The systems of families iNAV / iDIS are replaced since 2014 by our new designs iNAT, iTraceRT-MVT, iPRENA, iCOMBANA, iSULONA etc.

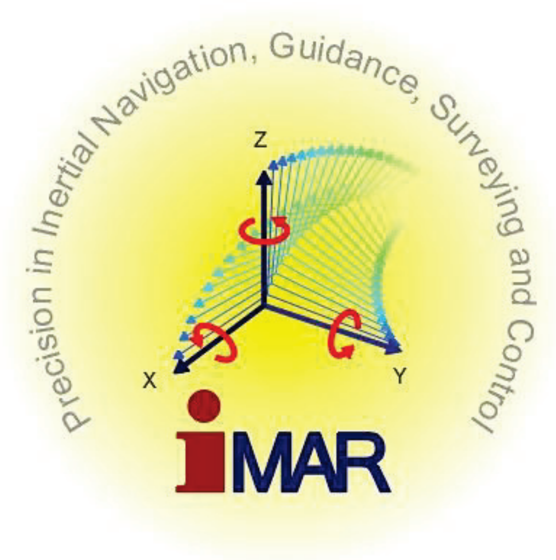
Please contact our sales engineers and have a look to our web pages.

Hardware ICD[1]

for

iNAV-FJI-001-J/Q
iNAV-RQH-100x
iNAV-FMS-E-DA
iNAV-FCAI-E-DA

Commercial in Confidence



iMAR GmbH
Im Reihersbruch 3
D-66386 St. Ingbert
Germany

www.imar-navigation.de

sales@imar-navigation.de

[1] Applicable for systems of type iNAV of 3rd generation, manufactured since 05/2011

Issued

Date	Name	Sign	Function
29.07.2011	MP / EvH	001	DE / HD

Checked

Date	Name	Sign	Function
29.07.2011	EvH	001	HD

Approved

Date	Name	Sign	Function
30.07.2011	EvH	001	AM

Table of Functions

Industrial / Industriell

CEO	Managing Director (Geschäftsführer)
PM	Production Manager (Fertigungsleiter)
HD	Head of Development (Entwicklungsleiter)
DE	Design Engineer (Entwicklungsingenieur)
CUST	Customer (Kunde)
QM	Quality Manager (Qualitätsmanagementbeauftragter)
QA	Quality Assurance (Qualitätssicherung)

Aviation / Luftfahrt

AM	Accountable Manager
HoA	Head of Office of Airworthiness (Leiter Musterprüfleitstelle)
PM	Production Manager (Fertigungsleiter)
HD	Head of Design (Entwicklungsleiter)
DE	Design Engineer (Entwicklungsingenieur)
CVE	Compliance Verification Engineer (Musterprüfingenieur)
HoD	Head of Design Organisation
CUST	Customer (Kunde)
QM	Quality Manager (Qualitätsmanagementbeauftragter)
QA	Quality Assurance (Qualitätssicherung)

CHANGE RECORD

Date	Issue	Paragraph	Comments
27.07.11	1.0	All	New Document created, updated to iNAV system updated architecture (base taken from iNAV-RQH user manual, rev. 2.71, those created in 03/2001 and updated untl 06/2011)
29.07.11	1.01	12	Notice regarding STEP files added

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LIST OF FIGURES

LIST OF TABLES

Related Documents

Name	Content	DocNumber
ICD_iNAV-1553B	ICD MIL-STD-1553B Interface of iNAV Systems	DOC100425002
MAN_NavCommand	Manual NavCommand Software	DOC090814002
MAN-iNAV_IMS_Operation_with_XIO	XIO open interface description	DOC091204003

1 INTRODUCTION

iNAV is a product family of one of iMAR's Inertial Navigation and Surveying Systems for inertial navigation, surveying, guidance, stabilization, control, gyro compassing and dynamically motion measuring equipped with fiber optic or ring laser gyros, which covers applications, which require accuracy, reliability and an open interface to the user.

This family consists of following systems:

- **iNAV-RQH-100x** Ring laser gyro based navigation system with highest gyro compass performance in autonomous and aided operation; ring laser gyros provide best long time bias and scale factor performance (< 0.002 deg/hr / < 5 ppm).
- **iNAV-FJI-001-J/Q** Fiber optic gyro based navigation system of class 0.01 deg/hr / 0.001 deg/sqrt(hr) with high gyro compass performance in autonomous and aided operation; silent operation.
- **iNAV-FMS-E-DA** Fiber optic gyro based system of class 1 deg/hr / 0.1 deg/sqrt(hr) with dual antenna GNSS for heading support; not export license required.
- **iNAV-FCAI-E-DA** Fiber optic gyro based system of class 1 deg/hr with low ARW (0.02 deg/sqrt(hr) and dual antenna GNS for heading support.

Details can be found in the related datasheets and product specification of these systems. All these systems have the same data interface and mechanical interface and hence are fully exchangeable.

Figure 1: iNAV-FJI-001 / RQH / FMS-E-DA / FCAI-E-DA

The iNAV systems. designed for advanced airborne, naval, AUV, UAV, ROV, surface and railway applications consist of three high precision ring laser (RLG) or fiber optic (FOG) gyroscopes, three servo accelerometers, a powerful strapdown processor, integrated GNSS receiver with 2 cm accuracy, up to 3 odometer interfaces and provide CAN and Ethernet and RS422/232 UART interface, optional MIL-STD-1553B bus interface, analog interface and offer an open and flexible user communication interface.

The iNAV systems are designed for commercial applications and are fully military qualified (MIL-STD-810F, MIL-STD-461E, MIL-STD-704D, partially DO160E with 50 ms hold-over time at power-interrupt) to meet highest reliability standards.

This document covers the operation of all above mentioned systems (named "iNAV" in the following chapters). Where necessary, specific explanations are made for specific systems.




The systems work with an external connected GPS receiver or they contain an integrated L1/L2 RTK/ GNSS receiver. The iNAV provides several additional interfaces for connecting aiding sensors like external (RTK)GPS or incremental encoders. Furthermore together with iMAR's iSCU (Stabilisation and Control Unit) the system can provide control output for antenna or camera stabilisation (gimballed platform with up to 3 axes) as an option, where the iSCU is connected to the iNAV via CAN interface. The data interface to an external control computer is Ethernet 100BaseT (UDP, TCP/IP) and/or RS232/RS422 UART. Additional an internal flashdisk (8…32 GByte) can be provided as an option to store all desired data during operation and to allow a post-processing and to log real-time results and other mission information. A CAN interface is also available as an option for real-time data output (up to 1 MBit/s baud rate).

Figure 2: iNAV-RQH on a Transall C-160, integrated in the German Airforce' Synthetic Aperture Radar (DOSAR)

Figure 3: iNAV-FJI on a DO-128, TU-BS / Germany

The user software NavCommand allows the user a full control of the system as well as data storing and to perform maintenance activities (e.g. download of stored data). NavCommand is operable on all standard MS Windows platforms (XP / VISTA / Windows 7). With the software iWP+ furthermore a powerful post processing tool is available for advanced surveying applications.

The iNAV systems offer an open user interface. With this XIO-interface, the user has access to all important internal data structures of the navigation system like sensor raw data, earth rate compensated rates and gravity compensated accelerations, data of external sensors etc. with an internal update frequency of up to 1'000 Hz at iNAV-FJI or 300 Hz at iNAV-RQH or 400 Hz at iNAV-FMS and iNAV-FCAI.

Each data packet can have a time stamp in relation to the IMU time or the GPS time (UTC or second of day). Lever arm corrections can be activated with special commands to transform the center of navigational calculation to a so-called virtual measuring point. A LabView DLL is available on request for those users which want to integrate the command interface into their own software.

The housing is precision machined, screwed and glued. It is water resistant according to IP67 if the cap is mounted using the sealing ring. The connectors of type Amphenol MIL-C-38999 Series III are standard. The sensor mount is not decoupled from the housing by shock-mounts to provide highest angular accuracy, but on request the system can be equipped by the user with outside mounted shock absorbers to prevent damaging the inertial sensors during rough handling.

The iNAV systems can be delivered with an integrated high performance L1/L2-RTK-(GNSS (GPS / GLONASS / GALILEO) receiver. This and the high sampling rate together with its open interface architecture makes the iNAV systems the unique solution for all high precision surveying, navigation and control.

CAUTION: *The iNAV systems are high precision inertial measurement systems. Nevertheless the internal sensors are shock mounted (resistant according to MIL-STD-810F), extreme shock shall be avoided.*

2 SPECIFICATION

2.1 ☐ iNAV-RQH-10018

The system iNAV-RQH-10018 fulfils the following specification (1 sigma):

Data Output:	Heading, Roll, Pitch, Angular Velocity, Velocity (body and world), Position, Raw data, internal status information, odo and GPS inf.	
True Heading:	< 0.025° sec(lat) free inertial; 0.01° with DGPS, 0.005 ° postproc RTK	
Attitude Accuracy:	< 0.01° free inertial (< 0.005° with DGPS, 0.002° postproc with RTK aiding)	
Position Accuracy:	0.6 nm/hr free inertial; < 1 m GPS (S/A off) and < 10 cm RTK online, < 30 cm DGPS and 2 cm RTK/INS postproc, < 0.1 % distance travelled (with odometer and GPS, applic. depend.) < 0.2 % dist.trav. on underwater vehicles (incl. RDI DVL interface)	
Velocity Accuracy:	5 mm/s (aided with L1/L2 RTK GPS receiver, < 2 mm/s postproc RTK)	
Alignment Time:	< 10 minutes on-shore, < 25 minutes off-shore	
Range:	± 400 °/s (no angle limitation)	±20 g
Drift (unaided)/Offset:	< 0.002 °/hr	< 25 µg
Bias Stability:	< 0.002 °/hr (const. temp.)	< 10 µg
Random Walk / Q:	< 0.0015 $°/\sqrt{h}$	< 8 µg/sqrt(Hz)
Resolution:	0.0003 ° (1,13"), < 0.001 °/s	< 5 µg (depends on data rate)
Scale/Linearity Error:	< 5 ppm / < 5 ppm	< 100 ppm / < 20 µg/g²
Axis Misalignment:	< 25 µrad	
Data Output Rate:	1...300 Hz, internal bandwidth 300 Hz	
Data Latency:	< 2 ms (sampling accuracy better 1 µs, time-stamped according to PPS)	
Data Storage:	8 GByte on internal flash drive	
Data Output (options):	RS232/422, Ethernet TCP/IP, ☐ PIO, ☒ NLOG, ☒ UDP, ☒ CAN ☒ MIL-STD-1553B bus	
Inputs (options):	- integrated GPS: RTK-GPS/GLONASS L1L2 (NovAtel) - external GPS: none - Marker event trigger input - 3 x Odometer input (opto-coupler A/B), PPS/SYNC (RS422 level) - Others:	
Synchronization:	Input for pulse-per-second [PPS, SYNC], opto-coupler input 4…36 V, 6 mA	
Marker Input:	4…36 V, 6 mA, opto-coupler input (option)	
PPT output:	TTL and RS422 level output (option)	
Shutdown input:	4…34 V, 6 mA, opto-coupler input (option)	
Power:	11...34 V DC, < 45 W	
Connectors:	according to MIL-C-38999-III	
Temperature (case):	-40...+71°C operating, -56...+85°C not operating	
Magnetic. Insensitive.:	< 500 µTesla (5 Gauss)	
Rel. Humidity:	8...100 %, IP67	
MTBF / MTTR:	> 25,000 hrs (estimated for surveying appl.) / < 30 minutes	
Shock, Vibration:	25 g, 11 ms ;60 g, 5 ms (operating); 20…2000 Hz, 3 g rms	
Weight:	approx 9.8 kg	
Total Size:	approx. 360 x 213 x 179 mm or 299 x 213 x 179 mm	
Qualification:	MIL-STD-810F, MIL-STD-461E, MIL-STD-704D, DO160E	
Software:	online INS/GNSS navigator, NavCommand, open I/F XIO, iWP+ INS/GNSS post-processing	

2.2 ☐ iNAV-FJI-001-Q

The system iNAV-FJI-001-Q fulfils the following specification (1 sigma):

Data Output:	Heading, Roll, Pitch, Angular Velocity, Velocity (body and world), Position, Raw data, internal statuis information, odo, GPS inf.	
True Heading:	< 0.1 deg sec(lat) pure inertial, < 0.01 deg with DGPS (motion dependent) < 0.005 deg postproc with RTK	
Attitude Accuracy:	< 0.01 deg pure inertial (< 0.005with DGPS), 0.002 deg postproc	
Position Accuracy:	< 3 nm/hr unaided; < 1 nm/hr unaided, after 30 minutes aiding; < 0.3 m DGPS online, 2 cm RTK/INS postproc < 0.1 % distance travelled (with odometer and GPS, applic. depend.) < 0.2 % dist.trav. on underwater vehicles (incl. RDI DVL interface)	
Velocity Accuracy:	<10 mm/s (online, with DGPS aiding), < 5 mm/s in post-proc.	
Alignment Time:	< 10 minutes static (in-flight alignment capability), 25 minutes dynamic	
Range:	± 450 *) deg/s (no angle limitation) *) The INS shall be switched on while angular rate is < 150 deg/s	±7 g
Drift / Offset:		
stability:	< 0.003 deg/hr (const temp.)	< 5 µg (const. temp. [for ±2 g range])
unaided:	< 0.01 deg/hr (Over Temp. Range)	< 100 µg (OTR)
Random Walk / Q:	0.001 deg/$\sqrt{h}$	< 8 µg/sqrt(Hz)
Resolution:	< 0.1 µrad (0.02 "), < 0.001 deg/s	< 1 µg
Scalef./ Linearity.error:	< 30 ppm / 10 ppm	< 100 ppm / < 20 µg/g²
Axis Misalignment:	< 100 µrad	< 100 µrad
Data Output Rate:	1...1000 Hz	
Data Latency:	< 2 ms (sampling accuracy better 1 µs, time-stamped according to PPS)	
Data Storage:	8 GByte on internal flash drive	
Data Output (options):	RS232/422, Ethernet TCP/IP, ☐ PIO, ☒ NLOG, ☒ UDP, ☒ CAN ☒ MIL-STD-1553B bus	
Inputs (options):	- integrated GPS: RTK-GPS/GLONASS L1L2 (NovAtel) - external GPS: none - Marker event trigger input - 3 x Odometer input (opto-coupler A/B), PPS/SYNC (RS422 level) - Others:	
Synchronization:	Input for pulse-per-second [PPS, SYNC], opto-coupler input 4…36 V, 6 mA	
Marker Input:	4…36 V, 6 mA, opto-coupler input (option)	
PPT output:	TTL and RS422 level output (option)	
Shutdown input:	4…34 V, 6 mA, opto-coupler input (option)	
Power:	11...34 V DC, < 45 W	
Connectors:	according to MIL-C-38999-III	
Temperature:	☒ -10...+55 °C (operating, standard temp. range) ☒ -40...+55 °C (oper. with selected option of internal heating at low temp.) ☒ -40...+71 °C (operating with sligthly degraded specification) -40...+85 °C (storage)	
Magnetic insensitivity:	< 200 µTesla (2 Gauss)	
Rel. Humidity:	8...100 %, IP67	
MTBF / MTTR:	> 25,000 hrs (estimated for surveying appl.) / < 30 minutes	
Shock / Vibration:	25 g, 11 ms / 60 g, 5 ms (operating) ; 90 g , 11 ms survival / 20…2000 Hz, 3 g rms	
Weight:	approx 11 kg	
Total Size:	approx. 360 x 213 x 179 mm	
Qualification:	MIL-STD-810F, MIL-STD-461E, MIL-STD-704D, DO160E	
Software:	online INS/GNSS navigator, NavCommand, open I/F XIO, iWP+ INS/GNSS post-processing	

2.3 ☐ iNAV-FJI-001-J (no ITAR export restrictions)

The system iNAV-FJI-001-J fulfils the following specification (1 sigma):

Data Output:	Heading, Roll, Pitch, Angular Velocity, Velocity (body and world), Position, Raw data, internal statuis information, odo, GPS inf.	
True Heading:	< 0.1 deg sec(lat) pure inertial, < 0.01 deg with DGPS (motion dependent) < 0.008 deg postproc with RTK	
Attitude Accuracy:	< 0.02 deg pure inertial (< 0.01deg with DGPS), 0.005 deg postproc	
Position Accuracy:	< 3 nm/hr unaided; < 1 nm/hr unaided, after 30 minutes aiding; < 0.3 m DGPS online, 2 cm RTK/INS postproc < 0.1 % distance travelled (with odometer and GPS, applic. depend.) < 0.2 % dist.trav. on underwater vehicles (incl. RDI DVL interface)	
Velocity Accuracy:	<10 mm/s (online, with DGPS aiding), < 5 mm/s in post-proc.	
Alignment Time:	< 10 minutes static (in-flight alignment capability), 25 minutes dynamic	
Range:	± 450 *) deg/s (no angle limitation) *) The INS shall be switched on while angular rate is < 150 deg/s	±7 g
Drift / Offset:		
stability:	< 0.003 deg/hr (const temp.)	< 20 µg (const. temp. [for ±2 g range])
unaided:	< 0.01 deg/hr (Over Temp. Range)	< 160 µg (OTR)
Random Walk / Q:	$0.001\ deg/\sqrt{h}$	< 15 µg/sqrt(Hz)
Resolution:	< 0.1 µrad (0.02 "), < 0.001 deg/s	< 1 µg
Scalef./ Linearity.error:	< 30 ppm / 10 ppm	< 160 ppm / < 20 µg/g²
Axis Misalignment:	< 100 µrad	< 100 µrad
Data Output Rate:	1...1000 Hz	
Data Latency:	< 2 ms (sampling accuracy better 1 µs, time-stamped according to PPS)	
Data Storage:	8 GByte on internal flash drive	
Data Output (options):	RS232/422, Ethernet TCP/IP, ☐ PIO, ☒ NLOG, ☒ UDP, ☒ CAN ☒ MIL-STD-1553B bus	
Inputs (options):	- integrated GPS: RTK-GPS/GLONASS L1L2 (NovAtel) - external GPS: none - Marker event trigger input - 3 x Odometer input (opto-coupler A/B), PPS/SYNC (RS422 level)	
Synchronization:	Input for pulse-per-second [PPS, SYNC], opto-coupler input 4…36 V, 6 mA	
Marker Input:	4…36 V, 6 mA, opto-coupler input (option)	
PPT output:	TTL and RS422 level output (option)	
Shutdown input:	4…34 V, 6 mA, opto-coupler input (option)	
Power:	11...34 V DC, < 45 W	
Connectors:	according to MIL-C-38999-III	
Temperature:	☒ -10...+55 °C (operating, standard temp. range) ☒ -40...+55 °C (oper. with selected option of internal heating at low temp.) ☒ -40...+71 °C (operating with sligthly degraded specification) -40...+85 °C (storage)	
Magnetic insensitivity:	< 200 µTesla (2 Gauss)	
Rel. Humidity:	8...100 %, IP67	
MTBF / MTTR:	> 25,000 hrs (estimated for surveying appl.) / < 30 minutes	
Shock / Vibration:	25 g, 11 ms / 60 g, 5 ms (operating) ; 90 g , 11 ms survival / 20…2000 Hz, 3 g rms	
Weight:	approx 11 kg	
Total Size:	approx. 360 x 213 x 179 mm	
Qualification:	MIL-STD-810F, MIL-STD-461E, MIL-STD-704D, DO160E	
Software:	online INS/GNSS navigator, NavCommand, open I/F XIO, iWP+ INS/GNSS post-processing	

2.4 ☐ iNAV-FMS-E-DA (no export restrictions)

The system iNAV-FMS-E-DA fulfils the following specification (1 sigma):

Measurement parameters:	Roll, pitch, yaw, acceleration, velocity, rate, position	
Measurement range:	± 450 °/s angular rate ± 10 g acceleration (5g / 20 g as option)	
Accuracy:	< 0.1 ° true north (with GPS/GNSS under motion – no gyro compassing capability) 0.1 ° true north with dual-antenna GPS and 5 m antenna distance < 1 °/hr heading drift (during outages of GPS) < 0.1 ° roll/pitch (initially after power-on) < 0.05 ° roll/pitch (INS/GPS under dynamic flight conditions) < 0.03 ° roll/pitch (INS/GPS under static flight conditions)	
Position error:	< 10 m with GPS (S/A off) < 1 m with DGPS, Omnistar supported [< 10 cm RTK mode option]	
Velocity error:	< 0.1 m/s (aided with DGPS)	
Alignment duration:	< 1 minute on land (for roll pitch inertially, heading by dual-antenna GPS) < 4 minutes on the fly with GPS aiding	
Resolution:	0.1 arcsec (roll/pitch/yaw) /	< 50 µg (accel.) (averaged)
Nonlinearity:	< 300 ppm (gyro)	< 100 µg/g² (accel.)
Scale factor error:	< 500 ppm (gyro)	< 1'500 ppm (accel.)
AngularRandomWalk / Accel. Noise:	0.1 deg/sqrt(hr)	100 µg/sqrt(Hz)
Bias repeatability:	0.75 deg/hr (1 sigma)	2 mg (1 sigma)
Dynamics capability:	> 1'500 °/s²	
Axis misalignment	< 200 µrad	
Sampling rate; Output rate:	400 Hz; 1...400 Hz (Ethernet, CAN, MIL-Bus)	
Latency:	< 3 ms (time stamp ±10µs)	
Data output (options):	RS232/422, Ethernet TCP/IP, ☐ PIO, ☒ NLOG, ☒ UDP, ☒ CAN, ☒ MIL-STD-1553B bus	
Data input (options):	internal/external (RTK)GNSS, marker event trigger, 3 x odometer, (RS422 level), [PPS / SYNC]	
GNSS aiding:	integrated L1/L2 GPS/GLONASS/GALILEO receiver, dual antenna	
Weight:	approx. 9.5 kg	
Size:	approx. 360 x 213 x 179 mm or 299 x 213 x 179 mm	
MTBF:	> 20,000 hrs (estimated for surveying applications)	
Temperature:	-40...+71 °C operating and -45…+85 °C storage (case temper.)	
Shock, Vibration:	25 g, 11 ms; 60 g, 5 ms; 3 g rms 10…2'000 Hz endurance	
Qualification:	MIL-STD-810F, MIL-STD-461E, MIL-STD-704D, DO160E	
Power supply:	11...34 V, < 50 W; 50 ms hold up time according to DO160E	
Software:	online INS/GNSS navigator, NavCommand realtime, open I/F XIO, iWP+ postproc	

2.5 Summary of Factory Set Features

The iNAV system for the customer named on the front page of this document is configured (factory settings) according to the following list. To understand details of it, please first read the other chapters of this manual and the NavCommand manual.

1. ☒ The PPS is fed from the internal GPS receiver to the IMU processor electronics and to the output connector. Inside of the housing of the iDIS-FMS there is a switch which can be used to feed PPS and external GPS to the processor.
2. ☒ The delivered system is equipped with CAN bus to support an operation at the user without requiring programming.
3. ☐ PIO interface is installed
4. ☒ NLOG interface is installed (NMEA data output)
5. ☐ Analog output is implemented (10 channels)
6. ☐ Analog input is implemented (8 channels)
7. ☒ Data transmission via Ethernet / TCP/IP for fast digital dat a storing on user's laptop is implemented
8. ☒ UDP protocol is installed
9. ☐ iDRPOS algorithm for dead reckoning is implemented
10. ☒ Data Flash Drive installed (8 GByte)
11. ☒ PPT output is implemented (pulse per time)
12. ☐ PPD output is implemented (pulse per distance, odometer based)
13. ☒ Marker input is implemented
14. ☐ Odometer input is implemented
15. ☒ RTK-GNSS (GPS and optional additional GLONASS / GALILEO)
16. ☒ L1L2-GNSS (GPS and optional additional GLONASS / GALILEO)
17. ☒ Omnistar aiding capability for GNSS applied
18. ☒ Advanced INS/GPS Kalman filter
19. ☐ Interface via CAN to iSCU implemented
20. ☐ HPST² mode is implemented
21. ☐ RDI DVL interface implemented
22. ☐ MIL-STD-1553B interface
23. ☐ CDU Control & Display Unit
24. ☐ Shut-Down digital input line to stop data storing of measurement data inside the iNAV system and controlled power-down of the system before performing a power-off
25. ☐ Customized features: ________________________________

For details in using these features please refer to the NavCommand manual.

3 USAGE OF THE SYSTEM

3.1 Inventory

The iNAV system will be delivered together with a set of lab cables. These cables can be used to supply the power to the system and to setup the communication with the customers computer (RS232, RS422, Ethernet). Also external sensors like GPS receivers, Doppler velocity logs or odometers can be connected using this cables. An integrated GPS engine can be included .

Also a MIL-STD-1553B interface (one dual redundant channel, transformer coupled) can be integrated as an option.

Nota: The set of delivered lab cables must not be used to integrate the iNAV into the application. It is useful to have these cables available e.g. if the system has to be recalibrated later or if some changes shall be made at the factory. Due to the fact that every iNAV system may have customer specific interfaces, these cables must be sent together with the iNAV system to the factory in Germany, if service is to be performed at iMAR.

3.2 Getting Started

The open XIO interface allows the customer to fully integrate the iNAV into his application.

To get iNAV system started first time without the need of interface adaptation/programming at the customer, some test software is delivered together with the system.

Connect the odometer to the A/B input port (4...30 V opto-coupler) and install the GPS antenna on your vehicle.

3.3 Standard users

Use the software NavCommand (Windows). See the additional documentation.

The NavCommand documentation describes the usage of the software and defines the available data logs and operational modes.

For autonomous operation (without NavCommand, i.e. direct commanded by the user via XIO interface or MIL-STD-1553B bus interface), beside of the full control by the user, the system provides two automated control schemes, which are described in detail in chapter 7). Powerful integrated state machines are provided to allow the standard user a simple operation of the iNAV system.

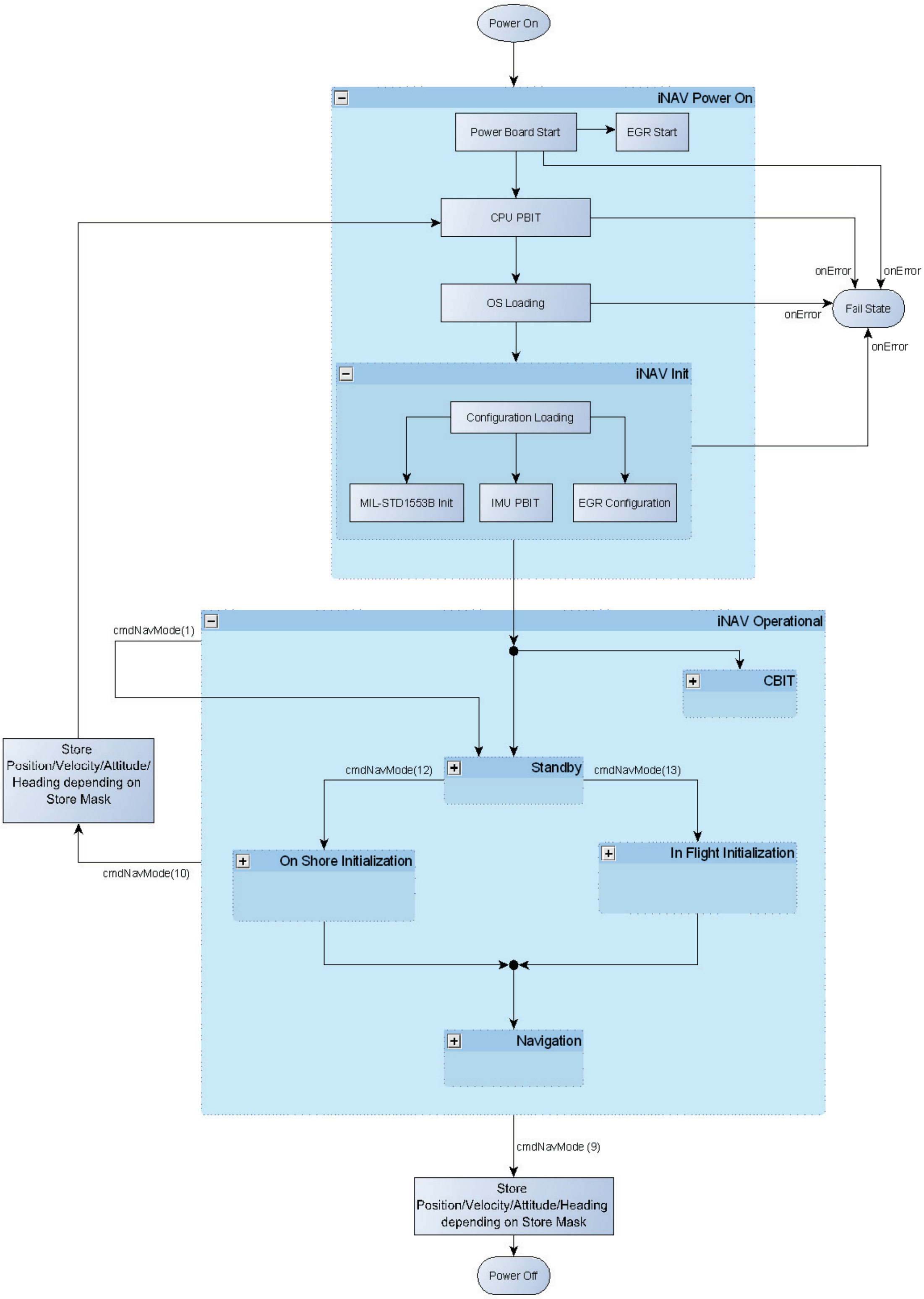

Figure 4: Operational State Diagram for Simplified Mode Control

3.4 Advanced users and system programmers

The advanced user has full access to the iNAV system. He can access to calibrated and raw data, to all internal status information and can even adjust Kalman filter parameters if desired.

Connect the iNAV system via an Ethernet link (RJ45 connector) [make sure that your PC IP address is set to the same network address area (but not the same routing address to avoid conflicts according to Ethernet network standards!) which is used by the iNAV system or via the serial port 1 and a crossed RS232-cable (2,3,5) to an external laptop and start the program XIO.EXE. After the connection is established between the XIO program and the iNAV system one can enter so called XIO commands by text and transmit them to the IMS. Also the full internal system configuration is accessible using simple tree structures.

To allow the user to integrate the INS into it's own application, a set of C/C++ header files defining the XIO protocol can be delivered. Also a fully functional sample application showing the basic communication capabilities is delivered as source code for MS Windows® and GNU/LINUX. A DLL for integration of the XIO protocol into NI LabView® environment is available on request.

The following two chapters give some general hints on using the INS. For a detailed view on the INS operation please refer to the chapter **Operational Concept**.

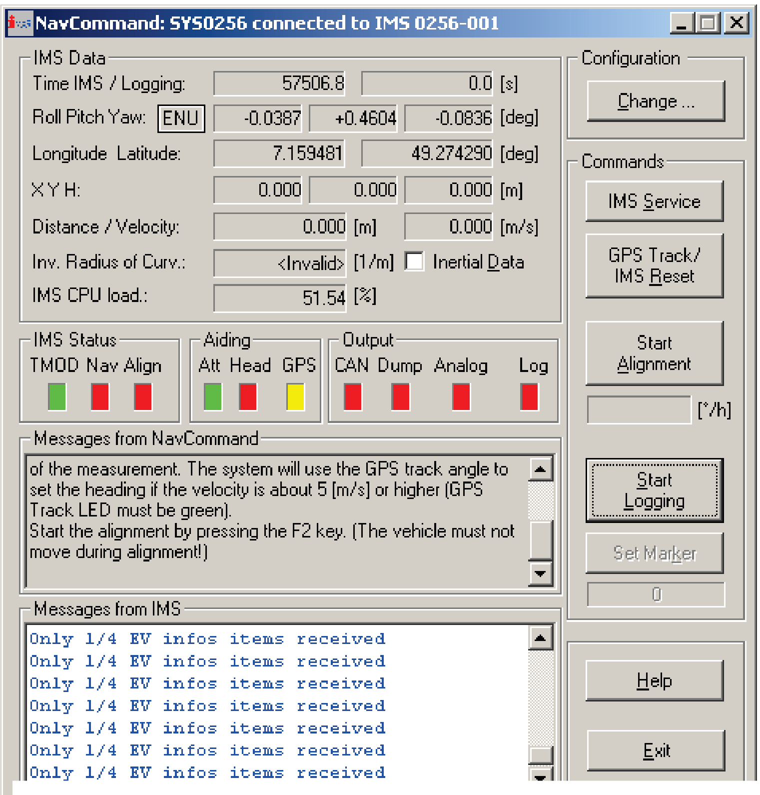

Figure 5: NavCommand GUI

3.5 Start Value Acquisition / Alignment

After power-on and sensor initialization, the iNAV system has to perform a start value acquisition before it can deliver valid navigation data. Position and velocity can be determined by the integrated GPS receiver or set on the user interfaces or taken from stored values obtained from the last mission. Roll and pitch is determined be levelling using the accelerometers. The iNAV-FJI and iNAV-RQH can determine the heading by performing a north seeking (gyro compassing) using an integrated Kalman filter algorithm (duration at standstill is 10…15 minutes and in-flight up to 20 minutes). The iNAV-FMS-E-DA and iNAV-FCAI can determine the heading from the integrated 2 antenna GPS solution or from motion together with GPS.

The start value acquisition/alignment procedure can be activated automatically after power-on or started manually by commands sent on one of the communication interfaces (XIO, PIO, MIL-STD-1553B). Also the NavCommand software can be used for this.

3.6 Measuring / Navigation / Surveying / Guidance

After the start value acquisition is successfully performed, the system switches to navigation mode where it continuously calculates the attitude/heading (Eulerian angles roll, pitch and yaw, quaternion etc.), position referenced to WGS84 coordinate system and velocity referenced to the local level frame (East, North, Up or North, East, Down). Also earth rate compensated rotation rates and gravity compensated acceleration can now be supplied to the user. The raw data as well as the processed data can be transmitted via Ethernet (10/100/1000BaseT), RS232/422 UART or CAN bus. The data rate is limited by the INS data sampling rate and the bandwidth of the transmission channel. Also all data can be stored on an internal flash-disk (up to 16 GByte as an option).

A post processing software iWP+ can be provided on request to achieve highest accuracy using raw GNSS data and performing a forward/backward calculation (requires raw data storing on the internal flash drive or online raw data transmission to an external computer).

3.7 Access to the IMS's file system using the SMB protocol

Using the SMB protocol (integrated in all MS Windows® systems, under Unix/Linux systems available by the SAMBA software) the user can access the internal file system of the IMS. This is helpful for downloading data files collected during the mission on the internal flash drive or to backup the IMS configuration files. Also updates of the IMS system software are accomplished by copying the new software to the IMS file system. The access to the internal file system is fully supported by the NavCommand software and described in the manual of that software.

3.8 Definition of Euler Angles

The IMS uses the following definition of Euler angles roll, pitch and yaw for rotational transformations between two arbitrary orthogonal coordinate systems (x,y,z) and (X,Y,Z):

1) Rotate yaw around the Z axis, until the X axis is in coincidence with the projection of the x axis into the X-Y plane -> new frame (R,S,Z)
2) Rotate pitch around the S axis to get the R axis parallel to the x axis -> new frame (T,S,U), where T = x

3) Rotate roll around the T (=x) axis to bring the S axis parallel to the y axis (which automatically rotates the U axis into the z axis) -> new frame (T,V,W) = (x,y,z)

The order of rotation (yaw -> pitch -> roll) is essential in this definition.

It should be noted that the IMS navigation algorithm does not use the Eulerian angles for it’s internal calculations. They are only used for input and output.

3.9 Definition of Coordinate Frames

Several coordinate systems are used. They are explained in the following.

- Platform Coordinate System: This is the coordinate system of the Inertial Measurement System with its inherent coordinate axes: x, y, z
- Body Coordinate System: This is the coordinate system of the aircraft. We define x in forward direction, y in left direction and z in down direction.
- Local Levelled Coordinate System: it is also called “Navigation Frame” and is defined by its x axis to North, its y axis to East and its z axis downwards (NED)
- Geographical Coordinate System: it is defined by the geoid of the earth and it is not local levelled; also the height is different to those of the “Navigation Frame”
- ECEF Frame: The Earth Centred Earth Fixed Coordinate System is defined with its origin in the centre of the earth.

The IMS is measuring in the Platform Coordinate System. As the measurements shall be provided in the aircraft’s Body Coordinate System, a transformation can be parameterized inside the IMS firmware to transform all Platform data into Body data. These parameters are called “misalignment adjustment values” or “boresight correction values”. They are described by three angles (delta_roll, delta_pitch, delta_yaw).

The angles of the IMS in space will be calculated inside the IMS in a so-called East-North-Up co-ordinate system.

- The Navigation Frame can be an ENU or an NED frame:

	ENU	NED
x-axis	directed to East	directed to North
y-axis	directed to North	directed to East
z-axis	directed to Up	directed to Down

- IMU-co-ordinate system (PlatformFrame):
  - x-axis see label on the IMU's housing
  - y-axis see label on the IMU's housing
  - z-axis see label on the IMU's housing
- Vehicle's co-ordinate frame (BodyFrame):
  - x-axis longitudinal in vehicles forward direction
  - y-axis lateral direction, so that a right hand system is defined by x,y,z
  - z-axis upwards (land vehicles) or downwards (aircrafts)
- RPY-angles (rotation from NavigationFrame to BodyFrame to obtain the orientation of the BodyFrame in space, starting from the NavigationFrame):

  Yaw ψ: Align the start coordinate system with x to North, y to East, z to Down. Rotate this coordinate system by angle ψ ("Psi") around the z-axis of the NavigationFrame (start of rotation!).

Pitch θ: Rotate by angle θ ("Theta") around the y-axis of the current BodyFrame, which is already turned with ψ around the NavigationFrame-z-axis.

Roll ϕ: Rotate by angle ϕ ("Phi") around the x-axis of the current BodyFrame. Having done these consecutive rotations, you have aligned the BodyFrame now according to the three angles Roll, Pitch, Yaw.

The order of rotation is Yaw, Pitch, Roll (starting with the NavigationFrame co-ordinate system).

In NED the heading angle is zero if the BodyFrame's x-axis directs to North (and heading value increases clockwise). In ENU the heading angle is zero if the BodyFrame's x-axis directs to East (and heading value increases counter-clockwise).

3.9.1 Example: NED output for airborne applications

If required by the application, a transformed output is used. The output coordinate system can be e.g. defined in NED (North-East-Down):

With the selection of output data logs the user has the possibility to get data in ENU as well as in NED co-ordinate system.

The MIL-STD-1553B implementation will provide data in NED (north-east-down).

The following figure shows the coordinate system definition:

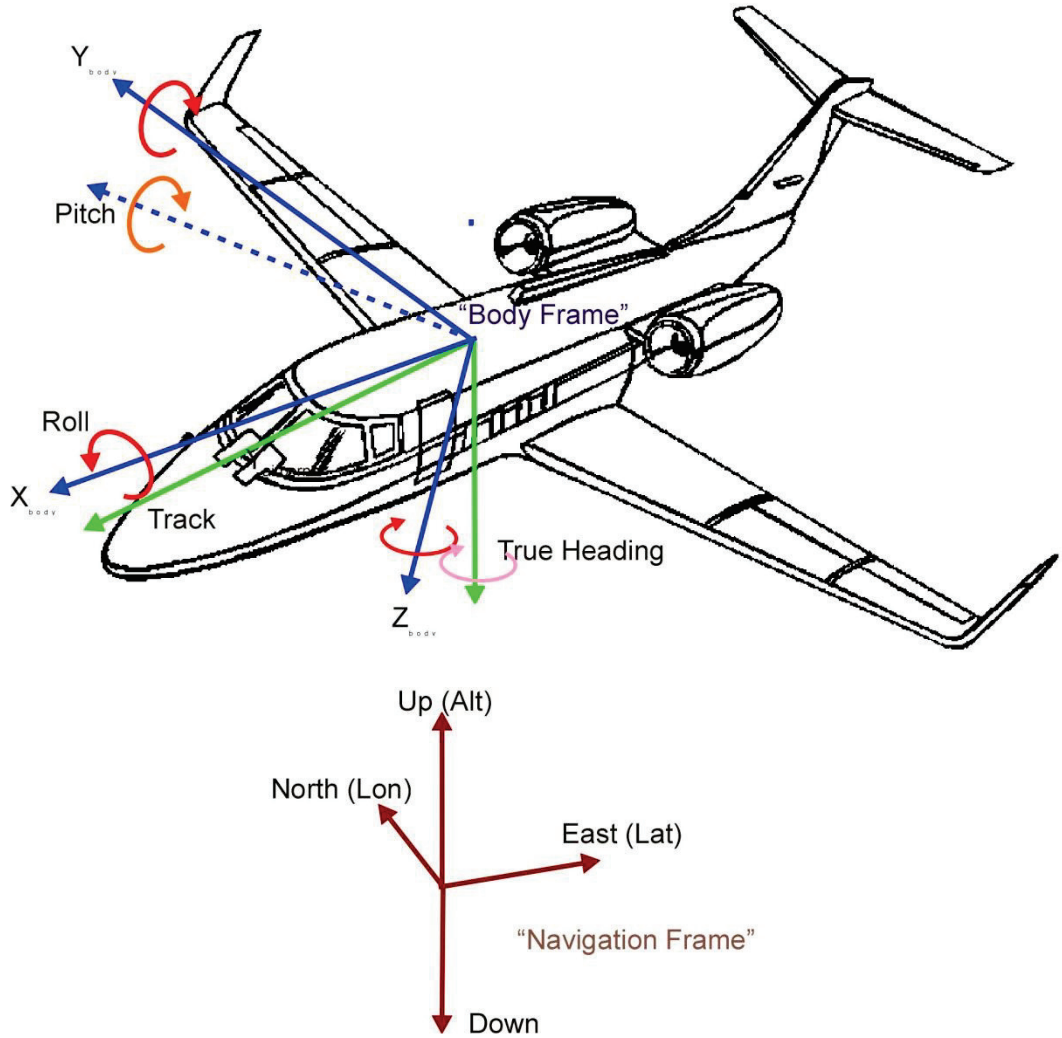

Figure 6: Definition of BodyFrame and NavigationFrame (Platform-Frame and ECEF not drawn)

The axes in the above figure (BodyFrame, perpendicular axes) show the direction of positive measured acceleration and the positive direction of angular rates.

The Pitch is measured according to its definition in the LocalLevelFrame (= Navigation-Frame).

The True Heading is measured according to its definition in the LocalLevelFrame. The True Heading is 0° if the nose of the aircraft is pointing to North and it is 90° if it is pointing to East.

The velocity in BodyFrame is positive if directed into the direction of the arrows (x, y, z).

The Track Angle (course over ground) is derived by atan2[velocity east / velocity north]. The Track Angle is 0° if flying to North and it is 90° if flying to East.

The “Altitude” output of the IMS is given in accordance to the WGS84 definition, i.e. the value increases if the distance of the vehicle to the centre of earth increases.

The “vertical speed” output of the IMS is a positive value, if the distance of the vehicle to the centre of earth is decreasing. (Attention: due to historical usage of NED coordinates in aircrafts it has to be recognized by the system integrator, that a <u>positive</u> vertical speed leads to a <u>de</u>creasing altitude according to the above given definition!).

The systems are designed for operation within ± 80 deg latitude. Flying over the pole requires specific system software (on request).

4 INERTIAL BRIEFING

To get highest performance of the iNAV systems, it is useful to understand the principle of operation of an inertial measurement system. To estimate the influence of measuring duration and motion on the measurement result, the following hints might be useful (numbers given here are for example only and depend on specific system):

- Gyro Drift: The gyro drift (in deg/h) gives an indication for the angular error over time. A drift of 0.002 deg/h means that the *unaided* system will drift in roll, pitch and yaw approx. with 0.002 deg/h (1 sigma, no extended motion) if no other error sources would be present.
- Gyro Scale Factor Error: It gives an indication about the angular error due to change of angles. I.e. if the scale factor error is 10 ppm and the heading of the vehicle is changing over 180 degree, then the heading error due to scale factor error is 10E-06 x 180 deg = 0.0018 deg due to this error source.
- Acceleration accuracy: A main error source is the imperfect gravity compensation on the accelerometers due to accelerometer sensor and roll and pitch errors. A roll error or a pitch error of 0.005 deg leads to an acceleration error on the horizontal axes (x and y) of 0.1 mg., i.e. g x sin(0.005 deg) = 10E-4 g = 0.001 m/s². This error can be reduced by using external information to aid the internal Kalman filter. Gravity models as well as the knowledge of depth are used to perform best error compensation.
- Heading Accuracy: The optical gyros inside of the iNAV- FJI allow to perform an autonomous north seeking with high accuracy. This heading gets worse over time (with the gyro drift) if no aiding is available. If the vehicle's dynamics is measured by the inertial measurements together with GPS and/or other position / velocity updates, this allows the integrated Kalman filter to provide best heading accuracy mostly independent of the duration of the mission. A heading error (or better said: a track angle) error of 0.057 deg (1 mil, 1 mrad) leads to a position error of 1 m over 1'000 m or of 100 m over 100 km distance (here for simplification a constant heading error is assumed).
- Free Inertial Navigation: If the INS is operating over a longer time without any additional aiding information (like external velocity or position updates), the INS is in free inertial navigation mode. In this mode the position and velocity error of the INS behaves similar to a harmonic function, which is called "Schuler Oscillation". The period of the oscillation is approx. 84 minutes. The position error increases approx. linear with time (instead of quadratically increase over the first minutes during free inertial navigation mode – the reason for that is the spherical contour of the earth). An example of such Schuler Oscillation is given in the next plot. The drift after 1 hour is called "free inertial position performance" and is in the area of 0.04 … 5 nm / hr, depending on the INS performance.

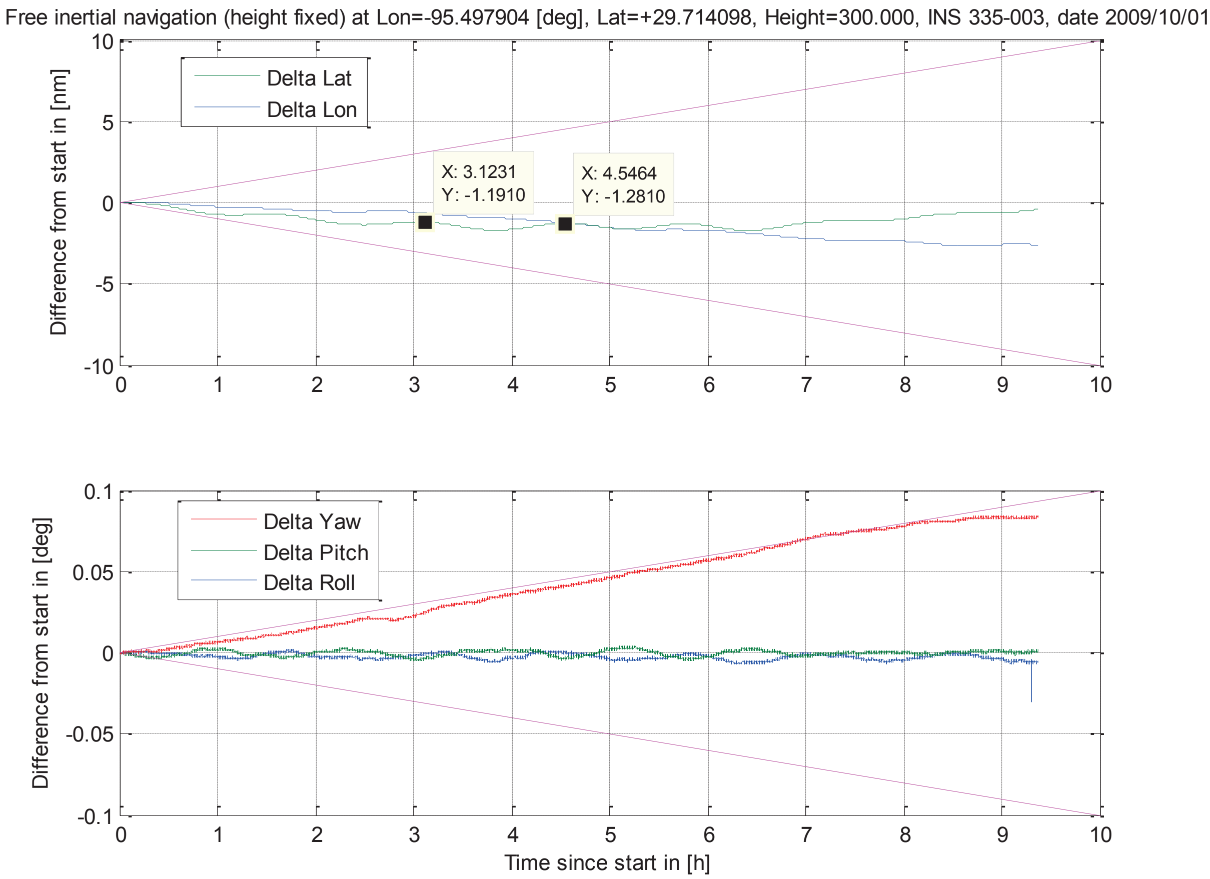

Figure 7: Schuler Oscillation damps the free inertial position error

5 MOUNTING, SYSTEM DIMENSIONS AND SYSTEM INSTALLATION

5.1 Mechanical Considerations

The iNAV system comes in a housing given in the drawing given in Section12. A careful mounting of the iNAV system is required to achieve highest navigation performance. Therefore, the usage of a mounting plate (an example is given in Section 12) is recommended (but not mandatory), where the iNAV system can be installed and removed without additional alignment errors.

It is recommended to use 2 (two) dowel pins, located on top of a mounting plate, to align the IMS accordingly. To achieve a mounting accuracy in heading of better than 1 mrad, the tolerance of the positioning of the dowel pins shall be smaller than 0.1 mm each (0.05 mm recommended).

The end-caps of connectors which will not be used are attached to the IMS housing by wires. Connectors which will be used are not protected by end-caps.

Attention: The INS is a high accurate measuring device. Strong shocks may result in sensor degradation or even damage.

5.2 GNSS Antenna Localization

For aircraft applications the GPS antenna shall be a FAA certified ARINC 743 antenna. It is highly recommended to mount the antenna

- close on top of a grounded metal plate, not smaller than 300 x 300 mm
- in sufficient distance to any SatCom antenna to avoid interference for GPS signal reception
- in sufficient distance to reflecting metal plates inside the field of view of the antenna to avoid disturbances induced by multi-path
- in an area where a sufficient view to the sky is possible (for elevation larger than 10 deg, outages (caused by obstacles etc.) should not happen permanently)

For surface or naval application a standard L1L2 GPS antenna (optionally including GLONASS / GALILEO / Omnistar) shall be used.

6 HARDWARE STRUCTURE

The structure of the system hardware is shown in the following figure. The internal bus structure is the so-called I-Bus (iMAR-Bus), which is designed to trigger

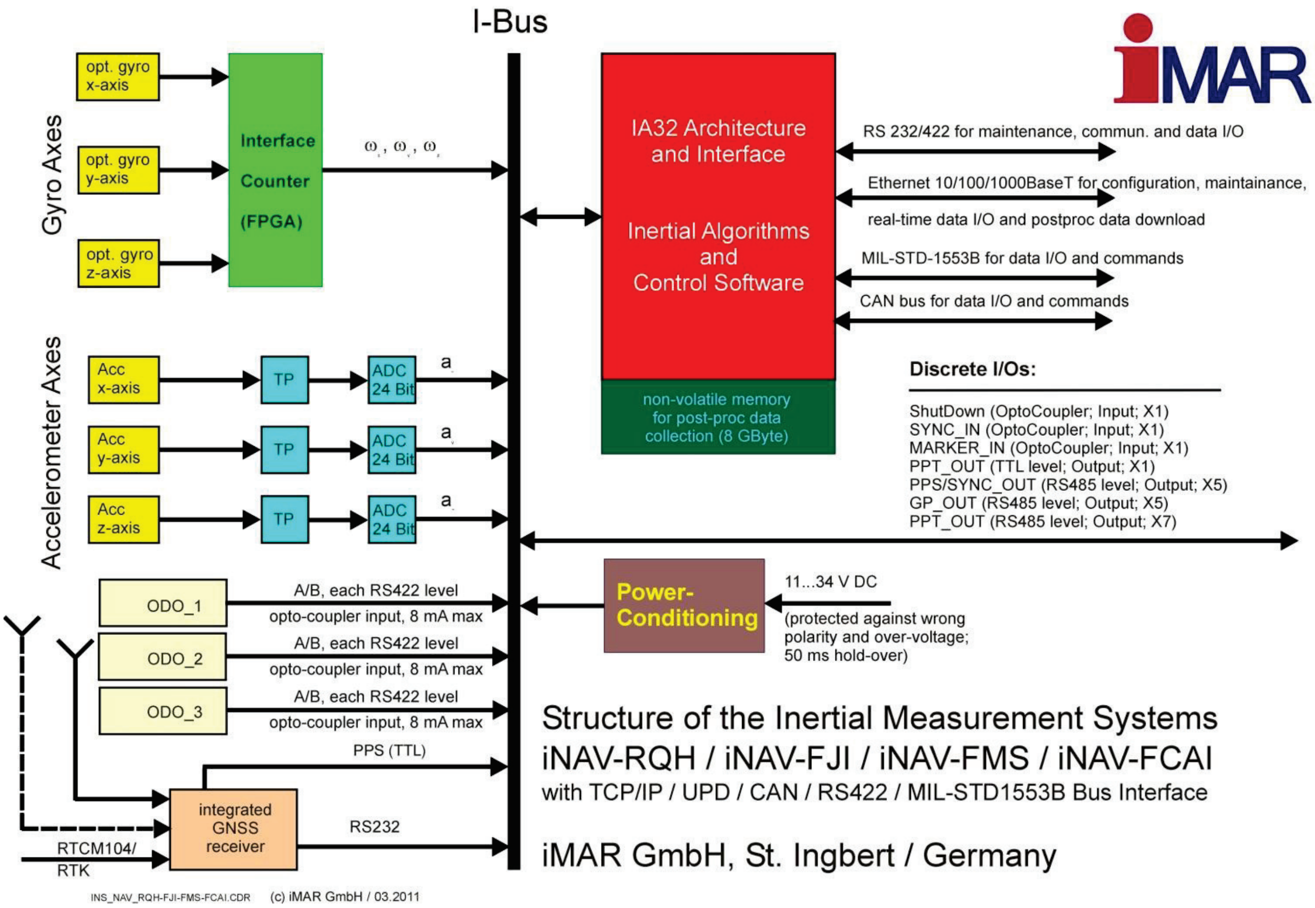

Figure 8: Block Diagram (© iMAR GmbH)

all inertial sensors at the same time. The external trigger (e.g. PPS), globally called "SYNC", can be generated by an integrated GPS receiver or an external source and is used to synchronize the internal clock which time stamps the inertial and all other I/O data on µsec level.

The processor operates with a multitasking real-time kernel used in industrial as well as in demanding military projects.

6.1 GROUND Definition

The system uses three separate GND networks:

- PGND: Power Ground, from power supply

