size of the logger.

Step 9.

The update process is now complete and the user may begin to use the datalogger.

# APPENDIX J
# INS Preventive Maintenance

## J.1. Introduction

At Inertial Labs™, developing proper preventive maintenance habits in the work place is a top priority for an effective operating work environment. Proper organization of such plans are backed by documentation for the Inertial Navigation System (INS) in both the Interface Control Document (ICD) and the User Manual (UM). Proper use of protective equipment for preventive maintenance of systems outside the use of the Inertial Labs™ INS is the customers' responsibility. For a preventive maintenance method of upkeep to be implemented into the work place, regular inspection of products and the surrounding system to identify small repairs is expected to prevent incidents requiring major repairs. The responsibilities of using a predictive method of monitoring are left to the customer. Warranty information on parts and products can be accessed from Inertial Labs™ support members or in the documentation received upon unit order arrival.

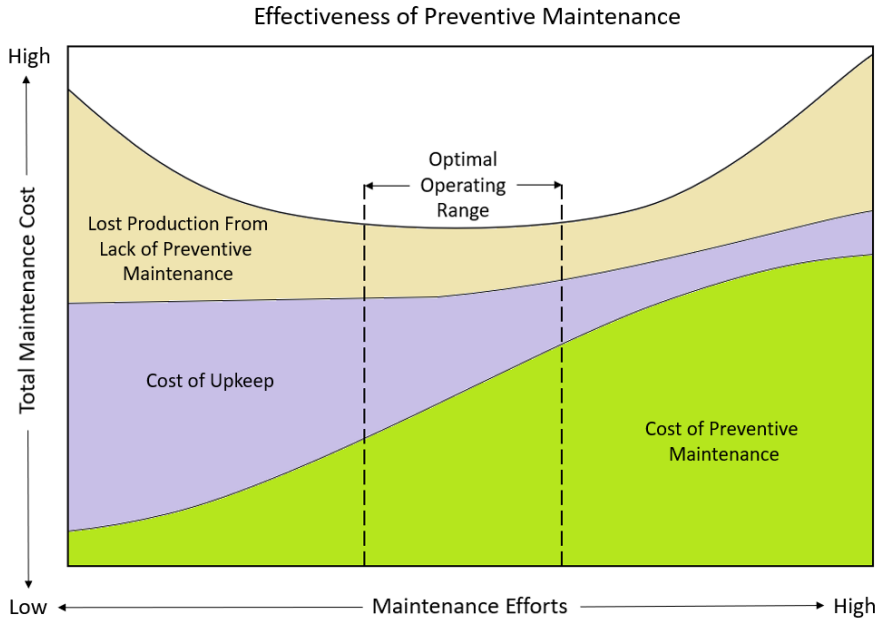



**Fig. J.1. A visual representation of the effectiveness of preventive maintenance**

When used effectively, preventive maintenance can be help decrease total operation costs. This is due to the positive effect it has on waste control and the mitigated cost of maintenance over time for projects. Because of the interruptions a "down product" causes on the flow of work and production, maintenance, when not dealt with consistently, can become financially consequential if put off. The goal of this

document is to help minimize losses for the user in both time and cost over the lifespan of the product in use.

## J.2. General Care

### J.2.1. Surface Cleaning

To increase longevity of the device and decrease opportunities for defects in the product's painting finish, regularly wiping down the device is good user practice. Before wiping down the device, ensure that power is not on, to reduce the risk of getting a harmful substance in the ports of the device. It is recommended that a clean microfiber cloth be used for wiping to reduce risk of scratching the surface. Ethyl, or conventional rubbing alcohol, is commonly used for cleaning and will ensure all surface defects like smudges, dirt, or grease are removed. To avoid getting unneeded amounts of cleaning solutions near sources of electrical communication for the device, please use caution when wiping around the communication ports on the device.

### J.2.2. Protection for Magnetic Interference

The Inertial Labs™ INS-P has magnetometers with wide dynamic range, and their sophisticated calibration algorithms allow them to operate in different environments. These units should be installed on an object as far as possible from large ferromagnetic masses of the object and powerful sources of magnetic, electrical, and electro-magnetic fields.

The location for testing must not have ferromagnetic (magneto-susceptible) materials, and the lab room itself must have the level of intrinsic magnetic and electro-magnetic fields suitable for the magnetic heading system testing:

- Inside and near the lab room there must be no powerful source of magnetic, electric, and electro-magnetic fields. The magnetic field intensity must not differ from the Earth magnetic field intensity at the test site more than 0.01%.
- Small ferromagnetic objects must be as far as 3 m from the test table. Large size ferromagnetic objects such as cars and trucks must be as far as 15 m from the table.
- It is necessary to conduct a regular check-up of the magnetic field uniformity inside the lab room.

It is highly recommended to degauss the INS before a heading test to remove permanent magnetization of some components in the INS (e.g., accidental exposure of the unit to a large magnetic field). A hand-held degausser (tape eraser) can be used to demagnetize the INS. (Most audio and video degaussing units can be used.) Follow the instructions for your demagnetizer.

### J.2.3. Safe Mounting Practices

To reduce the risk of unwanted noise in measurement data, regularly check the surface on which the unit is mounted when the device is operating in the field. Choose a location that is isolated from excessive shock, oscillation, and vibration. Similarly, excess data from unwanted shock, oscillation, and vibration may occur if the device is not securely fastened to the surface it is mounted to. Section 4.1 of the INS Interface Control Document (ICD) gives a detailed description on mounting surfaces for the device.

## J.3. Calibrations

### J.3.1. Correct Calibration Methods

To regularly see results that reflect the state of the object the unit is mounted to, it is essential to perform calibration methods correctly. Section 6.8 of the INS ICD explains how to properly perform the five different types of hard and soft iron calibration methods. Each of the calibration methods appeals to specific types of applications, so it is critical to choose the correct calibration method for an effective study to be run.

### J.3.2. Calibration Frequency

To ensure consistently accurate data collection, routinely performing calibrations for any high-performance sensing device is a practice that should be held at a high priority. The responsibility falls on the customer to determine the appropriate times to recalibrate, but the recommendations listed below are a good common practice. A device should be recalibrated when:

1. The device is moved to a new object carrier or mounting surface.
2. A new firmware update has been installed.
3. The object carrier or mounting surfaces mass-center has been changed.
4. External conditions have changed, such as
    a. Temperature

   b. Pressure
   c. Humidity
   d. Weather type (wind / rain / sunshine)
   e. Etc.
5. Aiding data conditions have changed for the INS.

If the necessity for recalibration is ever at question, the default answer should typically be yes. Recalibration often promotes a more successful study. However, if a study requires that certain parameters be held at a constant condition then careful consideration of the effects of recalibration is recommended.

### J.3.3. Degaussing for Magnetometer Calibration

Degaussing of the magnetometers prior to calibration is a safe practice to help reduce the effects of permanent magnetization of some components in the INS. Occasionally, when a device is exposed to a powerful magnetic or electro-magnetic field, magneto-conductive components inside the INS units may build up their own magnetic fields. Degaussers use a magnetic field of their own to neutralize any existing field inside the device. Either magnetic degaussers or electro-magnetic degaussers will do the trick. Data stored on the device will not be affected when degaussing the device because Inertial Labs™ does not use magnetic components for storage or memory. As previously stated, most audio and video degaussing units can be used.

## J.4. Transportation

### J.4.1. Carrying Case

When the Inertial Labs™ INS was purchased, it is delivered in a transportation case (as seen below) to protect the device from excess shock exposure in shipment. This case is also recommended to be used when transporting your device from location to location. Dropping your INS could prove extremely damaging to components and hinder the device from performing functions correctly. Any time the device is not being directly used, packing it away in its carrying case is a fantastic way to mitigate risk (see Fig. J.2).

**Fig. J.2. Inertial Labs™ carrying case**

## J.5. Connector Care

### J.5.1. Data Cable Handling

Regardless of what interface the device is using to transmit data (Ethernet, RS-232, or RS-422), it is important to use care when handling the connected cables. Following these few steps can help you ensure your cables last for as long as possible without data interruption issues.

1. Coil your cables properly. When storing your data cables, it is never a good idea to pack them all aimlessly into a bag without properly coiling them up. Knots could develop and the cables could be bent, which could cause communication issues when using the device. The figure below (Fig. J.3) shows a properly coiled cable.

2. Store cables in the device case. Similarly, to storing the unit, use the carrying case to protect your data cables from being lost or damaged when not in use. An opened display of the case for securing the device and its cables can be seen below (Fig. J.4).

Fig. J.3. A properly coiled data cable

Fig. J.4. Carrying case displaying area for device and cables

3. Be careful to not walk on the cables. When setting up a test station, organization is a key aspect to any successful test. Keep data cables off the ground when possible, and if it is unavoidable to have them cross a walking area, be sure to mark them clearly with bright colors to avoid having them stepped on. Repeated exposure to such forces could cause lag of data flow or stop it completely.

4. Avoid crossing with other cables. Although many cables are thoroughly insulated and proteced from interference with other high-voltage cables, it is a safe practice to avoid heavy interaction with such cables to ensure that assigned data rates are able to flow as intended.

## J.5.2. Data Rates for Given Cable Lengths

Below is information for commonly supplied data cables and their data rates for given lengths. Actual performance may vary depending on the type of cable quality being used and the conditions under which the device is being used (temperature, pressure, etc.).

**Table J.1. Data rate for cable lengths using the CAN Bus cable**

| Bit Rate | Cable Length |
|---|---|
| 3 Mbit/s | 5 meters |
| 1.5 Mbit/s | 15 meters |
| 1 Mbit/s | 30 meters |
| 800 Mbit/s | 50 meters |
| 500 Mbit/s | 100 meters |
| 250 Mbit/s | 250 meters |

**Table J.2. Data rate for cable lengths using the RS-232 cable**

| Bit Rate | Cable Length |
|---|---|
| 921.6 kbit/s | 2 meters |
| 460.8 kbit/s | 5 meters |
| 230 kbit/s | 12.5 meters |
| 115.2 kbit/s | 25 meters |
| 57.6 kbit/s | 50 meters |
| 28.8 kbit/s | 100 meters |

**Table J.3. Data rate for cable lengths using the RS-422 cable**

| Bit Rate | Cable Length |
|---|---|
| 3 Mbit/s | 5 meters |
| 1.5 Mbit/s | 15 meters |
| 1 Mbit/s | 30 meters |
| 800 Mbit/s | 50 meters |
| 500 Mbit/s | 100 meters |
| 250 Mbit/s | 250 meters |

## J.6. Electrical Protection

### J.6.1. Surge Protector

Whether it's from a storm or from a power surge at a local power plant, using a surge protector can protect users from high-voltage spikes when using your device. Surge protectors will give an extra layer of protection between dangerous voltage spikes and the device to help give users peace of mind when running tests. Surge protectors do, however, have a lifespan; it is recommended that when researching the types to invest in, that the chosen surge protector has LED indicators to notify you when the circuit is no longer protected.

### J.6.2. Powering Off

Unless the device is firmly mounted to a carrier for data acquisition, it is also recommended that the device be powered off. Aside from mechanical damages that may come from dropping a unit, additional electrical damages can be avoided by keeping the device powered off when not being used.

### J.6.3. Temperature Control

The unit's electronics are rated for unaffected performance on even the hottest days. Although the device may be too hot to the touch, outside temperature (as long as it is within specifications outlined in the device datasheet) will not affect electronic performance of the INS. With a Mean Time Between Failures (MTBF) rating of 100,000 hours and by performing functions at 65° C, users can be confident that the electronics will not be affected from prolonged exposure to heat.

## J.7. Software and Firmware Protection

### J.7.1. Frequency of Updates

Inertial Labs™ regularly produces firmware and software updates for devices to enhance the user experience and repair any known issues with older firmware versions. Although it is the customer's responsibility to ensure their firmware/software version is up to date, we recommend checking for updates on a yearly basis. You may also check with our support team whenever a question arises regarding firmware updates by accessing our support portal at https://inertiallabs.atlassian.net/servicedesk/customer/portals.

### J.7.2. Backing Up Data

Your data is important, and whether it be through the internal datalogger on exclusive versions of the INS, or through a PC, backing up data will prevent losses or wasted time in trying to recover lost data. Save a backup every time a test is run to ensure that you can easily access it in the unfortunate event of data corruption.

### J.7.3. Monitoring Storage

The internal datalogger has a limited amount of internal memory that can be used for storing data. Although output functions will never be affected in real-time usage of the device, once the memory is full, data can no longer be stored to internal memory. Before every repeated trial, make it a common routine to check the internal storage of your device by accessing the internal datalogger. Information on monitoring, exporting, and acquiring data can be viewed in the INS User Manual, see Appendix I.

### J.7.4. Datalogger Security

For a more secure experience logging data, using a Virtual Private Network (VPN) is recommended. It will help protect against unwanted access to your device's valuable data. Other services such as anti-virus or malware protection are also available through subscriptions from outside parties to better suit your security needs.

## J.8. Repair and Replacement

### J.8.1. Warranty Information

Product information regarding warranty on replacement and product repairs is detailed in the Products Warranty Certificate that is issued with the product upon its delivery This document does not hold merit for defining warranty coverage, but is meant to summarize the policy. For detailed information, please see the Product Warranty Certificate. Inertial Labs™, Inc. warrants that all new parts purchased from Inertial Labs™, Inc. authorized distribution network, that have been purchased by a member of that network from Inertial Labs™, Inc., are free from design and manufacturing defects for a period of 12 months from the date of purchase, subject to the terms set out in the Products Warranty Certificate. Extended warranty periods are available, but only upon request by customer.

Inertial Labs
Attitude is Everything

Copyright © 2021 Inertial Labs - All Rights Reserved