Inertial Products

Application Note

Mechanical Integration of Inertial Systems

IXBLUE
DEEP INSIGHT. SHARPER SENSES.

Document Revision History

Edition	Date	Comments
A	092011	First Edition
B	02/2012	Table 2 deleted, Marins & Quadrans products added
C	04/2013	iXBlue new style guide applied
D	10/2013	ATLANS product added
E	09/2014	Interface plate examples removed. Subsea products chapter added
F	02/2015	OCTANS NANO product added
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J	04/2017	Chapter 2 & 3 updated.

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Text Usage

bold	Bold text is used for items you must select or click in the software. It is also used for the field names used into the dialog box.
`Courier`	Text in this font denotes text or characters that you should enter from the keyboard, the proper names of disk Drives, paths, directories, programs, functions, filenames and extensions.
italic	Italic text is the result of an action in the procedures.

Icons

The **Note** icon indicates that the following information is of interest to the operator and should be read.

The **Caution** icon indicates that the following information should be read to forbid or prevent product damage.

The **Warning** icon indicates that possible personal injury or death could result from failure to follow the provided recommendation.

Abbreviations and Acronyms

Abbreviations and acronyms are described in the document *Inertial Products - Principle & Conventions (Ref.: MU-INS&AHRS-AN-003).*

Table of Contents

1 OBJECT

This document is an Application Note that describes the mechanical recommendations for installing an iXBlue Gyrocompass or Inertial Navigation System.

Do not hesitate to contact iXBlue technical support for further information: support@ixblue.com

2 INTERFACE PLATE DESIGN

2.1 Introduction

In order to install the system on a vehicle, an interface plate is needed between the Gyrocompass (resp. the INS) system and the vehicle structure to ensure good planarity of the surface and alignment pins are necessary to ensure mechanical mounting repeatability.

It is recommended to mark the mounting plate screw with paint after the measurement in order to help the end user for the commissioning activities.

2.2 Interface Plate Material

The interface plate material can be of two types:

- Stainless Steel (Young modulus: 200 GPa, Density: 8 g/cm^3)

The advantage of this material is its resistance to corrosion. The disadvantage in some cases is the high weight. With this material there is no need for screw inserts since material is very hard and there is no need for protective coating against corrosion. However planarity can be difficult to machine.

- Aluminum (Young modulus: 67 GPa, Density: 2.7 g/cm^3)

The advantages of this material are its light weight, low cost and ease of machining. The disadvantage is the necessity to put screw inserts for stainless steel screws due to softness of material and perform a hard corrosive grade protective coating (i.e., in conformance with specification IFREMER 31STOI-C).

2.3 Dimensions and Tolerances

The dimensions and tolerances are described hereafter:

Thickness The thickness is important to maintain sufficient stiffness to prevent any deformation due to external loads (vehicle deformation) that would induce roll, pitch or heading errors. As guidance we recommend a thickness of 20 mm approximately. Thickness will depend on plate size, material (aluminum or stainless steel) and loads that will be applied to the interface plate.

Stiffness To be independent of design parameters (interface plate size, material, load) the specification will be described in terms of stiffness requirement expressed in angle.

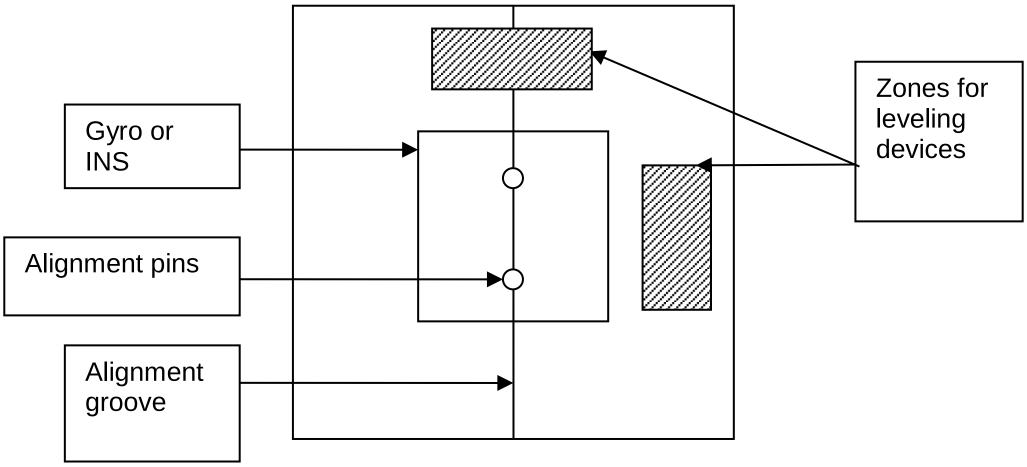
Planarity The planarity of the surface that is in contact with the base plate of the Gyro (resp. the INS) must be compatible with the planarity of the interface plate of the Gyro (resp. the INS). This is to avoid any mechanical constraint in the instrument base plate. Hence the planarity should be < 0.03 (mm/m).

2.4 Mechanical Elements for Aligning the Gyro (resp. INS) to the Vehicle Frame

On the interface plate we can add:

- Alignment groove: that indicates the alignment pins axis of the instrument, hence the gyro reference frame.
- Planarity zones: planarity specification can be applied over the total top surface of the interface plate so that electronic leveling instrument can be positioned on the interface plate to measure roll and pitch misalignment with respect to an horizontal reference plate that would be mounted nearby.

  The pins should preferably be mounted with no clearance in the interface plate to the vehicle. Refer to Section 7.2 for mechanical tolerance to achieve this.



2.5 Interface Plate Mounting to the Vehicle

Depending on the constraint of the application, the plate can be mounted directly onto the vehicle floor but this implies constraint on planarity of the vehicle floor. To relieve this constraint the interface plate can be held above floor with threaded rods and nuts on three points. We do not recommend soldering of the interface plate on the floor since the soldering process could deform the interface plate.

The interface plate should be mounted so that the Gyro (resp. the INS) heading direction, with respect to vehicle frame, is one of the following directions 0°, 90°, 180°, 270° approximately with respect to vehicle frame.

The interface plate should be mounted approximately horizontal to allow use of precise inclinometers that may have limited range (1°). This will minimize crosstalk calculations when measuring the Gyro (resp. the INS) misalignments with respect to vehicle frame (see Section 5).

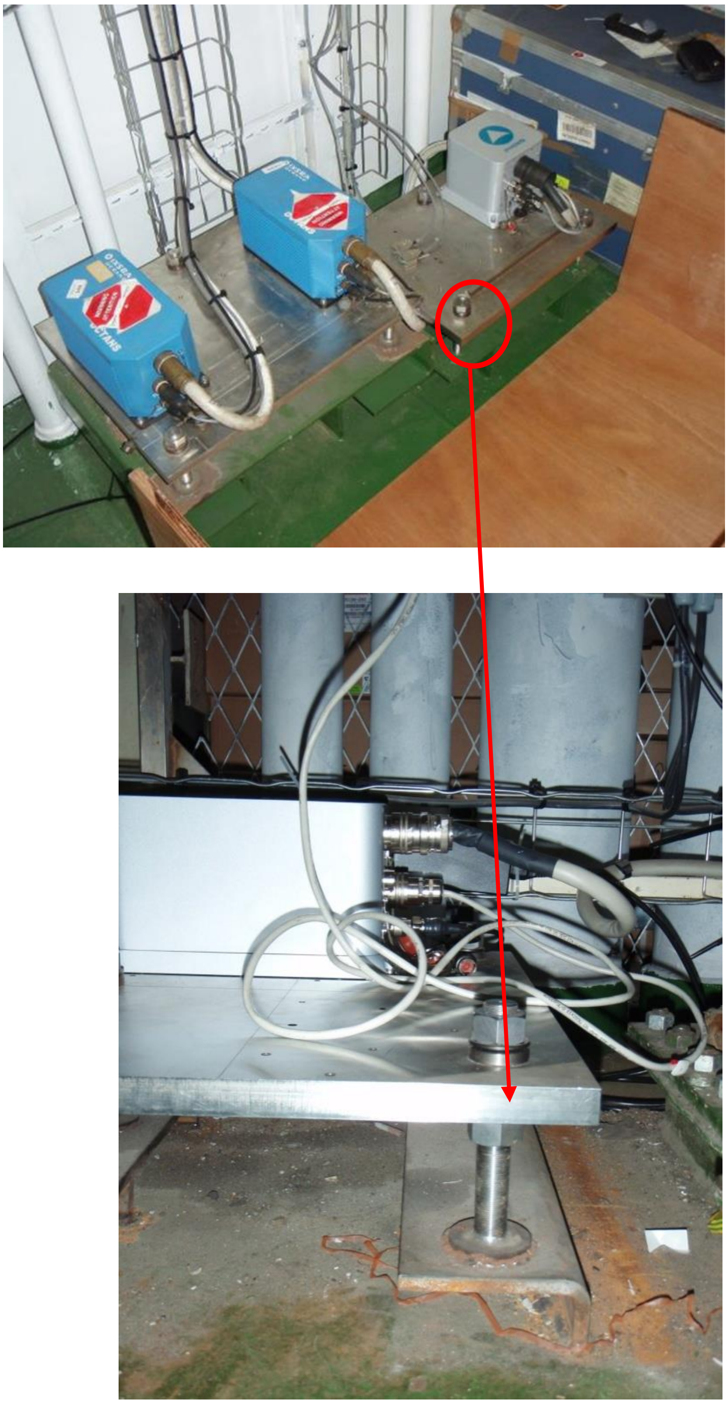


Figure 1 – Example of Mounting stainless steel plate with 3 nuts and bolts

Figure 2 - Installation in replacement of old mechanical gyro (retrofit):
Aluminum interface plate

3 MOUNTING RECOMMENDATIONS

3.1 Surface Products

Gyrocompass (resp. INS) must be placed and pushed against the alignment pins in the X2 direction (Arbitrary convention) to guarantee mechanical mounting repeatability (see Section 7 Heading Mounting Repeatability).

When MARINS is installed with the alignment pins, the same product can be removed and replaced without re-harmonization. When MARINS is installed with the mirror, an harmonization has to be reprocessed if the unit is swapped by another one (it stays the same if the same MARINS is unmounted and put back).

The example below shows a PHINS, but the mounting recommendations apply to all the surface products.

Alignment pins are pushed into the interface plate using a press since they are mounted with no clearance. In their center, they have a threaded hole to enable the extraction of the pin using a screw, in case a replacement is needed.

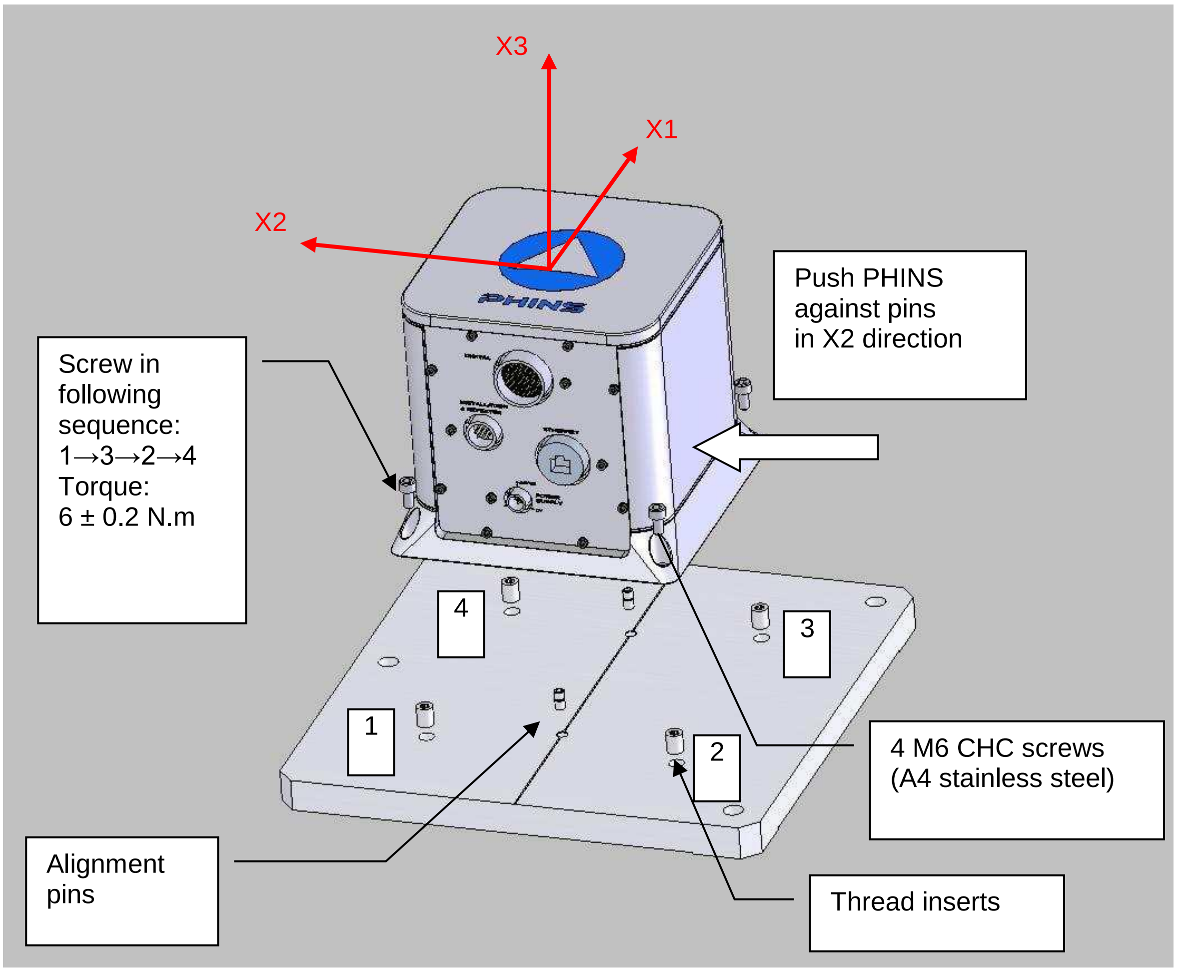


Figure 3 - Mounting of PHINS on interface plate

(example: Aluminum plate with M6 inserts)

This interface plate with alignment pins can be provided by iXBlue on request.
Contact your local sales representative.

For more information about the interface plate of your product, refer to:

- MU-MARPLATE-AN-001 for MARINS
- MU-MARPLATE-AN-002 Lightweight interface plate for MARINS M3 and MARINS M5
- MU-MARPLATE-AN-003 for MARINS M7
- MU-INSPLATE-AN-001 for PHINS/HYDRINS/AIRINS/OCTANS
- MU-QATPLATE-AN-001 for QUADRANS and ATLANS

3.2 Subsea Products

PHINS 6000 or ROVINS is fixed on the interface plate used to couple PHINS 6000 or ROVINS with the DVL using six CHC M6 screws.
Two centering pins fixed by press in the 5 H7 holes on the interface plate are provided for PHINS 6000/ROVINS alignment.
We recommend pushing PHINS 6000 or ROVINS against the pins in X2 direction (arbitrary choice) while securing the screws to insure mounting repeatability.
The DVL is fixed on interface plate using four M8 screws.
Two centering pins, inserted in 8 H7 holes, are provided for DVL alignment.
The whole assembly can be fixed onboard using 8 HM8-35 stainless steel screws, tightening couple should 18N.m for in stainless steel and 20N.m in aluminum.

For more information about the DVL option, refer to:

- PHINS 6000 Interface Control Document, ref.: MU-PHINS6G3-AN-021
- ROVINS Interface Control Document, ref.: MU-ROVINS-AN-021

For OCTANS NANO there are no centering pin holes on the product.
On the base plate of the product (left side of the product in X2 direction) there is a mechanical reference plane used in factory to calibrate the heading. This mechanical plane should be pushed in contact with 2 pins installed on the vehicle for best mechanical mounting repeatability.
For more information about the OCTANS NANO mechanical interface refer to OCTANS NANO User Manual (ref: MU-OCTNANO-AN-001) or OCTANS NANO Interface Control Document (ref. MU-OCTNANO-AN-012)..

4 INTERFACE TO VEHICLE REQUIREMENTS

4.1 Location of Gyro (resp. INS) System on the Vehicle

The location of the Gyro (resp. INS) should take into account the following recommendations:

- Fixed to the rigid structure of the vehicle (linked to main vehicle beams). Do not put it on a thin wall that can deform for instance.
- Located where vibrations are as low as possible. (Not in the Engine room for instance).
- Located in a temperature stabilized environment if possible.
- Located close to the equipment using the Heading, Roll, Pitch data. This to reduce any errors due to warp/torsion of the vehicle between the location of the Gyro (resp. the INS) and the location of the equipment.

4.2 Vehicle Basement Stiffness Requirements

The stiffness k is the resistance of the vehicle body to deformation. It is described by

$k = \frac{P}{\delta}$, where P is the applied force and δ the displacement produced by the force.

The stiffness requirements of the vehicle local designed structure will depend on angular errors that the specification requirements tolerate.

Torsion or warp can be observed on large vehicles (case of ships in heavy sea). The Figure 4 illustrates this.

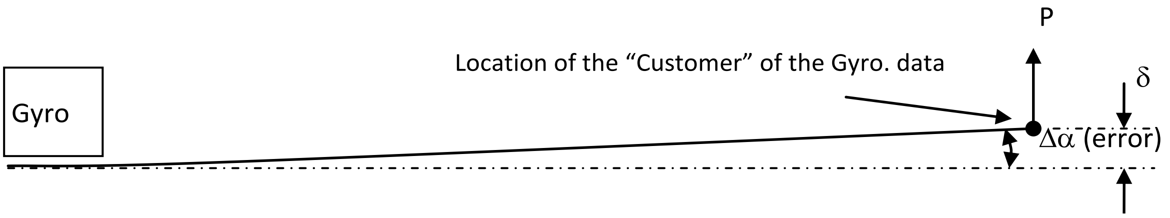


Figure 4 - Torsion or warp will give Roll, Pitch, Heading error

The stiffness design is under the responsibility of the workshop in collaboration with the “Customer” of the Gyro. (resp. INS) data (heading, roll and pitch). This needs to be studied and designed by mechanical modeling.

The basement engineering specifications where the Gyro. (resp. INS) interface plate will be mounted is described hereafter:

Table 1 - Vehicle basement specification

Specification	PHINS III, MARINS	OCTANS IV	QUADRANS/ATLANS
Stiffness around vertical axis (Heading) (1)	< 10 arc sec	< 100 arc sec	< 250 arc sec
Stiffness around horizontal axis (Roll, Pitch) (1)	< 10 arc sec	< 10 arc sec	< 100 arc sec
Stiffness regarding linear movement in horizontal plane	0.1 mm	0.1 mm	0.1 mm
Natural resonant frequency of basement with mounted Gyro. (resp. INS) interface plate (2)	> 50 Hz	> 50 Hz	> 50 Hz

(1) 10 times better than heading, roll or pitch absolute accuracy (see product technical specification).

(2) Far from standard vehicle vibration spectrum of 4 – 33 Hz (cf. MIL-STD-167)

5 TYPICAL GNSS ACCURACY AND LEVER ARM REQUIREMENTS

Lever arms values must be entered into the system. The lever arms are a point coordinates expressed in the Gyro (resp. INS) reference frame. There are two types of lever arms:

- An external point from the Gyro (resp. INS) where the user wants data to be calculated. Lever arms affect the following physical parameters:
  - Acceleration
  - Speed
  - Heave, Surge, Sway (in case of ships)
  - Position

  Rotation rate, Heading, Roll, Pitch are not affected by lever arms.
- Sensor lever arms. The Gyro (resp. INS) needs to know the position of the external aiding sensor (i.e., GNSS, EM Log, DVL, Depth sensor) in its reference frame.

Errors on lever arms have two main possible impacts:

- Error on absolute position calculated by INS due to lever arm error with GNSS. A rule of the thumb is that lever arm accuracy should be 1/10 of required absolute accuracy. For example if you want to position the vehicle with a 1-meter accuracy, your GNSS lever arms should be measured with a 10-cm accuracy.
- If lever arms are not sufficiently accurate with respect to GNSS accuracy the INS can reject the GNSS when the vehicle is performing accelerations or gyrations. As a rule of the thumb the accuracy of the measurement of the lever arm in this case should be 1/10 of the accuracy of the GNSS. As an example we present accuracy of GNSS lever arm with respect to GNSS accuracy:

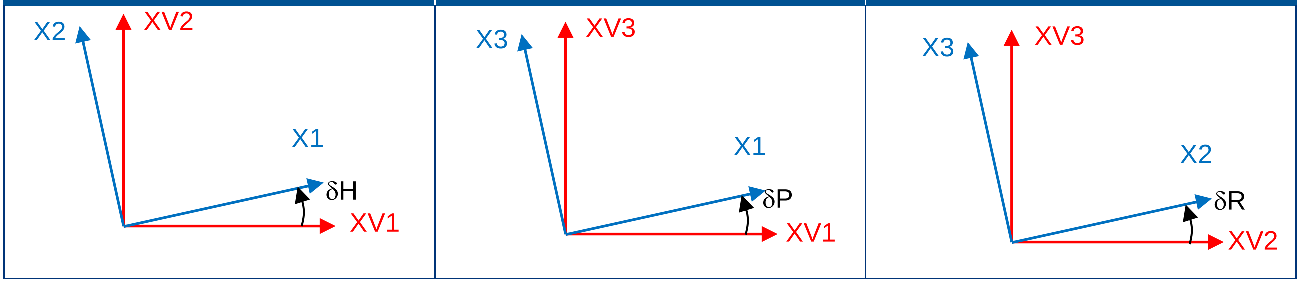
Table 2 – Position accuracy

GNSS Mode	Standard deviation on position	Accuracy required on lever arm measurement
RTK GPS	5 cm	5 mm
DGPS	1 m	10 cm
NATURAL GPS	10 m	1 m

6 ALIGNMENT OF THE GYRO (RESP. INS) TO VEHICLE REFERENCE FRAME

When the Gyro (resp. INS) is installed on the vehicle, misalignments of the Gyro (resp. INS) reference frame with respect to vehicle reference frame are measured as shown below.

Heading misalignment	Pitch misalignment	Roll misalignment



XV1, XV2, XV3: vehicle reference frame.

X1, X2, X3: Gyro (resp. INS) reference frame.

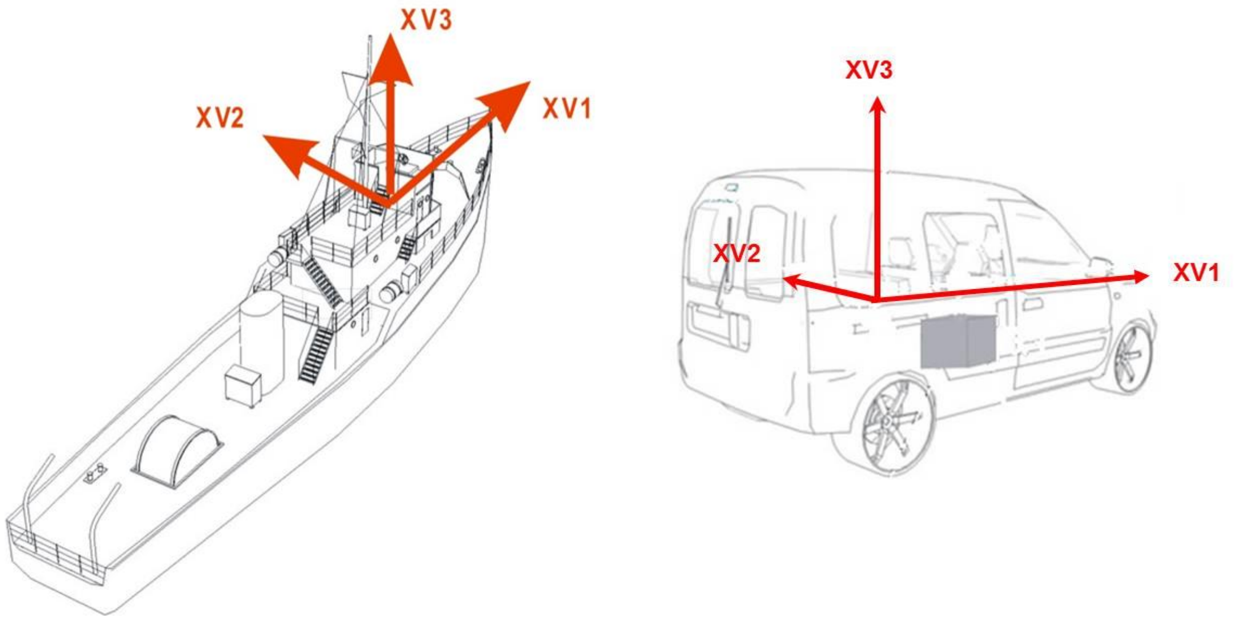


Figure 5 - Vehicle reference frame definition

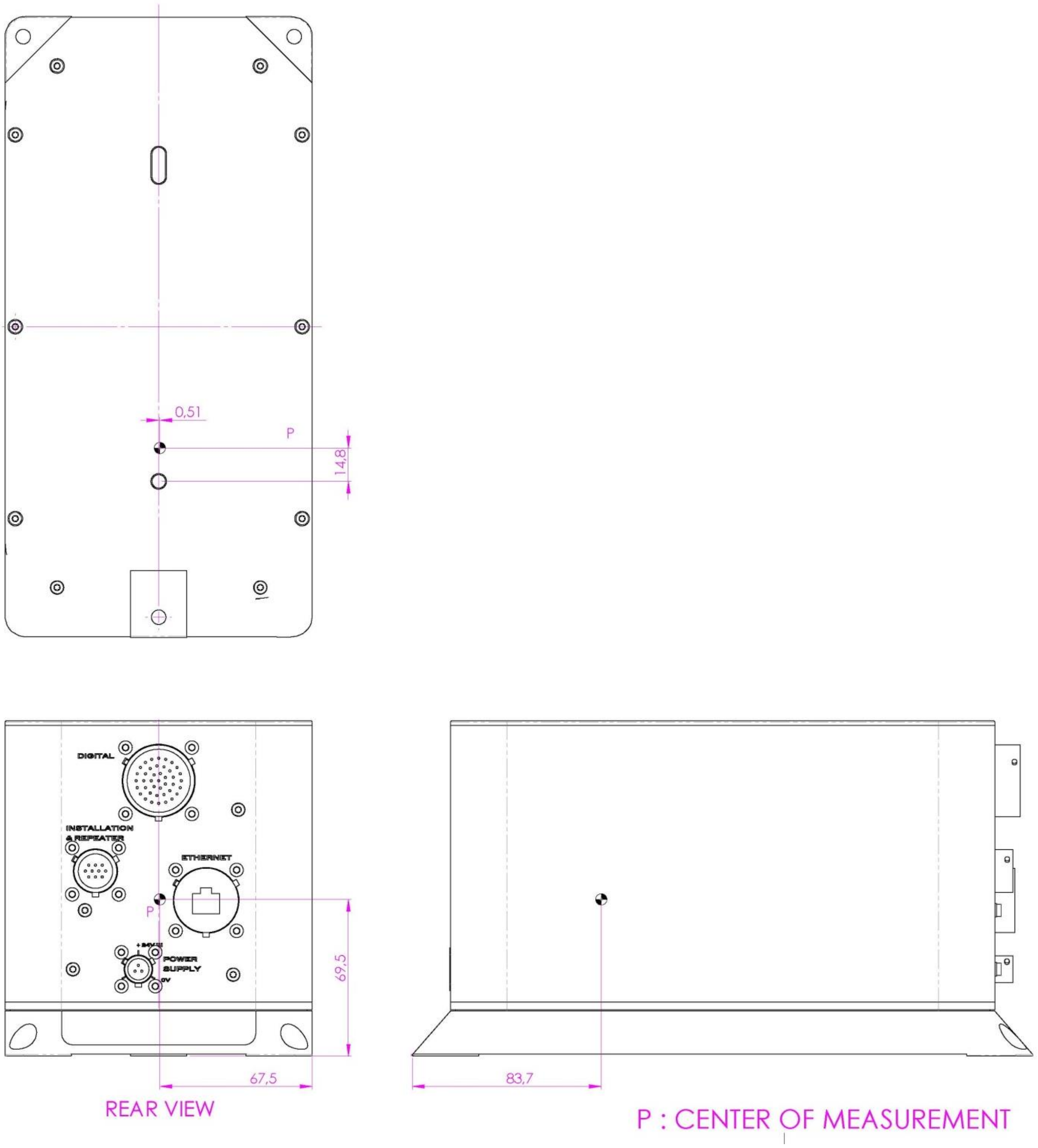


Figure 6 - Gyro (resp. INS) reference frame definition

This work must be performed by a professional surveyor. iXBlue recommends the following company:

Starmountain Survey & Consultancy (http://www.starmountain.nl/)
Oude Haarlemmerweg 46C
1901NC CASTRICUM
Noord-Holland
The Netherlands
Tel: +31 (0)251 67 15 15
Mob: +31 (0)6 5319 5002
info@starmountain.nl

There are different possible methods in dry dock or at float. We will not describe all methods. Direct measurement in the Gyro room using well defined vehicle centerline, theodolite, dihedral mirror tool for heading and electronic level instruments when an horizontal reference plate is available in the gyro room. This method is very accurate if the heading mark positions are known with millimeter order accuracy.

"Gyro calibration": heading of the vehicle is measured with respect to calibrated quay side heading or using known points on the quay side and using a total station to measure absolute position of the bow and the aft of the vehicle. Roll can be measured using leveling instrument and a theodolite to look at two rulers placed at each side of the vehicle. Pitch misalignment can be measured using water lines when at float.

Photogrammetry.(http://www.starmountain.nl/)

Direct external measurement of heading, roll and pitch of the vehicle will be more accurate if length and width are large. The greater the distances are the more accurate angular measurements are.

Hereafter 2 examples of what sort of accuracy was obtained with different methods:

Case 1: Frigate

Vehicle size (L x W)	Heading closing error	Roll closing error	Pitch closing error
N/A	0.008°	0.011°	0.001°

Case 2: Missile Launch Patrol Vehicle

Vehicle size (L x W)	Heading closing error	Roll closing error	Pitch closing error
50 m x 7 m	0.03°	0.06°	0.00°

Roll alignment uncertainty of measurement is greater since width is only 7 m. Pitch uncertainty is very small since 50 m length gives a very good accuracy on angle measurement (i.e., 2 mm/50 m= 0.003°).

The heading accuracy is to be compared to PHINS accuracy of 0.03°.seclat (3 RMS). At 37° latitude the PHINS maximum error (3 RMS) is 0.04°. The PHINS roll and pitch accuracy is 0.01° (RMS) so maximum error (3 RMS) is 0.03°.

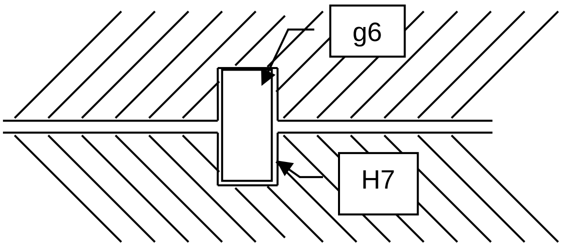
7 HEADING MOUNTING REPEATABILITY

This chapter describes the calculation of heading repeatability assembly / disassembly of an iXBlue Gyro. (resp. INS) on the vehicle plate.

It is studied for two possible assembly configurations. Firstly using a single diameter g6 pin and secondly using a double diameter g6/p6 pin.

7.1 Mounting with g6 Single Diameter Pin

The pin holes in the Gyro. (resp. INS) base plate are 6 H7 (+0 µ/+12 µ) and the standard pins are 6 g6 (-4 µ/-12 µ). This implies that Jmin = 4 µm and Jmax = 24 µm between pin and PHINS or vehicle pin holes.



Case 1: contact imposed on the alignment pin

We make the assumption that the system will be installed with contact imposed on the alignment pins (i.e., in OCTANS or PHINS X2 direction).

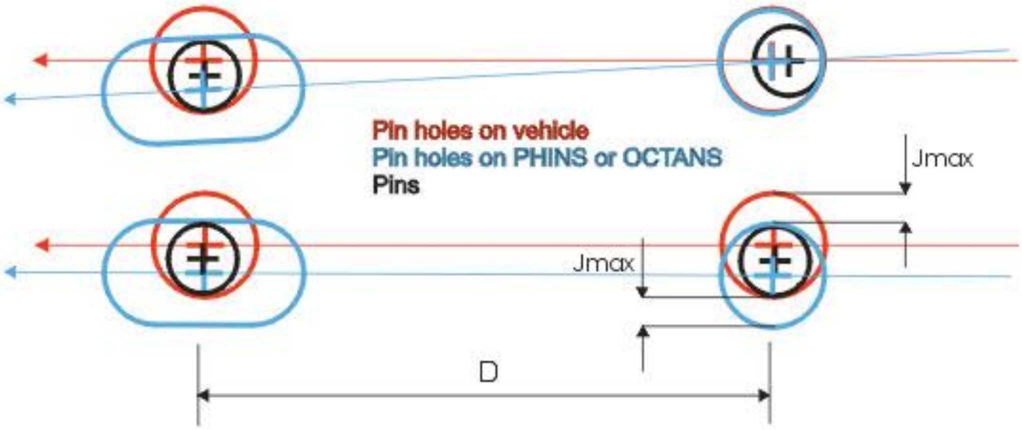


Figure 7 - PHINS is applied against pins.

Theoretically perfect repeatability

In theory the heading mounting repeatability error is zero. To be on the safe side we have depicted a more realistic situation where repeatability of assembly / disassembly is not zero.

So in this case the error is:

$$\beta = \frac{J\max}{2 \cdot D}$$

Case 2: no mounting precaution

Here we make the assumption that no special care is taken when repositioning the Gyro. (resp. INS) on the vehicle plate.

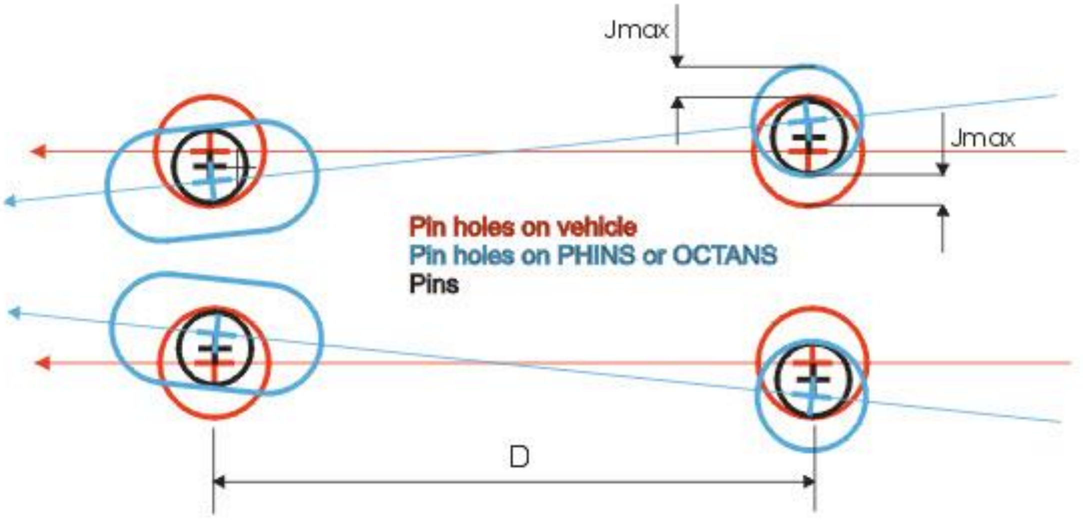


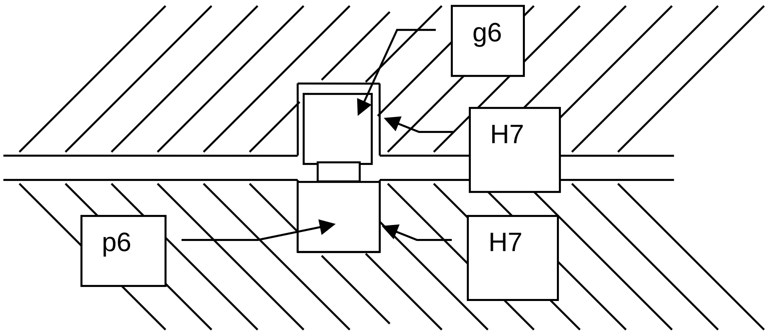
Figure 8 - Clearance in both PHINS and vehicle pin holes. Worst case depicted.

The maximum error is obtained when vehicle pin holes are maximum and pins diameter are minimum. This is the worst case. In this case the error is:

$$\beta = \frac{4 \cdot J\max}{D}$$

7.2 Mounting with Double Diameter g6/p6 Pin

The pin holes in the Gyro. (resp. INS) base plate and vehicle plate are 6 H7 (+0 µ/+12 µ) and the double diameter pins are 6 g6 (-4 µ/-12 µ) on PHINS side and 6 p6 (+20 µ/+12 µ) on vehicle plate. This implies that Jmin = 4 µm and Jmax = 24 µm between pin and PHINS pin holes. On the vehicle plate the pins have to be assembled with a press or a hammer. This implies a tight fitting with no clearance on the vehicle plate.



Case 1: contact imposed on the alignment pin

We make the assumption that the system will be installed with contact imposed on the alignment pins (i.e., in OCTANS or PHINS X2 direction). The results are identical to Case 1 (see Section 7.1).

Case 2: no mounting precaution

Here we make the assumption that no special care is taken when repositioning the PHINS on the vehicle plate.

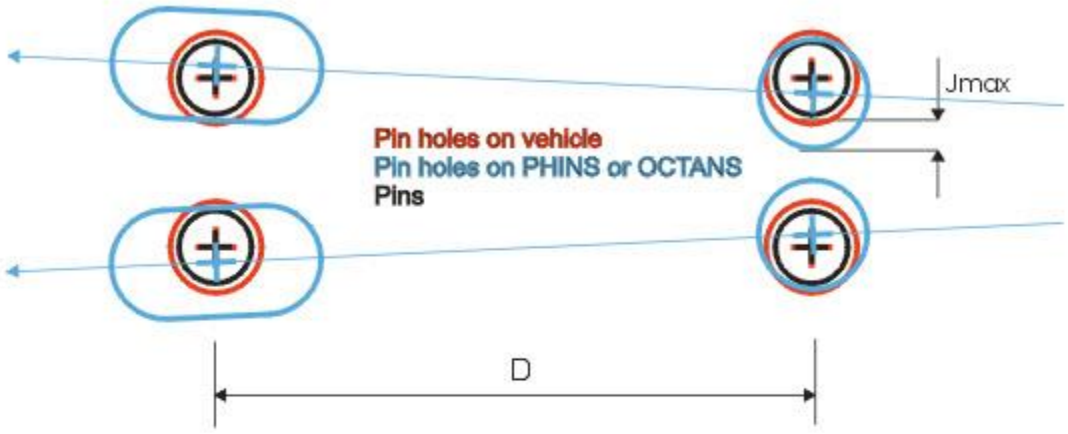


Figure 9 - No clearance in vehicle pin holes. Clearance in PHINS pin holes. Worst case depicted.

In this case the error is:

$$\beta = \frac{2 \cdot J\max}{D}$$

The error is divided by 2 compared to the situation where you have clearance in both PHINS and vehicle pin holes.

7.3 Mechanical Repeatability Measurements

We present hereafter the repeatability measurements in the case of mounting PHINS in contact with pins.

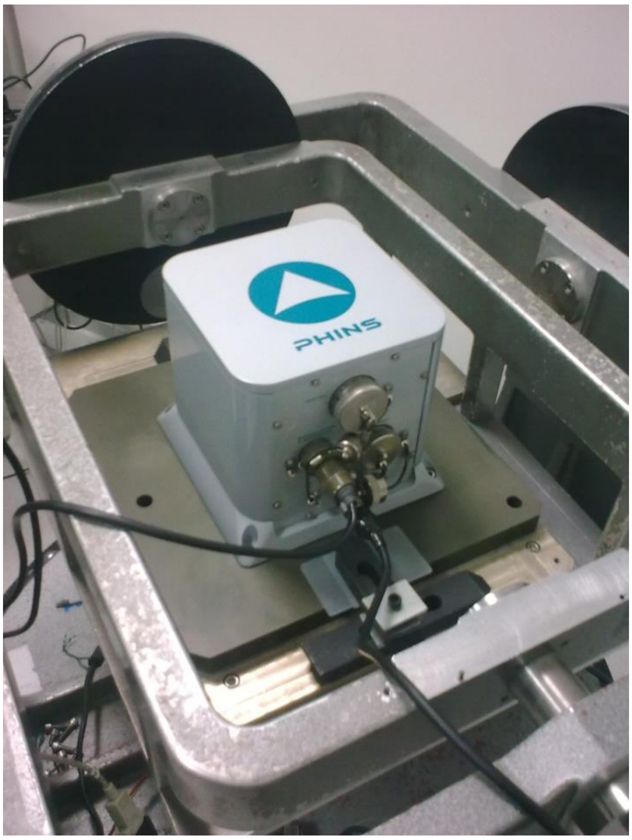
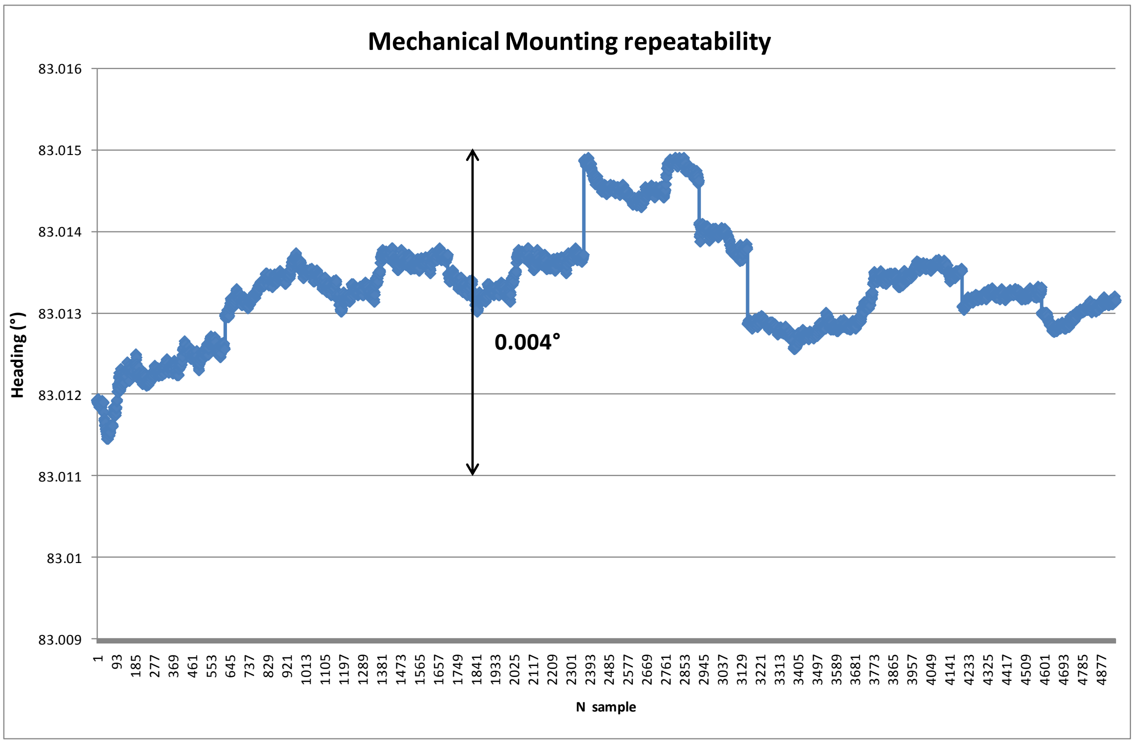


Figure 10 - Mechanical repeatability setup measurement

Before measuring we perform an alignment by performing 30 minutes at heading H and 30 minutes at heading H+180° in “Autostatic Bench” mode.

Then we have taken 10 Heading measurements after mounting/dismounting the PHINS from the interface plate. Each time, we force PHINS in contact with pins in X2 direction. We log data for approximately 2 minutes on each position (200 ms sampling rate).

	Heading
Before dismounting	83.015
After mounting	83.012
Before dismounting	83.012
After mounting	83.013
Before dismounting	83.013
After mounting	83.013
Before dismounting	83.014
After mounting	83.015
Before dismounting	83.015
After mounting	83.014
Before dismounting	83.014
After mounting	83.013
Before dismounting	83.013
After mounting	83.013
Before dismounting	83.013
After mounting	83.014
Before dismounting	83.013
After mounting	83.013
Before dismounting	83.013
After mounting	83.013



We see here that the maximum difference between Heading measurement values is 0.004°. This is validation of the theoretical predicted maximum error of 0.006°.

The table below summarizes the alignment uncertainty for INS assembly/disassembly.

Table 3 – Alignment uncertainty for INS assembly/disassembly

	Single diameter pin (clearance with vehicle plate)		Double diameter pin (no clearance with vehicle plate)	
	Forced contact with pins	No mounting precaution	Forced contact with pins	No mounting precaution
MARINS (D=347)	0.002°	0.016°	0.002°	0.008°
PHINS (D=125)[1]	0.006°	0.044°	0.006°	0.022°
OCTANS (D=140)[2]	0.005°	0.039°	0.005°	0.020°
QUADRANS/ATLANS (D=120)	0.006°	0.046°	0.006°	0.023°
ROVINS / PHINS6000	N/A	N/A	0.005°	0.020°

1 PHINS Surface, HYDRINS Surface

2 OCTANS surface, OCTANS Subsea, ROVINS, PHINS6000

In all cases, mounting repeatability is best if INS is mounted always in contact with the pins in a given direction (i.e., X2 direction).

If no mounting precaution is taken, the repeatability is best with double diameter pins that have no clearance in vehicle plate.

Experimental verification is in accordance with prediction regarding the case where INS is forced against the pins at mounting.