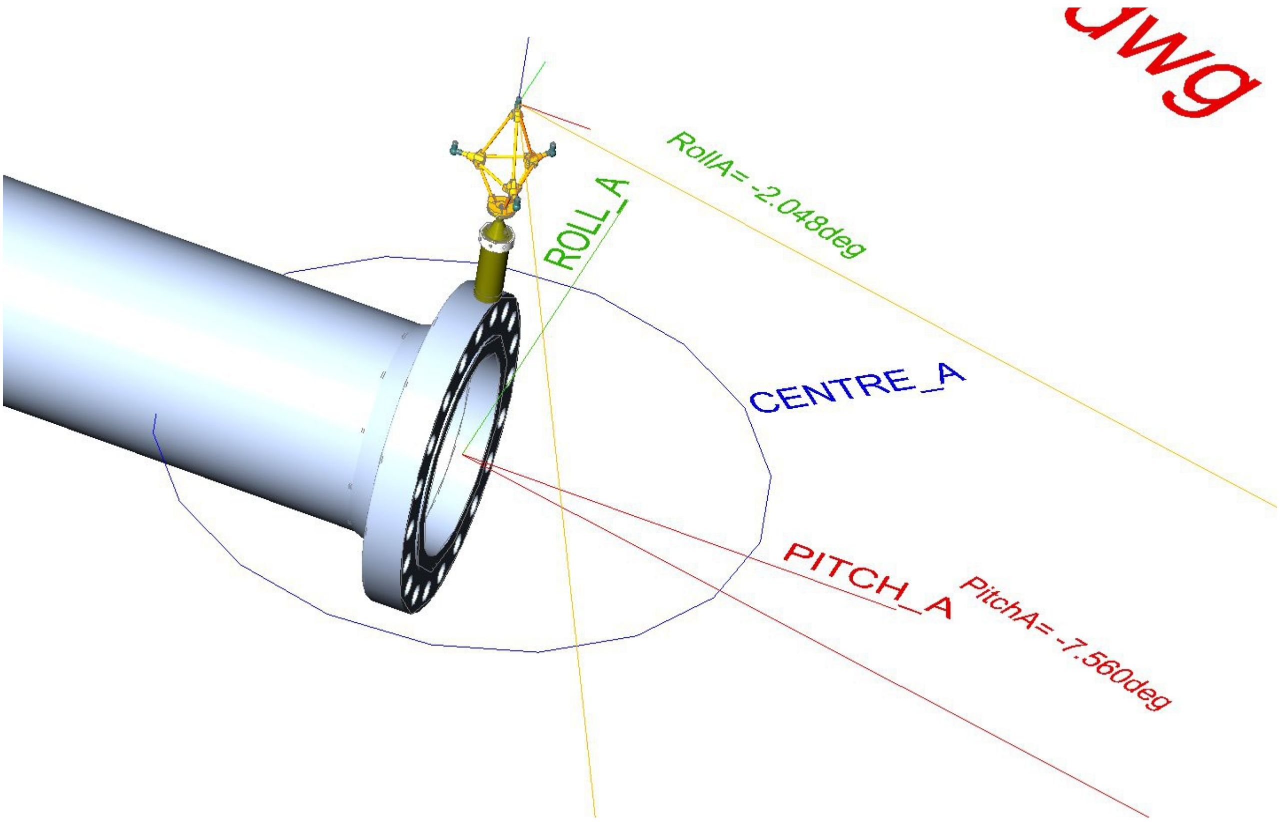
P.L.S.M.
BP 18
78354 Jouy en Josas
France
Phone : +33 9 7244 7216   Fax : +33 9 7244 7213
www.plsm.eu
infos@plsm.eu

AQUA-METRE R3000-NG
for
spool piece or jumper metrology



An AQUA-METRE R3000-NG Base unit on a flange (CAD result of a metrology)

Doc ref: 0114-803-006

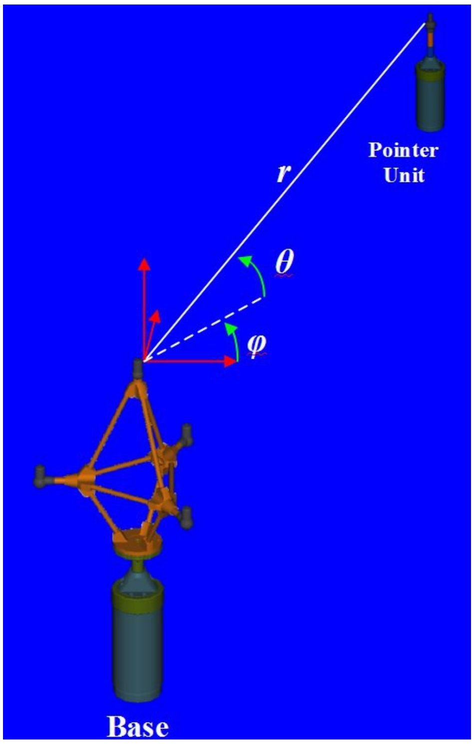
Summary

Document history

Document ref.		Modifications
0114-803-000		Draft issue
0114-803-001		first issue
0114-803-002 **0114-803-003** **0114-803-004** **0114-803-005** **0114-803-006**		Modification of PLSM address & tel/fax Advanced measurements added, details on mechanical interfaces added, list of achieved metrologies added Updated with R3000-NG version Direct-Inverse advanced QC added Minor corrections

1 AQUA-METRE R3000-NG System

The AQUA-METRE R3000-NG is a local underwater positioning system based on an acoustical interferometric scheme (mainly known as Ultra Short Base Line or USBL). It is particularly well suited to Metrology Class local 3D positioning within the range of up to 250 metres (more than 800 feet) from the reference point (the Base). The system may be ROV or diver operated and managed from the surface using acoustical networking features. The AQUA-METRE R3000 has been designed for deep offshore metrology, the system is operated through a set of commands (monitor commands and acoustic commands) and may be operated using the **AQUA-CAD** software from PLSM that allows real time interface to a range of CAD software (Intelliplus and BricsCAD).



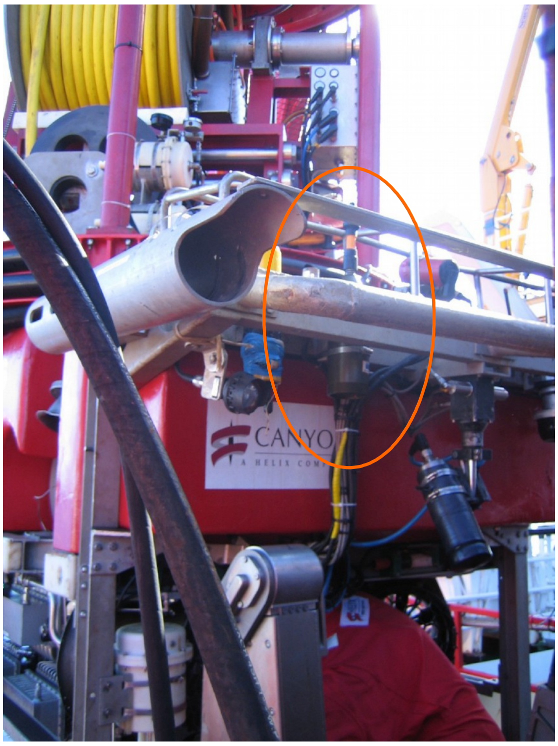
The simplest AQUA-METRE system configuration able to measure 3D coordinates underwater is made of at least two main components:

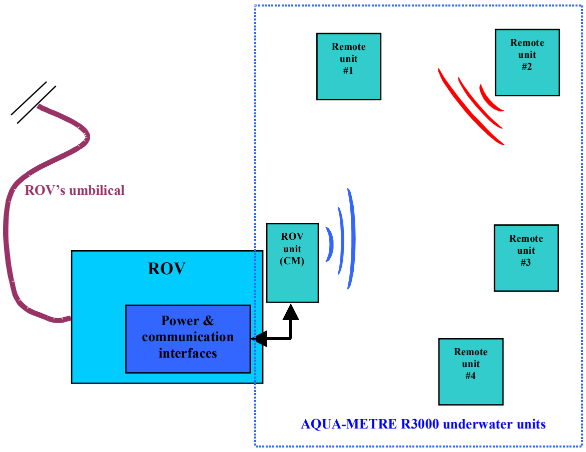
-The measurement **Base,** which constitutes the local reference Cartesian coordinate system {0,0,0}),
-At least one **Pointer** which replies to Base interrogations.

R3000-NG Base with its interferometric frame and R3000 Pointer (Right)

Basically, the system is dedicated to 3D measurement of Pointer(s) location in the local coordinate system(s) defined by the Base(s). Each unit also includes a bi-axial accurate inclinometer that allows, among other capabilities, to give access to Pitch, Roll angles, as well as difference of height between units as detailed later in this document.

The AQUA-METRE R3000 allows a very flexible system configuration made of several stand alone units (a unit is a Base or a Pointer), all units communicate using acoustic messages, one unit on the ROV allows underwater system management from surface through a serial data-link (RS232 compatible). This specific unit, that can be any Base or Pointer, is called the Communication Master (CM later in this manual).





R3000-NG Pointer working as Communication Master (CM) on a work class ROV

Due to a recurrent demand for spool piece metrology and a collaboration with STOLT OFFSHORE company in 2003 (STOLT is now SUBSEA7), PLSM has developed a specific script for this application included in the AQUA-CAD software. This script automatically managed the underwater units measurements and directly draw the metrology result in a CAD software, taking into account all mechanical interfaces offsets, in order to speed up the survey report and avoid processing error (as well as surveyor nightmare and headache…).

This specific way of using the AQUA-METRE R3000-NG is described in the present document.

2 AQUA-METRE R3000-NG for Spool Piece Metrology

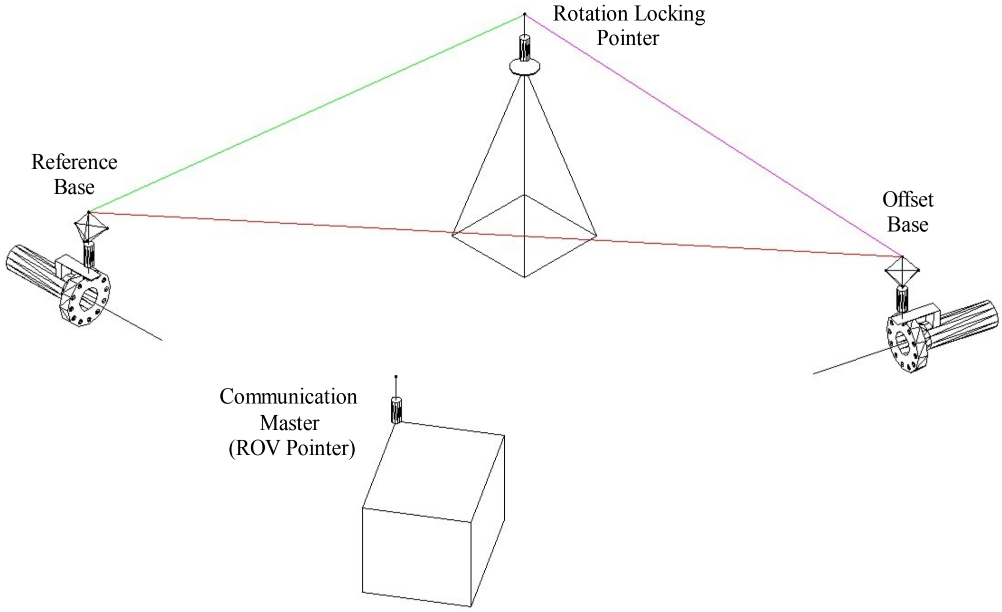
There are two AQUA-METRE R3000-NG configurations expected depending on flange-to-flange distance.

When the distance is less than about 70/80 metres with a clear flange-to-flange path, then a direct flange to flange metrology can be set up.

Distance greater than 70/80 metres may be affected by multipath due to seabed proximity, in this case a middle Base is recommended to split the metrology into two steps. This is also recommended when a clear path between flanges cannot be guaranteed (direct path masked by a large steel structure for instance).

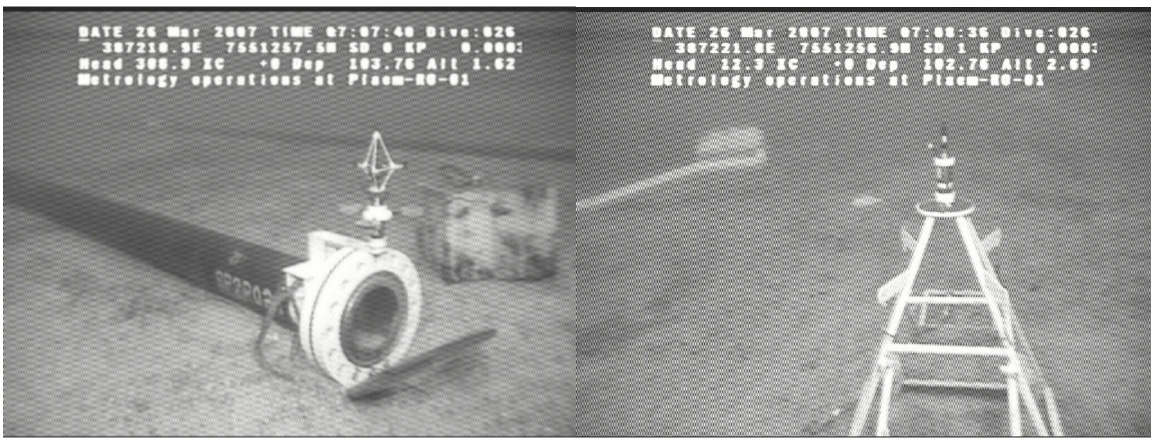
2.1 Direct flange to flange configuration

The AQUA-METRE configuration in this case appears below:



Direct Flange-to-Flange Spool piece Metrology

One Base is set up on each flange, the first one is called the Reference Base and defines the relative coordinate system, all results will be output according to this Base coordinate system (which is defined by the interferometric frame), the other Base is called the Offset Base and attached to the second flange. One Pointer is set up on a seabed support in order to create roughly an isosceles triangle (see sketch).



AQUA-METRE R3000-NG Base on 20" flange and Pointer on seabed support frame

Each Base to flange mechanical interfaces have to be defined in an CAD drawing (.dwg) prior to starting the metrology (see later how to define this interface).

A Pointer attached to and preferably powered by the ROV is linked up to the survey room through a bi-directional RS232 channel and acts as the Communication Master, thus sending commands to and receiving results from the others units working on batteries (2 Bases and one Pointer in this case)

The metrology consists of four measurement steps:

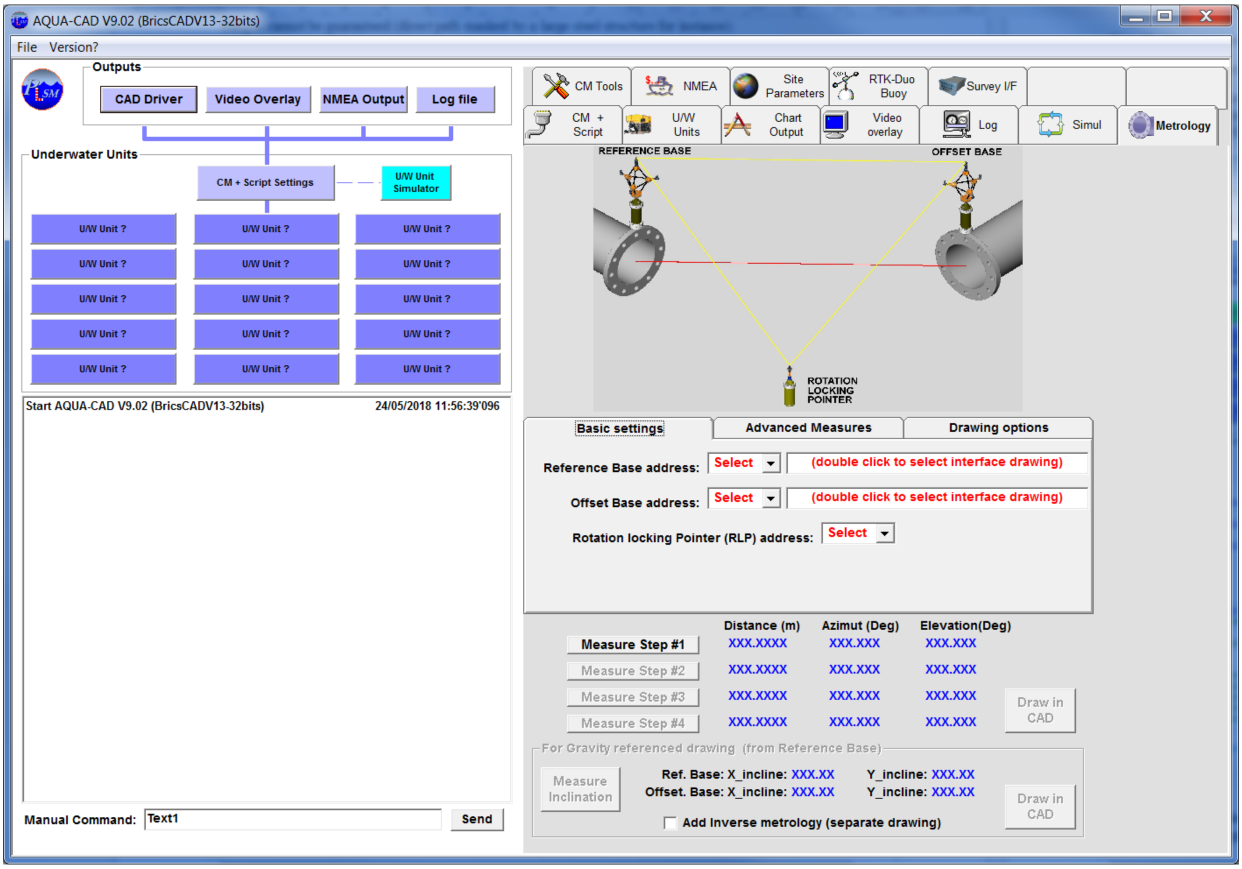
Step #1: Measurement of Offset Base location from Reference Base,

Step #2: Measurement of Rotation locking Pointer from Reference Base,

Step #3: Measurement of Reference Base location from Offset Base,

Step #4: Measurement of Rotation locking Pointer from Offset Base,

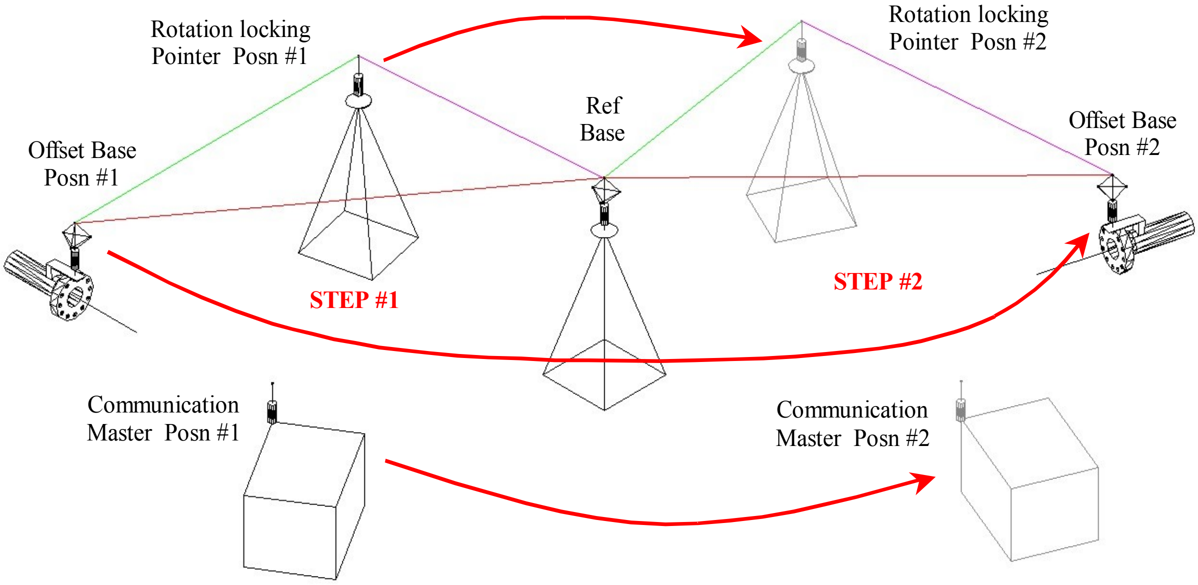
All these acoustic measurements (four times Azimuth, Elevation and Distance) are processed by AQUACAD to produce a final drawing of the metrology including the mechanical interfaces, subsequently getting direct access to the flange-to-flange 3D distance, deltaZ, horizontal angles, pitch...



AQUA-CAD screen when using the Metrology script

The typical duration to do the measurements and process the data up to the final CAD file is less than 5 minutes! (the overall metrology duration is mainly dictated by system set up and retrieval)

2.2 Mid Base configuration



Mid Base Spool piece Metrology

The Reference Base is set up on the seabed support and defines the relative coordinate system; all results will be output according to this Base coordinate system (which is defined by its interferometric frame).

The metrology is then split in two steps corresponding to the two flanges:

1) The Offset Base is attached to the first flange. The rotation-locking Pointer is set up on a seabed support in order to create roughly an isosceles triangle with the two Bases (see sketch).

2) The second step consists of moving the Offset Base to the second flange and the rotation locking Pointer in order to create another isosceles triangle with the two Bases (see sketch)

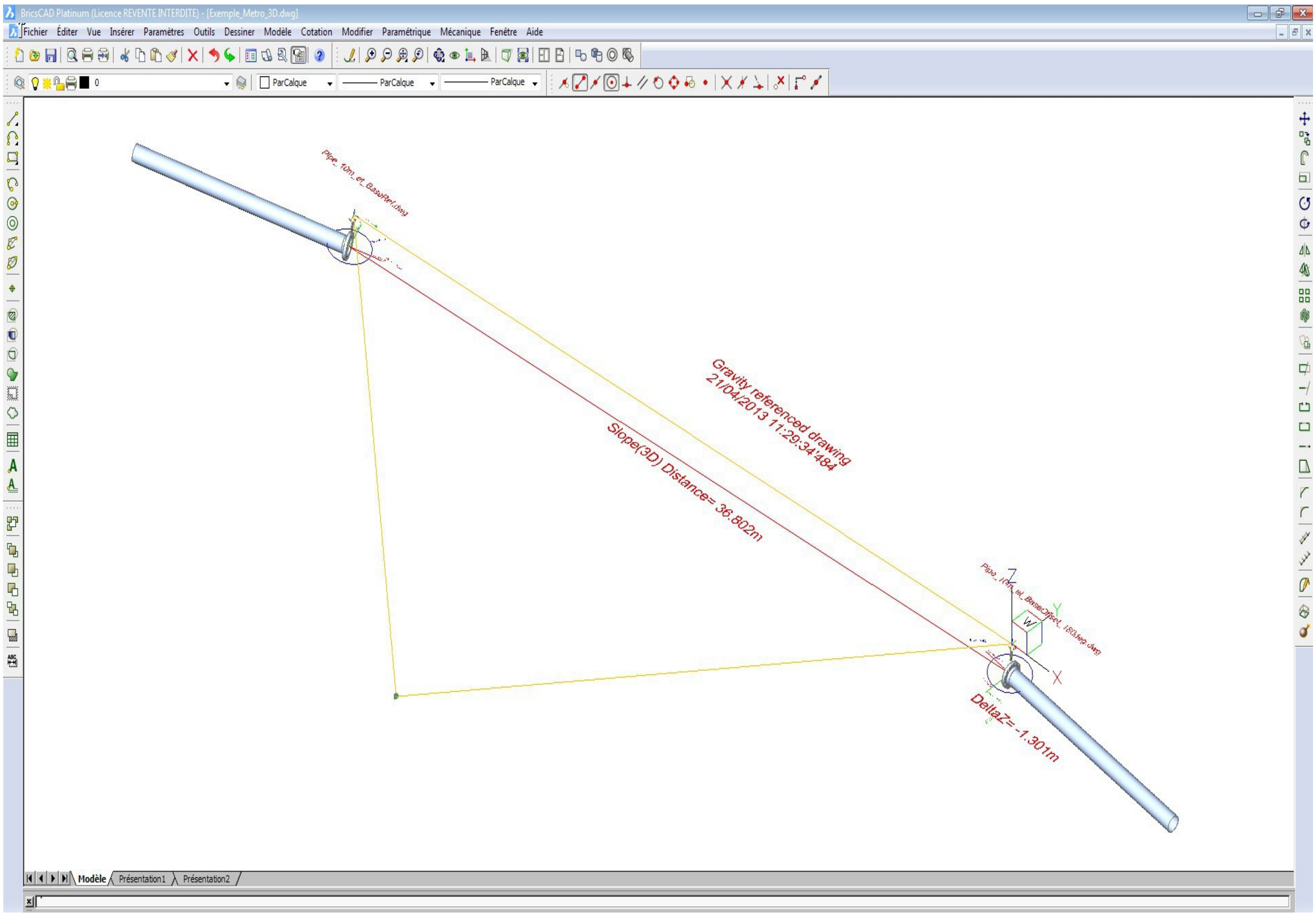
A Pointer attached to and preferably powered by the ROV is linked up to the survey room through a bi-directional RS232 channel and acts as the Communication Master, thus sending commands to and receiving results from the others units working on batteries (2 Bases and one Pointer)

Each step requires the same type of 4 acoustic measurements and output the same type of results like the direct flange-to-flange metrology.

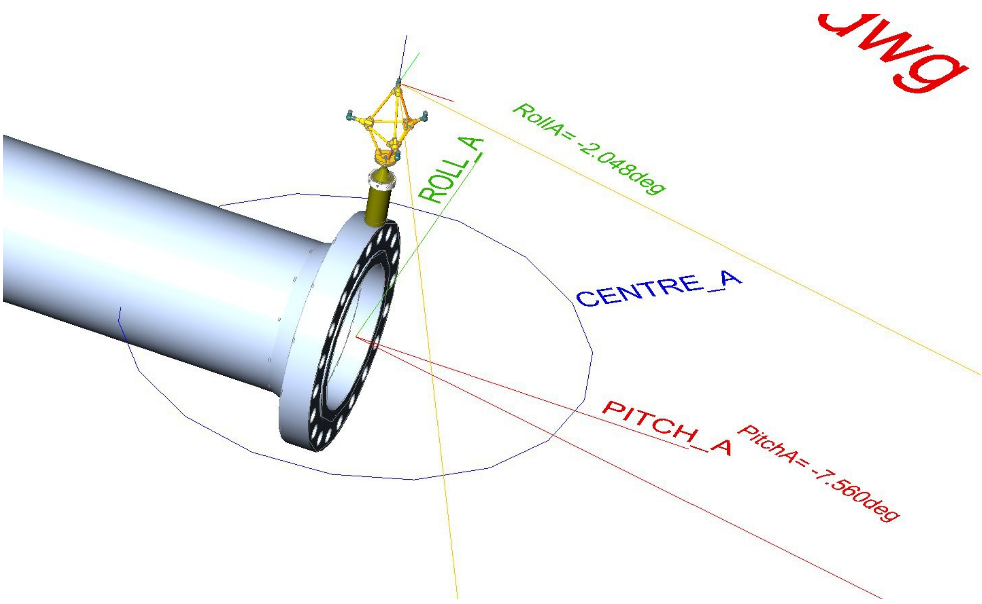
Example of AQUA-METRE R3000 Base potentially masked by large steel structure

2.3 Metrology results

The Metrology result is directly drawn in a CAD file (.dwg) that allows the surveyor to quickly produce direct flange to flange final report.



Example of Spool Piece metrology result



Flange detail

2.4 Mechanical interface definition, automatic measurement

The mechanical interface between the Base unit (Reference Base or Offset Base) and the flange (connector in case of Jumper) is a key point that lead to a successful metrology.

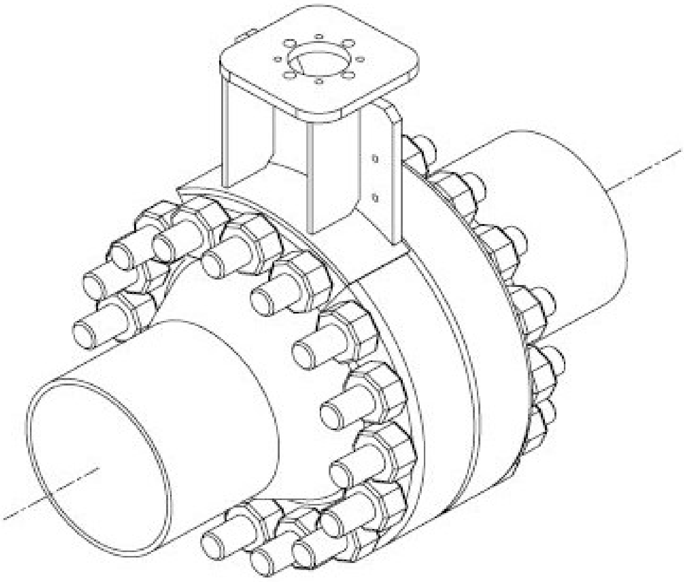
This mechanical interface must be designed in order to:

- guarantee a known and repeatable Base location & attitude relatively to the flange center & axis,

- offer a way to easily plug the Base unit into it, by diver or ROV,

There is no universal design to address these constrains, it also depends if the interface can be installed prior to pipe laying. However, this interface is most often made of two parts: one mechanical interface with a receptacle attached to the flange, and a mechanical interface to the Base unit that fits in the receptacle,

PLSM offers a standard male-female cone interface, the female cone/receptacle being attached to the flange interface, and the male cone to the Base unit as illustrated below:



example of flange mechanical interface with a female receptacle

Base unit with the mechanical interface to the male metrology cone

The male/female cone interface includes two alignment pins that guarantee accurately the relative positioning (6 DOF locked).

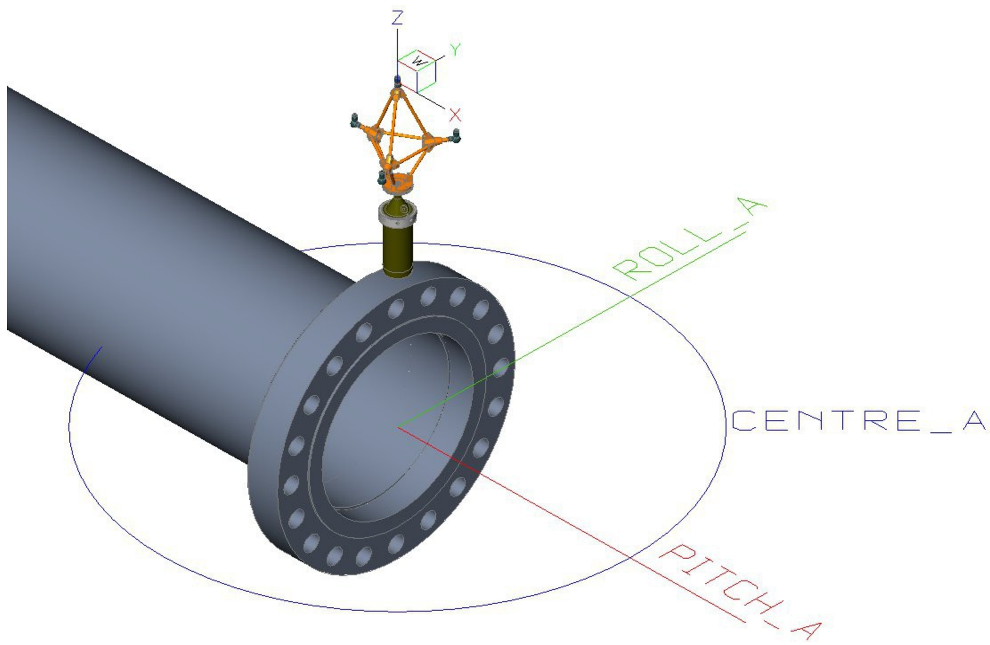
The mechanical interface offered by PLSM between the Base unit and the male cone is made of machined parts in inox (316L), thus the offset and angles alignment are perfectly known for this part of the interface between the Base and the flange. The rest of the interface between the receptacle and the flange is often made on the yard using welded metal plates, thus it has to be surveyd prior to the metrology in order to identify the offsets and misalignments (6 DOF) between the receptacle and the flange center and axis.

Male/female cone metrology interface

PLSM also offers ROV's grab handles and a protection frame to secure the interferometric frame (check PLSM's web site at www.plsm.eu or contact PLSM for more details).

Mechanical Interface CAD definition file:

When the mechanical interface is defined and has been built and surveyd, a specific CAD (dwg) file must be prepared for the metrology process. This mechanical interface drawing defines the way each Base is attached to the Flange. This is a very important file because it will be inserted in the final metrology drawing and allows the user to directly get the flange-to-flange distances and angles measurements taking into account the offset and misalignments introduced by the mechanical interface between the Base unit and the flange.



Example of Mechanical interface definition drawing

In case of error when drawing this interface, AQUA-CAD offer a replay mode that allows to replay a metrology with a different mechanical interface.

Advanced measurement :

Within the mechanical interface definition file (dwg), the user may define for each flange:

- the center from/to which the distances and DeltaZ will be calculated ,

- the Pitch and Roll axis along which Pitch and Roll angles will be calculated,

The centers will be defined by a circle, the Pitch&Roll axis by simple line, these entities will be placed on specific layers (CENTRE_A, PITCH_A and ROLL_A respectively for the reference Base mechanical interface, and with suffix "_B" for the Offset Base).

After the completion of the four acoustic measurement steps, and the reference and offset Base inclination measurement, the following metrology results will be automatically extracted and added to the CAD file:

- the horizontal (2D) or slope (3D) distance from flange center to flange center,

- the difference of height (DeltaZ) from flange center to flange center,

- the Pitch and Roll angles along the axis defined in the mechanical interfaces,

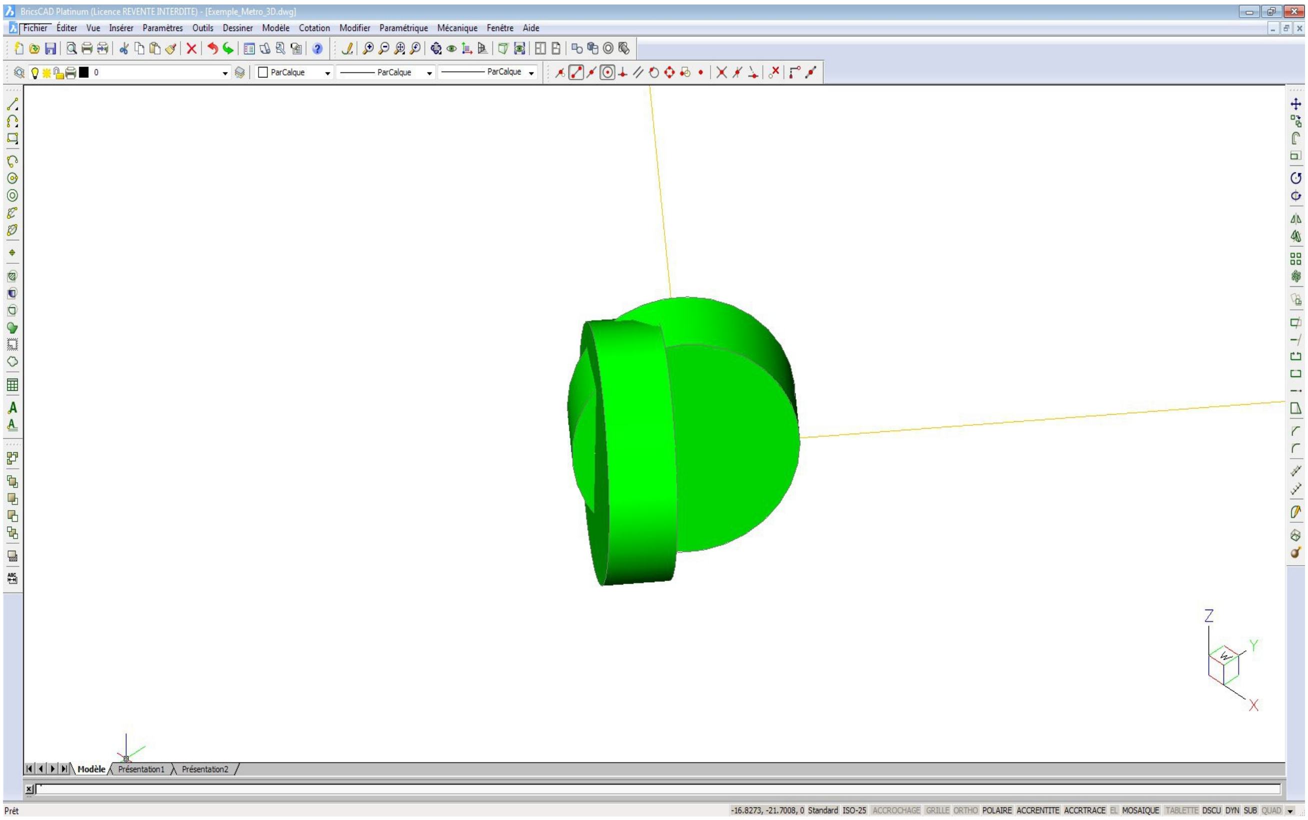
- in case of a jumper metrology, the user can alos choose the Pitch/Roll along/perpandicular to the center to center axis.

2.5 Measurement Quality Check

2.5.1 Acoustic Measurement Checking

It is possible to check the consistency of the acoustic measurements by looking how the measurements close together at the rotation locking Pointer location. The distance and angular errors for each end line is the combination of both Base to Base and Base to Pointer measurements, the standard deviation for each is 2cm for distance (for distances less than 50m) and 0.1° for angle.

The method to check the consistency of the metrology just consists of drawing the error volumes, which are slices of cone, at the end of each Rotation Locking Pointer measurement and to check that they overlap, if they overlap it assures the user that the flange to flange accuracy is consistent with the nominal system accuracy (2cm for distance when distance is less than 50m, 0.1° for angles measurement). AQUACAD automatically add these measurement error volumes in the CAD file.



Example of QC: passed when error volumes overlap

2.5.2 Direct-Inverse full Metrology Checking

This new feature is available since AQUA-CAD version 9.0

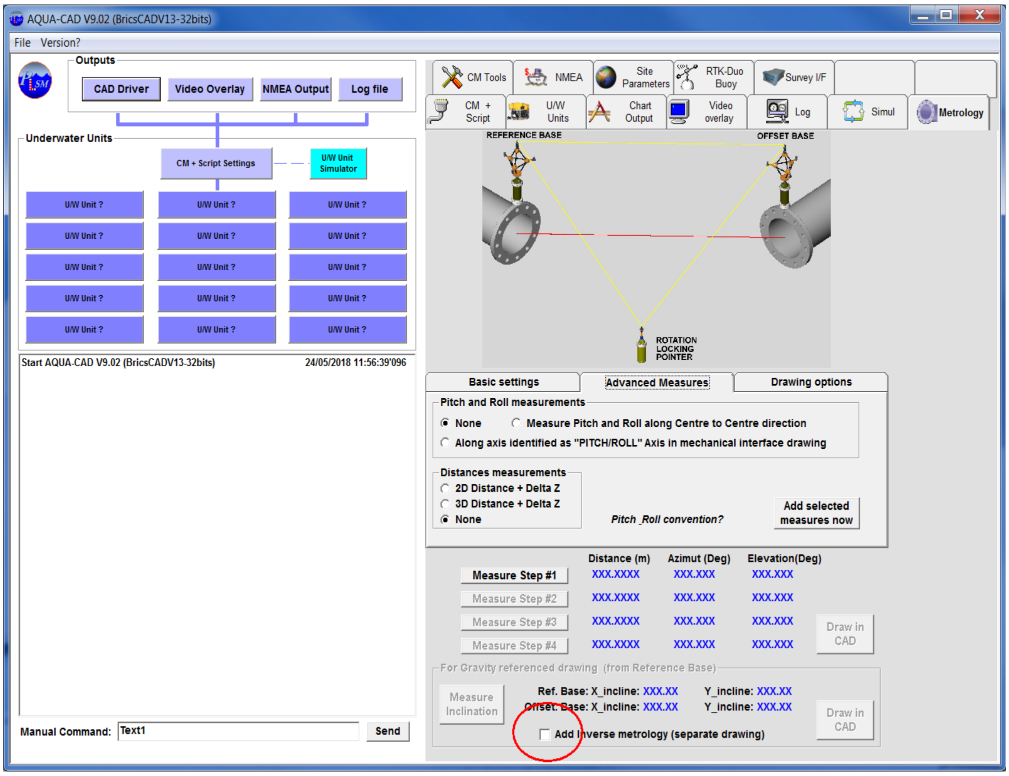
In addition to the acoustic measurement checking, it is also possible to check the consistency of the inclinometer measurements using the direct-inverse metrology check. The direct metrology is the one defined by the user with a reference Base and offset Base units. The final metrology is computed by taking into account the acoustic measurements and the inclination (from inclinometer) of the reference Base unit only. At this stage, the computed offset Base inclinations can be compared to the inclinometer measurement of this offset Base. Then, it is possible to swap the reference and offset Bases in the computation, this is called the inverse metrology, which allows to check the reference Base inclination using the same comparison.

The direct-Inverse metrology checks:

- The inclination measurements of the reference and offset Bases,

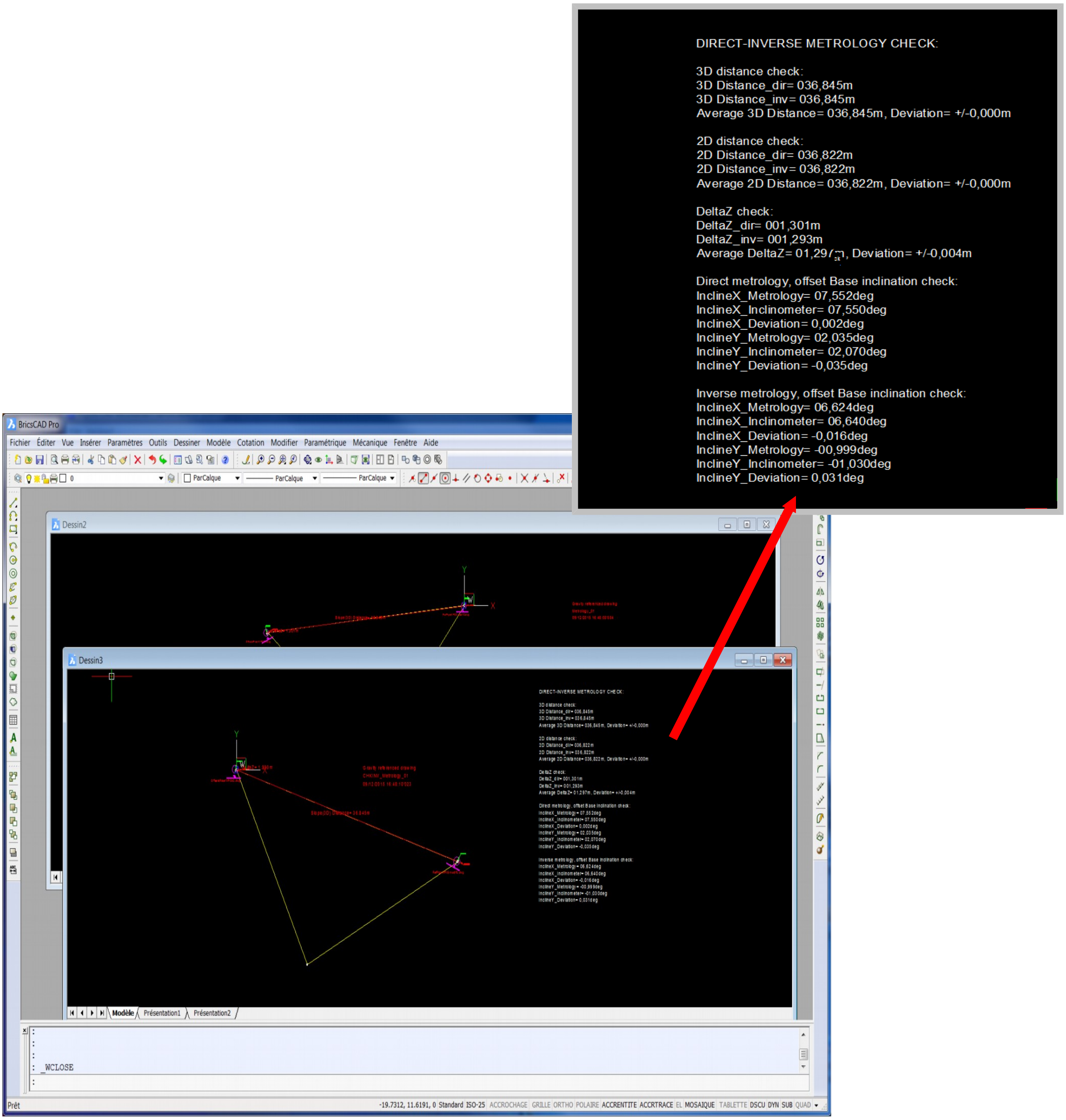
- then the DeltaZ from Base to Base,

It also secure the mechanical interface compensation by reducing the orientation error.



Activation of inverse metrology analysis through AQUA-CAD

The results of the direct-inverse metrology analysis are directly included in the « Inverse » CAD file:



Results of direct-inverse metrology analysis in CAD file

2.6 List of Spool & jumper already completed since 2006

The AQUA-METRE R3000 system developpement started in 2004 along a collaboration with the STOLT OFFSHORE company (now SUBSEA7). The system has been qualified in shallow water in 2006, then in deep water in 2007. It has regularly been used since then around the world, the following table sum up all metrologies achieved with the system up to now (more than 110 spools & jumpers). The AQUA-METRE R3000 has also been deeply redesigned in 2014 (major soft & hardware improvements), it then became AQUA-METRE R3000-NG.

Project	Year	Depth,	Comment
Mad Dog, Gulf of Mexico	2006	250m	Customer: ACERGY USA/BP Qualification of AQUA-METRE R300, 4 vertical spool metrologies, diver operated, ROV as CM and diver support
Greater Plutonio, Angola	2007	1400m	Customer: ACERGY WEST AFRICA/BP Angola Qualification of AQUA-METRE R3000, 12 horizontal spool metrologies, ROV operated, direct comparison with Compatt mk5 + Octans
PRA1, Brazil	2007-2008	100 to 180m	Customer: ACERGY USA/Petrobras AQUA-METRE R3000 as primary system, more than 50 spools (measured along 28 metrologies), diver operated with ROV for CM
Tombua Landana, Cabinda	2007	450m	Customer: ACERGY WEST AFRICA/ Chevron Texaco AQUA-METRE R3000 as primary system, 4 horizontal spool metrologies, ROV operated.
Baku Phase 1, Azerbadjian	2007-2008	100 to 280m	Customer: BP/Mac DERMOTT/OCEANEERING AQUA-METRE R3000/R300 as primary system, 6 vertical "M shape" jumpers, ROV operated.
Baku Phase 2, Azerbadjian	2008-2009	100 to 280m	Customer: BP/SAIPEM/OCEANEERING AQUA-METRE R3000 as primary system, 6 vertical "M shape" jumpers , ROV operated.
Anguille, Gabon	2009	28m	Customer: ACERGY WEST AFRICA/ Total Gabon AQUA-METRE R3000 as primary system, 2 horizontal spool metrologies, diver operated, "dunked Pointer" as CM (no ROV)
North Amethyst, Canada	2009	150m	Customer: TECHNIP-CANADA/ Husky Energy AQUA-METRE R3000 as primary system, diver operated, ROV Pointer as CM , 6 jumpers
Mexilhao, Brazil	Early 2010	<200m	Customer: ACERGY BRAZIL/PETROBRAS AQUA-METRE R3000 as primary system, 2 horizontal 34" Spool metrologies, diver operated, CM Pointer on a ROV,
Baku Phase 3, Azerbadjian	2010-2011	100 to 280m	Customer: BP/SAIPEM/OCEANEERING AQUA-METRE R3000 as primary system, 3 vertical "M shape" jumpers (up to mid-2010) , ROV operated.
B17, Angola	Early 2011	40m	Customer: ACERGY/TOTAL AQUA-METRE R3000 as primary system, 1 spool, ROV operated

EGP3B, Nigeria	Late 2011 to early 2012	7 to 30m	Customer: SUBSEA 7 AQUA-METRE R3000 as primary system, 9 spools in shallow water, diver operated
Sul Norte-Capixaba Phase 1, Brazil	April 2012	70m	Customer: SUBSEA 7 Brazil/Petrobras AQUA-METRE R3000 as primary system, 4 spools, length 37 to 71m, diver operated
Sul Norte-Capixaba Phase 2, Brazil	June 2012	40m	Customer: SUBSEA 7 Brazil/Petrobras AQUA-METRE R3000 as primary system, 2 spools, length 33 to 49m, diver operated
Anguille, Gabon	Nov. 2012	30m-40m	Customer: SeaTrucks/Total Gabon AQUA-METRE R3000 as primary system, 2 spools in shallow water, diver operated
Zawtika, Myanmar	March 2013	158m	Customer: OCS/PTTEP AQUA-METRE R3000 as primary system, 1 spool, lenth 36m, ROV operated
Baku Phase 4, Azerbadjian	July 2013	220m	Customer: BP operated by FUGRO-TOPNAV AQUA-METRE R3000 as primary system, 4 vertical "M shape" jumpers , ROV operated.
Baku Phase 5, Azerbadjian	June 2014	<200m	Customer: BP operated by FUGRO-TOPNAV AQUA-METRE R3000-NG as primary system, 2 vertical "M shape" jumpers , ROV operated.
Baku Phase 6, Azerbadjian	Feb. 2016	<200m	Customer: BP operated by FUGRO-TOPNAV AQUA-METRE R3000-NG as primary system, 3 vertical "M shape" jumpers , ROV operated.
Baku Phase 7, Azerbadjian	April 2017	<200m	Customer: BP operated by FUGRO-TOPNAV AQUA-METRE R3000-NG as primary system, 4 vertical "M shape" jumpers , ROV operated.
Bengladesh	Feb. 2018	30m	Customer : GEOCEAN/ENTREPOSE AQUA-METRE R300-NG as primary system, 1 spool, length 28m, diver operated, no visibility and high current
Bengladesh	Dec. 2018	30m	Customer : GEOCEAN/ENTREPOSE AQUA-METRE R300-NG as primary system, 1 spool, length 35m, diver operated, no visibility and high current