Zupt's Inertial Metrology Service

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Presentation Agenda

01 Zupt's Metrology Track Record
02 Client Provided Preliminary Data
03 Personnel Requirements
04 Mechanical Interface
05 Task Plan
06 Mobilization Sequence
07 Communications ROV/Surface – Surface/Onshore
08 Operational Sequence
09 Real-time Data QC
10 Deliverables

Zupt's Inertial Metrologies

To-date we have commercially delivered apx. 200 metrologies in:

Regions:

- **West Africa - Angola, Congo, Ghana -** rig and survey vessels
- **U.S. Gulf of Mexico** rig and survey vessels (worked to 3,200m)
- **North Sea** from rig
- **Bahamas** (42" dia. spool) shallow water barge with divers
- **Mexico** divers in deep water (130m)

Fields worked:

- **Angola: Shenzi, Pazflor, Girassol, CLOV, Dahlia, Girri**
- **Congo: Moho Bilondo, Moho Nord**
- **Ghana: Jubilee, TEN**
- **GoM: Mississippi Canyon, Green Canyon, Bay of Campeche, etc.**
- **North Sea: Pelican**

Clients:

- **Total**
- **BHP Billiton**
- **Oceaneering**
- **Fugro**
- **Shell**
- **DOF Subsea**
- **LLOG**
- **Harkand**
- **Marubeni**
- **Tullow**
- **TAQA**
- **Acergy**
- **Statoil**
- **Jan de Nul**
- **Hess, etc.**

Client Preliminary Data

Client provided preliminary data:

Local field drawing of job location that hopefully includes:

- Estimated Well location
- Structure Location – manifold, PLET, PLEM, template, etc

Jumper name fully defined

Hub naming full defined

Metrology receptacle fully defined (what are we stabbing into)

All dimensional Control (DC) data:

- Offsets (linear and angular) from stab to hub reference face – at both ends
- Structure reference frame definition

Deliverables required with required accuracy

Personnel Requirements

International work: Three* Zupt personnel offshore for 24 hour operations.
Domestic Work: Two Zupt personnel
Remote Work: No survey personnel offshore – 2 monitoring

Data is quality controlled on the vessel and reviewed in Houston. The offshore deliverable (ODEL) is delivered on the vessel within 24** hours of the recovery of the equipment.

**If multiple (>3) back to back metrologies a 4th team member is added.*
*** In some cases we are required to deliver the ODEL within 12 hours.*

In many cases we work as part of a survey contractors team and we utilize their personnel (once trained) as part of our team. With experienced companies we can end up with just a single Zupt (PC) on the job once the survey contractors team are fully trained.

ROV Interfacing

Power:

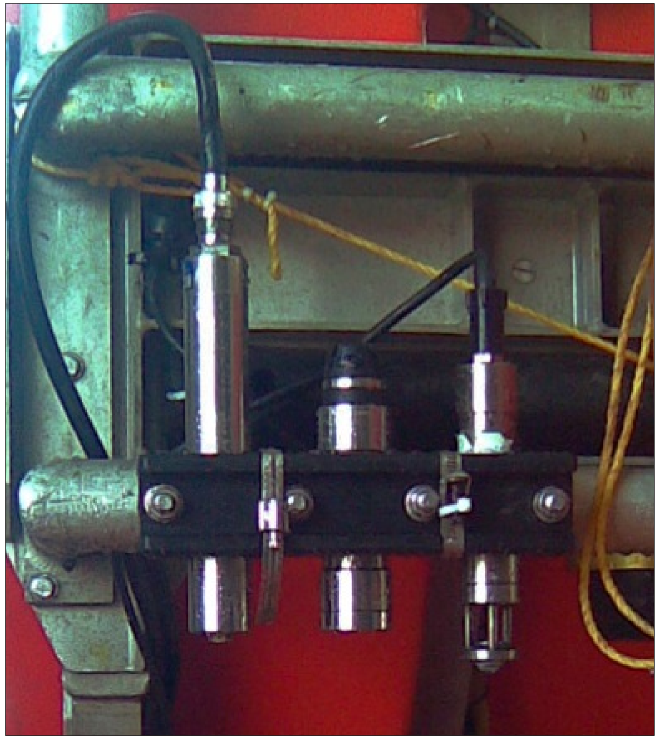
24V dc, 75W (We also have battery back up internal to our tool)

Communications:

One RS232 serial survey channel on the ROV

RS232 channel (>=38,400 baud/bps).

We supply a serial multiplexer [MicroTTU] with C-PINS for all external sensors. ROV's rarely have the channels available that were available when talking about the job on the beach.



Mobilization

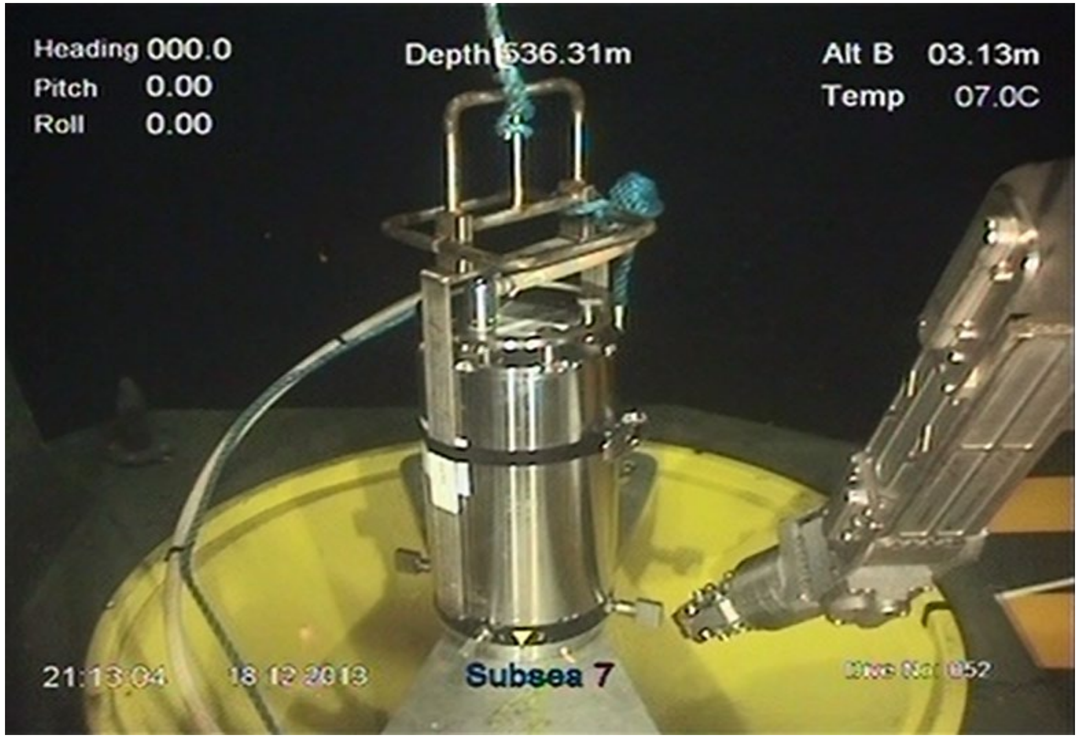
- Mobilize ROV with the metrology tool - check communications and power
- Prepare all metrology tooling for deployment
- If two ROV's available - one does cleaning of receptacles and GVI
- The second ROV is deployed with C-PINS

Inertial Metrology Components

C-PINS alignment	(<1 hr)
Hub attitude (heading, pitch, roll) measurements	(1 - 2 hrs)
Position loops (range between hubs)	(2 - 3.5 hrs)
Depth difference between hubs	(0.5 – 0.75 hrs)
Step height survey of both hubs	(0.5 - 1 hrs)
Bathymetric survey of jumper route	(0.75 -1.5 hrs)
Total	**Approx 6-12 hrs**

C-PINS Alignment

C-PINS alignment / 4 quadrant rotation (<1 hr)



Top

Front

Back

Hub Attitude Loops

Attitude loops using a rotating stab (1-2 hrs)

0°

90°

180° Twice for each Hub (client requirement)

270°

360°

Attitude loops provide heading, pitch, roll of well and manifold (Hub A & Hub B)

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Hub Position Loops

Position Loops (2 – 3.5 hrs)

Minimum of 5 (6 for 50mm) good position loops to deliver range between hubs.

A loop is defined as:

ROV starts at Hub A with position fix (Well or Manifold).

ROV picks up C-PINS & traverses to Hub B.

ROV stabs C-PINS into Hub B receptacle.

Position fix at Hub B

ROV picks up C-PINS & traverses to Hub A

ROV stabs C-PINS into Hub A receptacle.

Fix at Hub A taken to close position loop.

Position loops provide relative range between well and manifold (Hub A & Hub B)

Depth Difference Loops

Depth Difference Loops (Digiquartz) (0.5 - 1hr)

Hub A

Hub B

Depth Difference Loops provide hub depth comparison

Step Height Survey

Step Height Survey (Digiquartz) (0.5 - 1hr)

Top of hub and plant North mudline depth measurements

Step Heigh Survey provides hub heights and mudline data

Step Height Measurements

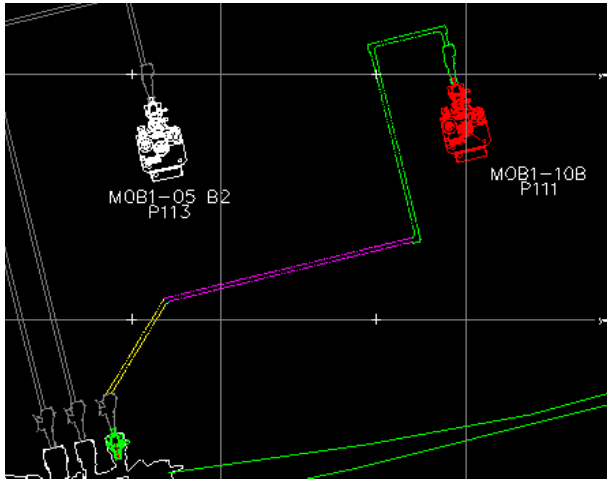
Step heights at manifolds are easy.
At the well – a whole other story. Frame grabs should be included in reports to explain why.

Bathy Survey, Step or Fly?

Step Bathymetric Survey (Digiquartz)

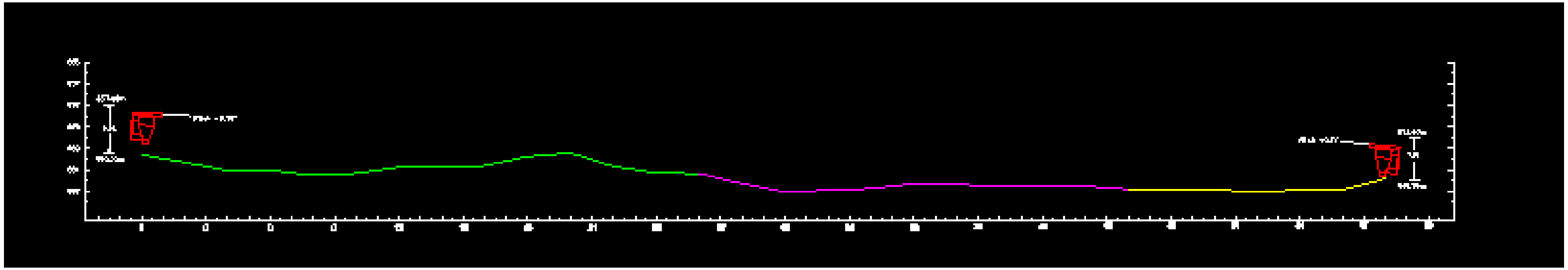
(0.75 – 1.5 hrs)

Log position every 2m along jumper route with Digiquartz. Our preferred method.



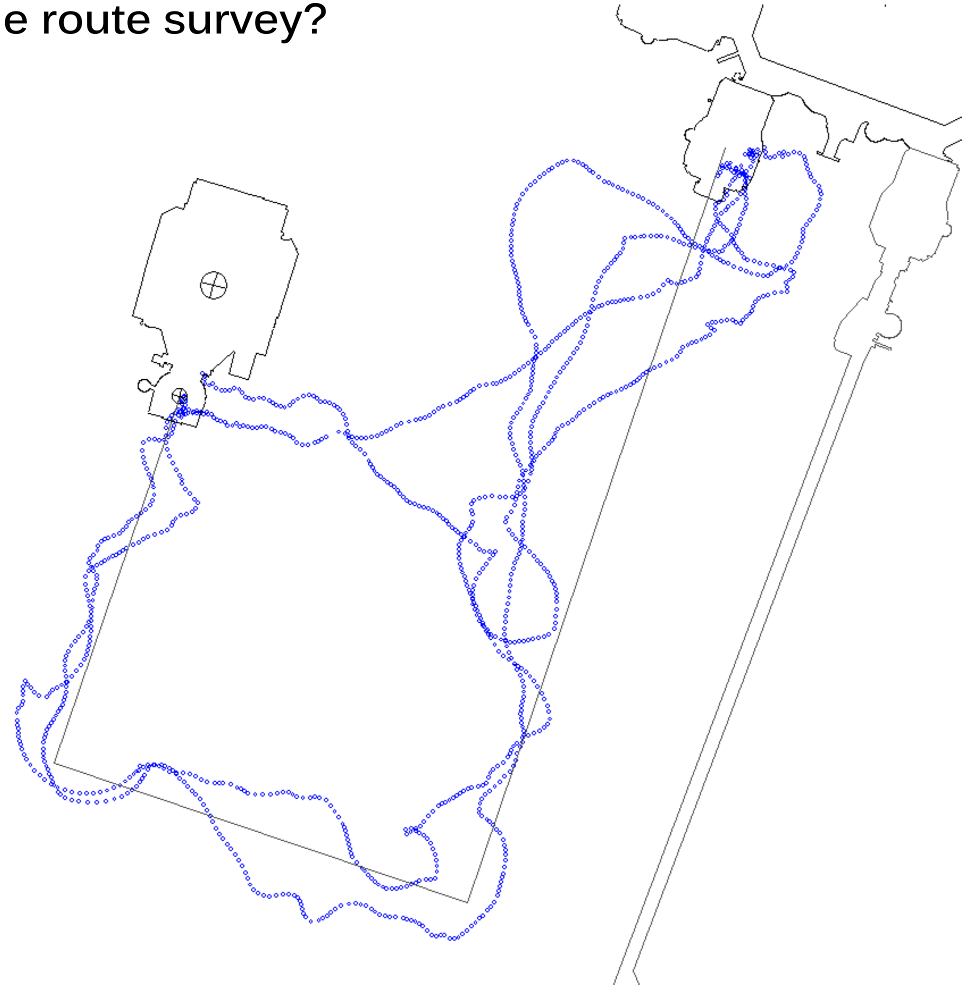
Fly

Using mini SVS and an altimeter in addition to the Digiquartz, we can fly the route.



Bathymetric Survey

Why don’t we always fly the route survey?



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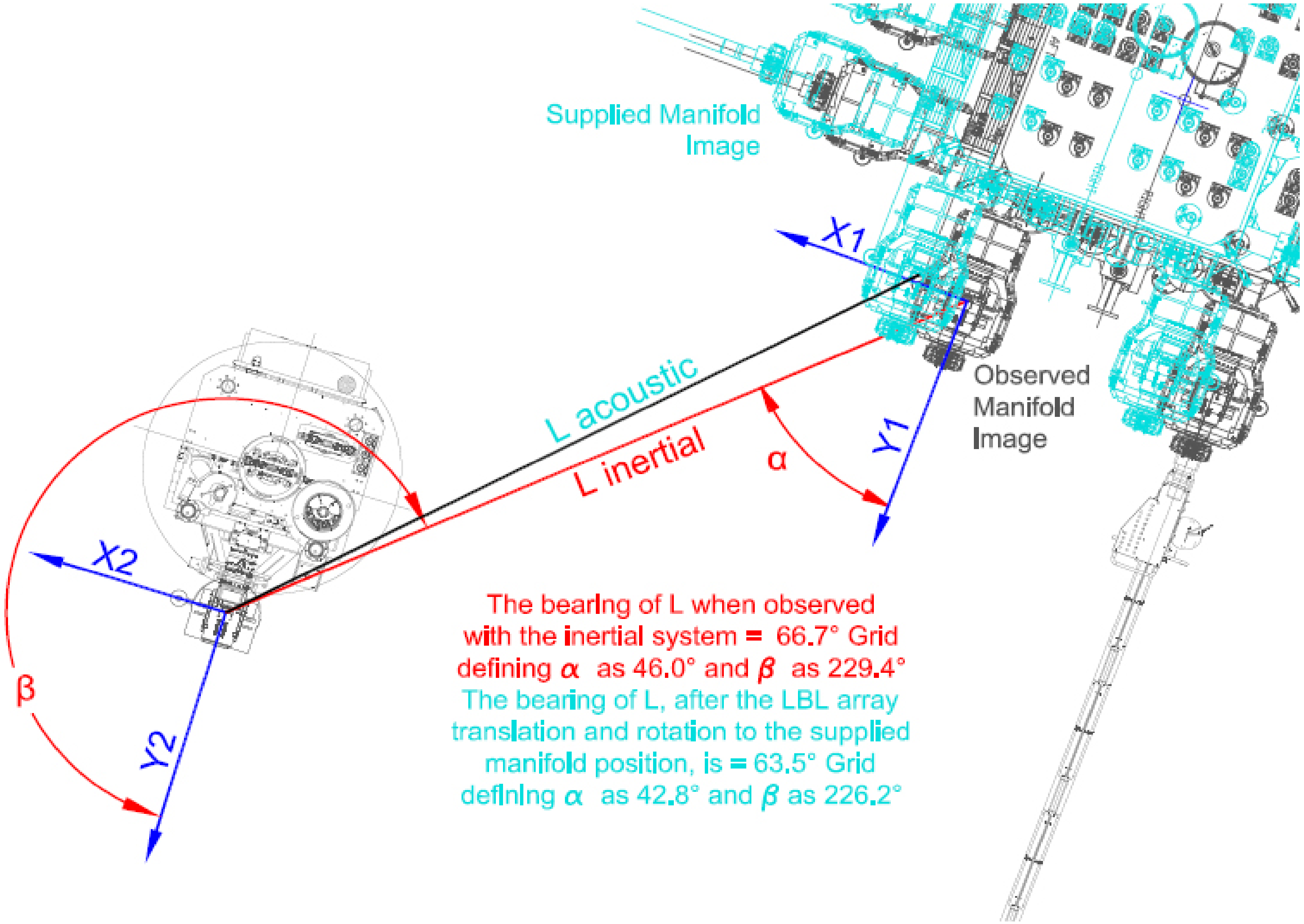
Alpha and Beta Angle Quality



The bearing of L when observed with the inertial system = 66.7° Grid defining α as 46.0° and β as 229.4°

The bearing of L, after the LBL array translation and rotation to the supplied manifold position, is = 63.5° Grid defining α as 42.8° and β as 226.2°

Real-time Quality Control

It is critical that we see real time quality data as we are working.

Position loop selection on the left.

Processing HIDE

Position Loops

Loop	Ena	Position Loops					
		Tie N	Tie E	Tie D	E@S N	E@S E	E@S D
1	X	-0.041	0.078	-0.278	0.000	0.000	0.000
2	X	-0.172	0.213	-0.327	-0.012	0.026	-0.080
3	X	-0.022	-0.032	-0.184	-0.070	0.100	-0.172
4	X	-0.070	-0.023	-0.132	-0.039	0.033	-0.173
5	X	0.048	0.094	-0.178	-0.049	0.006	-0.151
6	X	0.019	0.075	-0.137	0.002	0.046	-0.166

Individual data sets and their impact on the final solution are on the screen in front of us – as we collect the data.

We know when we are done!

SD at ~65% of client spec.

Processing HIDE

HUB Results

Hub	Hub Results							
	Distance	DDepth	Northing	Easting	Depth	Head +	Pitch	Roll
2	22.653	-0.008	3315065.557	257058.966	7.982	0.108	0.429	0.003
	Std.Dev.		0.015	0.018	0.041	0.063	0.103	0.120

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Deliverables

Zupt uses pure inertial (unaided) navigation to perform subsea metrologies using our C-PINS systems. Inertial drift is constrained using zero velocity updates (zupts).

Deliverables:
The results of a C-PINS metrology consist of jumper fabrication measurements for the construction of a jumper/spool piece that include:

Hub to Hub Horizontal Distance
Depth Difference between Hubs
Hub Attitude (Heading, Pitch, Roll)
Alpha / Beta Angles between Hubs (for horizontal connectors)
Hub Step Heights (hub to mud line)
Bathymetric Profile of Jumper Route

Deliverables

ODEL (Offshore Deliverable)

Prior to departure from the survey platform (vessel or rig) the metrology results are delivered to the client in the form of an offshore deliverable.

ODEL contains all metrology data required to generate the isometric/pipeline drawings for jumper fabrication.

Metrology data gathered is sent to Houston for QC during and immediately upon completion of survey. Client is issued raw data distance, attitude and bathymetry data within an hour of survey completion (many times – during the survey).

Results delivered within 12 (if required) or 24 (standard) hours of the recovery of the equipment to the surface.

Offshore Deliverable

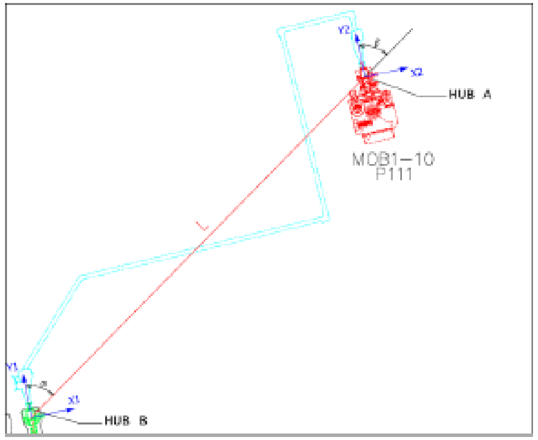
TOTAL E&P CONGO

Metrology Result MOB1-10 P111 M11

ZUPT

	Variable	Metrology Result	Notes
Horizontal Distance	L	**40.804 m**	**True Horizontal Length**
Angle Alpha	α	**57.70°**	Horizontal angle between Y1 axis and direct line between reference points
Angle Beta	β	**54.22°**	Horizontal angle between Y2 axis and direct line between reference points
Manifold M11 **Hub B Pitch**	X1 Rotation around X1	**0.11°**	**Forward Up** - in the direction of the jumper at Manifold M11
Manifold M11 **Hub B Roll**	Y1 Rotation around Y1	**0.02°**	**Port Up** - in the direction of the jumper at Manifold M11 (Manifold Heading: 346.35°)
PGB MOB1-10 **Hub A Pitch**	X2 Rotation around X2	**-0.36°**	**Forward Down** - in the direction of the jumper at PGB MOB1-10
PGB MOB1-10 **Hub A Roll**	Y2 Rotation around Y2	**-0.03°**	**Port Down** - in the direction of the jumper at PGB MOB1-10 (PGB Heading: 349.83°)
Difference in Depth	Z	**1.613 m**	**Manifold is deeper** From center of hub to center of hub

Note: All distances are in meters.
All angles are in degrees.
UTM horizontal scale factor from UTM positions to true = 1.00059755



	Name	Position	Date
Computed	Alex Spriggs	INS Surveyor	25 Jan. 2014
Computed	Ozer Ozturk	CAD/Data Processor	25 Jan. 2014
Computed	Geoffrey Knowles	Party Chief	25 Jan. 2014
Checked	Tim Griffin	Project Manager	25 Jan. 2014
	Bruno Hommet	Client Representative	25 Jan. 2014

NOTES:
1. Data computed from C-PINS inertial navigation system
2. Data collected onboard the GSF135 Jan 24th and 25th 2014
3. Differential depths established using C-PINS inertial system
4. Bathymetry established using external Digiquartz pressure sensor

IFC ODEL 01282014-MOB1-10 P111 REV1.DOCX

TOTAL	TOTAL EXPLORATION AND PRODUCTION CONGO MOHO BILONDO METROLOGY OPERATIONS Project No.4640002069	METROLOGY SURVEY RESULTS PGB MOB1-10 to M11 (P111)	Zupt, LLC 10963 Cutten Rd, Suite A102 Houston, TX 77066

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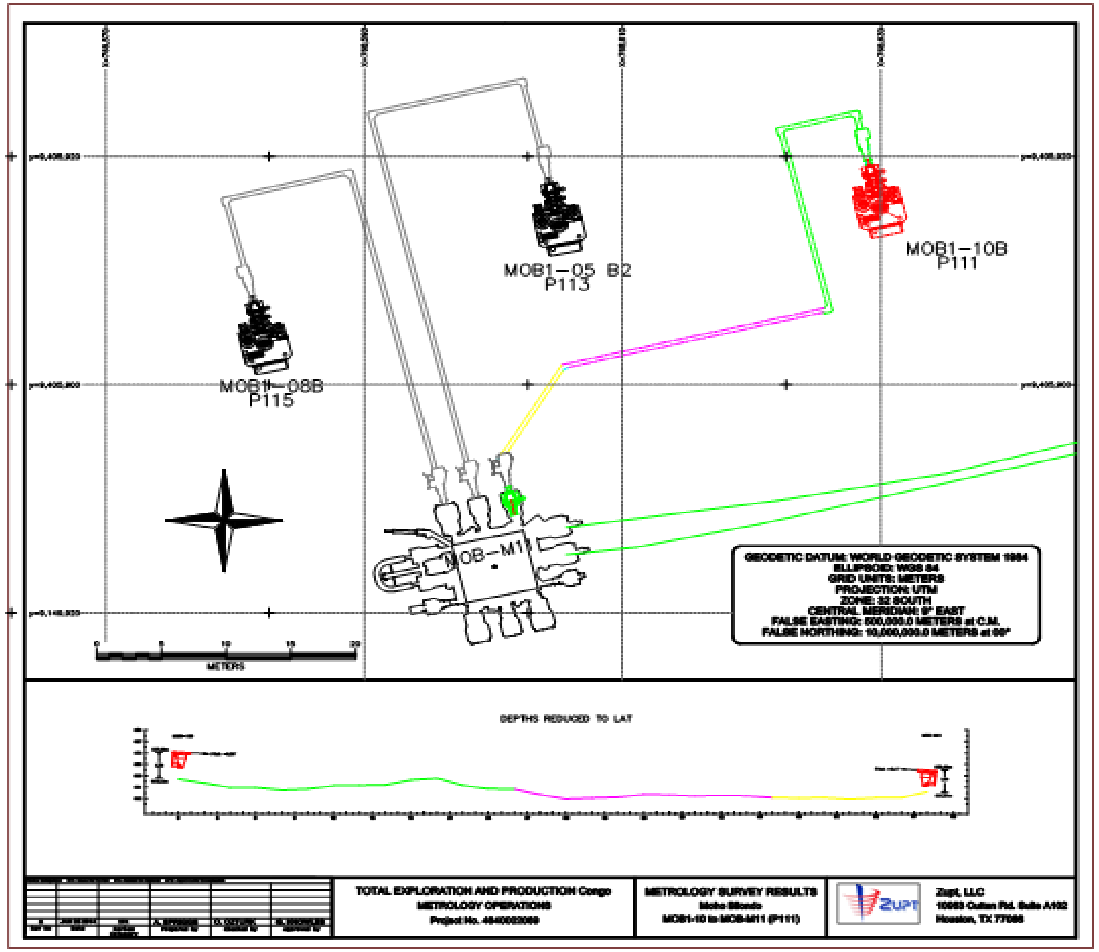
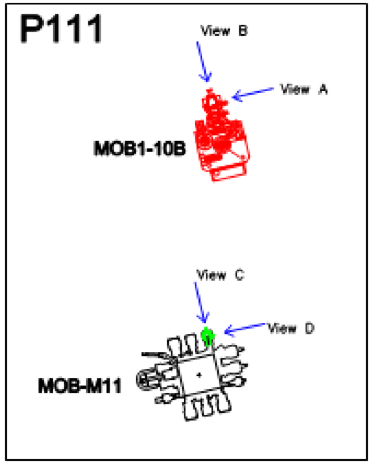
Offshore Deliverable

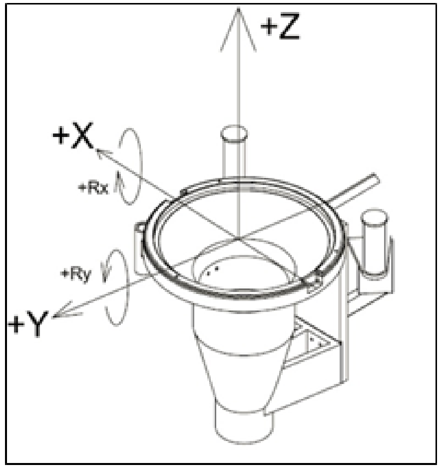
Bathymetry Data

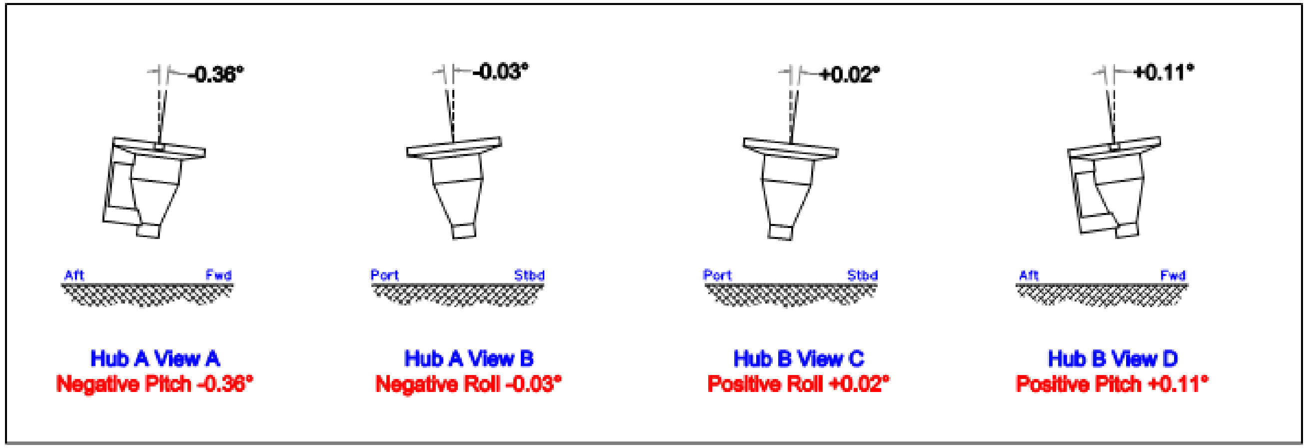


Offshore Deliverable

Attitude Data





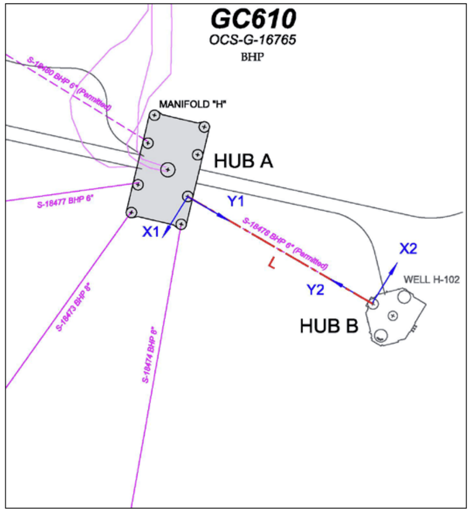


Offshore Deliverable

Metrology Results – GC610 - Manifold H to Well H-102

Parameter	Variable	Metrology Result	Notes
Horizontal Distance	L	64.25	True Horizontal Distance
Manifold H Hub A **Pitch**	**X1** Rotation around X1	-0.24°	**Forward Down** - in the direction of the jumper at Manifold H
Manifold H Hub A **Roll**	**Y1** Rotation around Y1	+0.33°	**Port Up**– in the direction of the jumper at Manifold H
Well H-102 Hub B **Pitch**	**X2** Rotation around X2	+0.07°	**Forward Up** – in the direction of the jumper at the Well H-102
Well H-102 Hub B **Roll**	**Y2** Rotation around Y2	-0.16°	**Port Down** – in the direction of the jumper at the Well H-102
Difference in Depth	Z	0.65	**Manifold H is deeper** Vertical reference with cap offsets

Note: All distances are in feet.
All angles are in degrees.
Combined scale factor from UTM positions to true = 1.00082233



	Name	Position	Date
Computed	Geoffrey Knowles	Party Chief	October 29, 2013
	Quinn Guidry	INS Surveyor	
	Timothy Griffin	Project Manager	

NOTES:
1. Metrology completed on October 27, 2013.
2. Data computed from C-PINS inertial metrology.
3. Differential leveling measured with an external Digiquartz sensor.
4. Bathymetry measured with an external Digiquartz sensor.
5. Measurements at Well H-102 had a higher standard deviation than measurements at Manifold H due to circulation induced vibration.

IFR - ODEL-GC610-H Manifold to Well H-102-10292013 Rev0

bhpbilliton	BHP BILLITON GC610 METROLOGY OPERATIONS PROJECT NO. 130946	METROLOGY SURVEY RESULTS GC610 Well H-102 BHP 6" - SEG NO. 18478	ZUPT, LLC 10963 CUTTEN RD, SUITE A102 HOUSTON, TX 77066

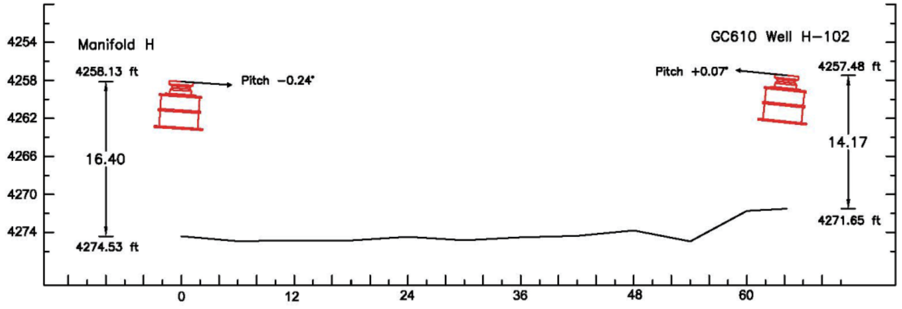
Page 1 ODEL-GC610-H Manifold to Well H-102-10292013 Rev0

Offshore Deliverable

C&C Technologies

Bathymetry Data - GC610 - Manifold H to Well H-102

ZUPT



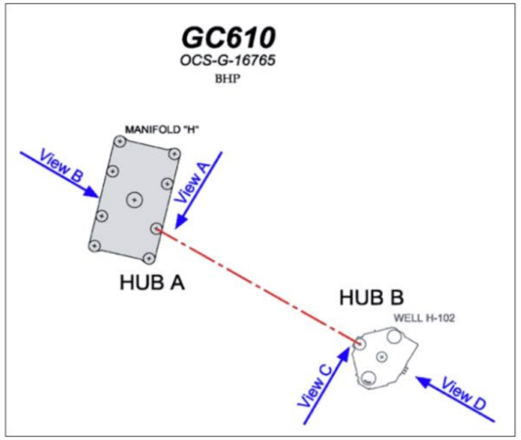
Description	Depth (ft)
Manifold H Hub	4258.13
Manifold H Mudline	4274.53
6’ from Manifold in jumper direction	4274.9
12’ from Manifold in jumper direction	4274.8
18’ from Manifold in jumper direction	4274.8
24’ from Manifold in jumper direction	4274.5
30’ from Manifold in jumper direction	4274.8
36’ from Manifold in jumper direction	4274.5
42’ from Manifold in jumper direction	4274.4
48’ from Manifold in jumper direction	4273.8
54’ from Manifold in jumper direction	4272.9
60’ from Manifold in jumper direction	4271.7
Well H-102 Mudline	4271.65
Well H-102 Hub	4257.48

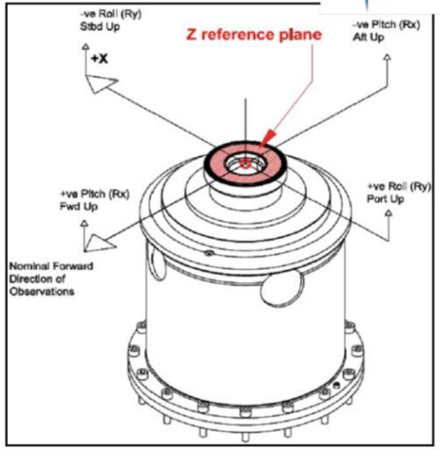
bhpbilliton	BHP BILLITON GC610 METROLOGY OPERATIONS PROJECT NO. 130946	METROLOGY SURVEY RESULTS GC610 Well H-102 BHP 6" - SEG NO. 18478	ZUPT, LLC 10963 CUTTEN RD, SUITE A102 HOUSTON, TX 77066

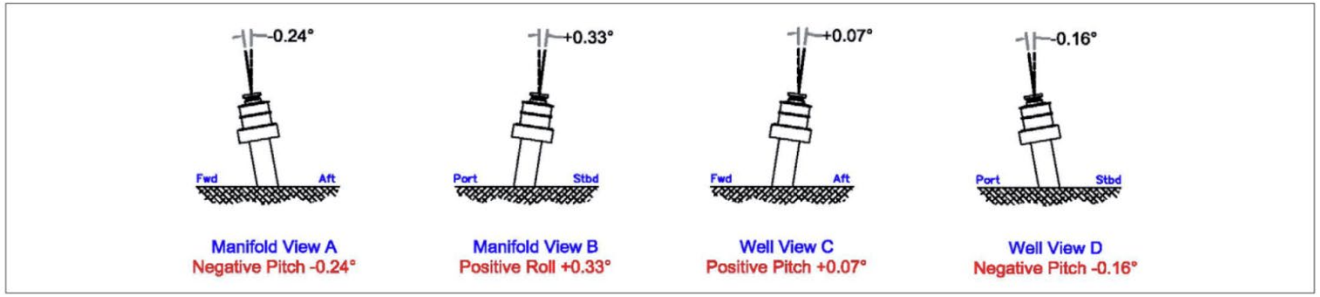
Offshore Deliverable

C&C Technologies

Attitude Data – GC610 - Manifold H to Well H-102







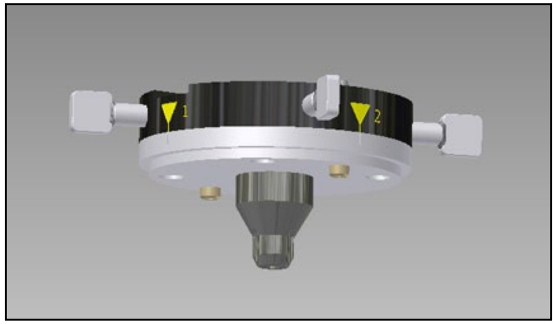
bhpbilliton	BHP BILLITON GC610 METROLOGY OPERATIONS PROJECT NO. 130946	METROLOGY SURVEY RESULTS GC610 Well H-102 BHP 6" - SEG NO. 18478	ZUPT, LLC 10963 CUTTEN RD, SUITE A102 HOUSTON, TX 77066

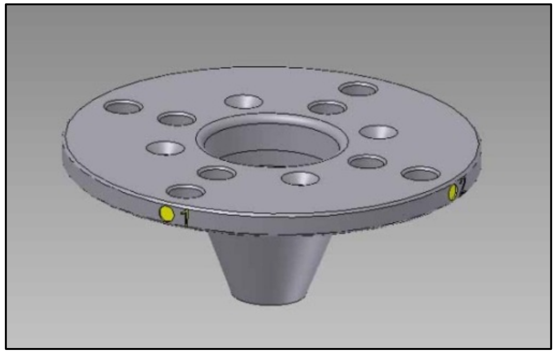
Page 3

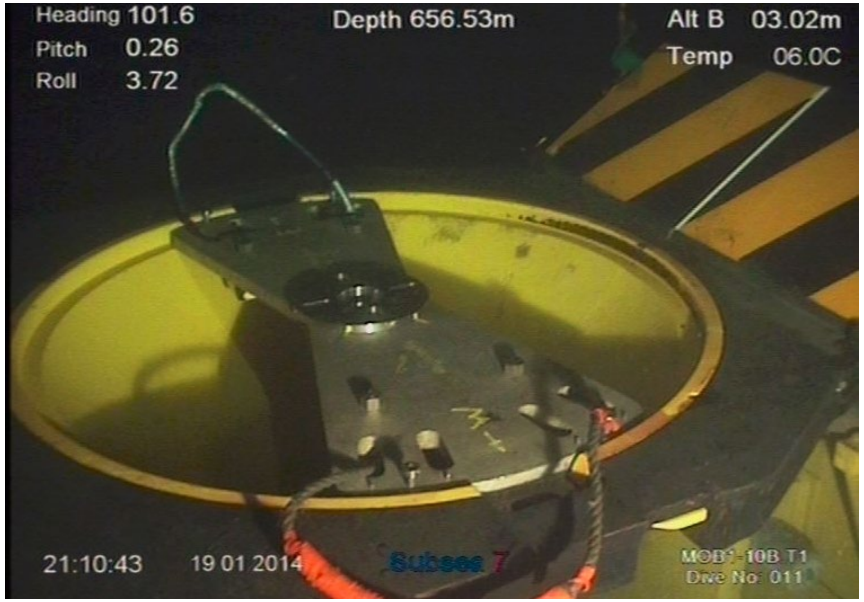
ODEL-GC610-H Manifold to Well H-102-10292013 Rev0

Tooling

We believe that the definition of the mechanical interface is **critical to a successful metrology**. Zupt has multiple tooling options available and has designed many tools for unique operational constraints. We prefer to use standard receptacles wherever possible. We have completed precise dimension control surveys of both stabs and receptacles as a part of several of our projects.







DC – Offsets and Accuracy

If possible, we would like some involvement in yard DC work – or the ability to understand the quality of the DC work.

Hopefully receptacles are close to hub and accessible.

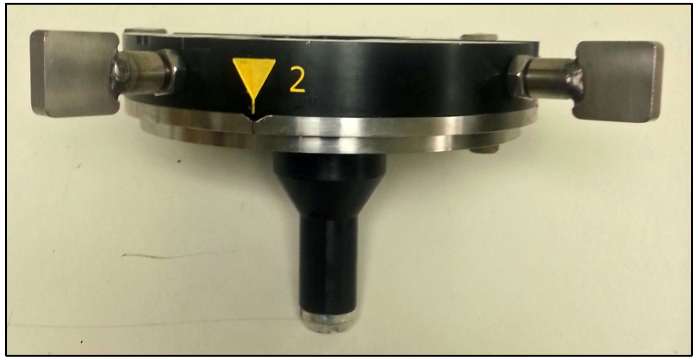
Make sure both linear and angular lever arms are measured.

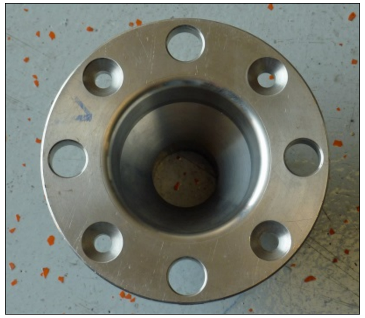
In some instances, we work with both a fixed receptacle away from the hub and tooling that installed onto the hub face.

Tooling

We believe that the mechanical interface to the structure is one of the ***most critical issues*** that impacts the ***accuracy, efficiency*** and ***quality*** of metrology surveys.

OR





Tooling

Does it matter that the stab has an interference fit with the receptacle – or if we can stab the tool in faster.

OR

OR

Slightly longer stabs make up easier.
Protect the nose of the stab and it will always fit

Tooling

Complete a make up test of tooling if at all possible.

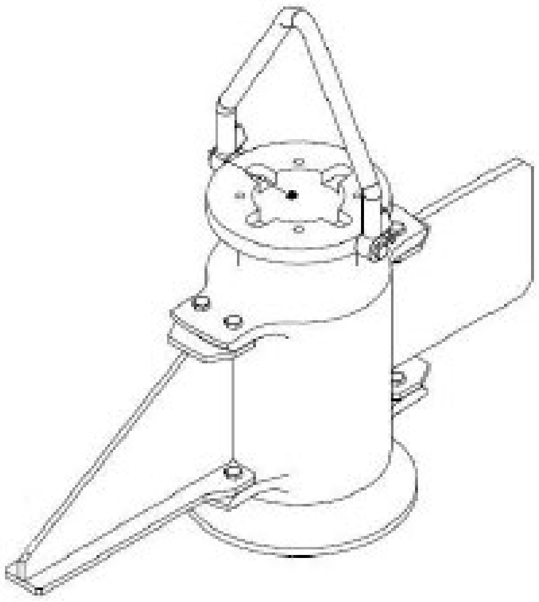
Good

Bad

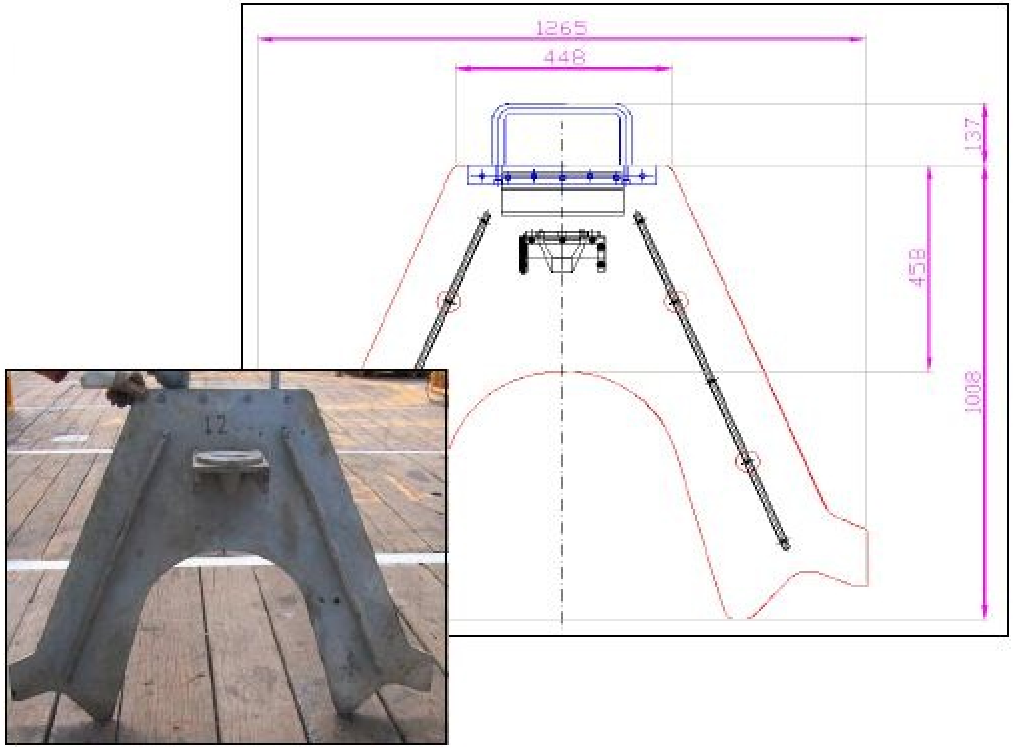
Tooling

Some inappropriate client provided tooling and inappropriate plastic receptacles.

Tooling Examples



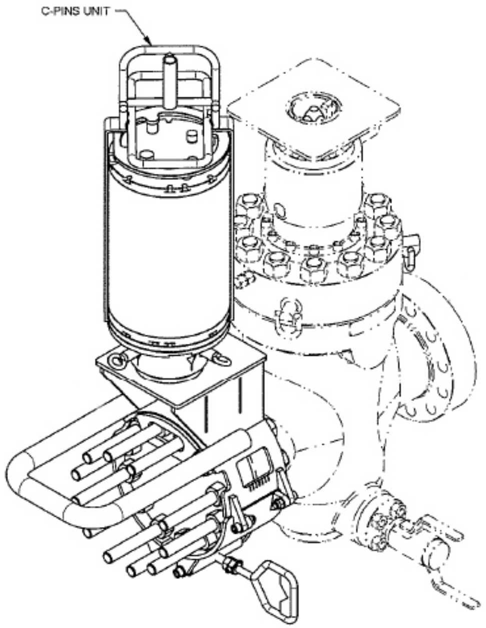
CLOV Tool



Trouser Plate

Tooling Examples

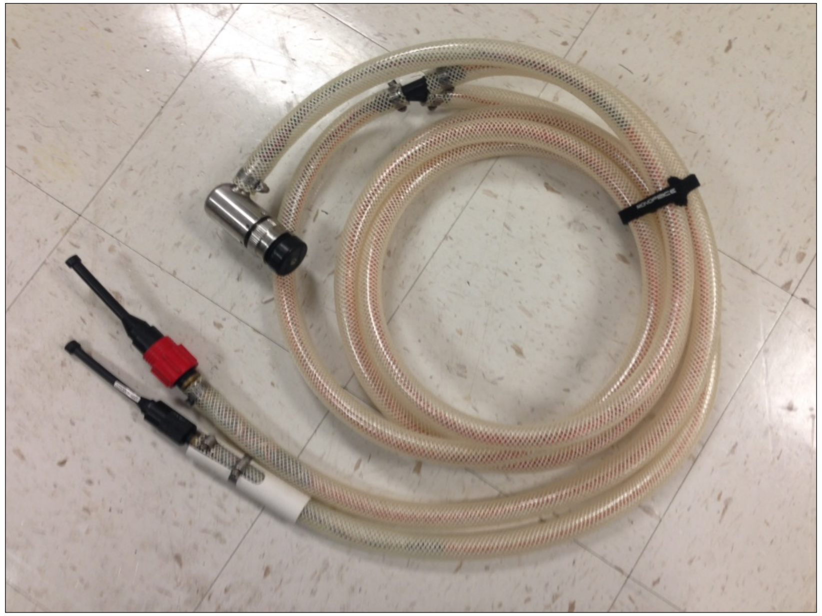
Vertical connector standard in GoM



Brownfield existing jumper measurements

ROV Operational Issues

Cabling – ground faults and make up time!!



OR

Equipment Footprint

Currently the system components (qty 2 C-PINS systems, 2 sets of external sensors, cabling, tooling and 2 laptops, etc.) are housed in 4 shipping cases for domestic use and can be flown or sent offshore via crew boat.

For international shipment additional shipping cases are required for the long term support spares, printers, additional tool cases, Scotchcast as well as multiple ROV lifting tools and assorted cabling (apx. $2m^3$).

International

GoM

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What is a System?

Two of everything:

C-PINS
Tooling stabs
Lifting Hardware
Cabling (PBOF and rubber)
Surface PC's /w SSTT Software

CTD (Seabird SBE 19+ or AML Minos X)

Digiquartz Pressure Sensor (rated for project)

Vaisala Surface Barometer

If flying the route survey:

Tritech Altimeter PA200
Valeport Mini SVS

Metrology Conclusions

Mature and fully proven – if you have a place to stab inertial metrology works
Accurate
+/- 30mm to 15m jumper/spool length
+/- 50mm to 50m
+/- 75mm to 90m
+/- 100mm for longer lengths <150m
Practical – clients can QC our data within hours of first exposure
Very efficient (much less boat/rig time needed) ~ 6 hours for full metrology including route survey

- Works in the presence of drilling noise and vibration
- No "line of sight needed"
- Smaller footprint - less people on board (POB) – less bunk space needed
- Vessel independent – MSV, divers or a rig – no need for USBL
- Connector independent – Horizontal, Vertical, SHO, PLET, FLET etc.
- One channel needed from ROV – hence very fast ROV mob time
- Inertial needs no vessel time to deploy array frames or complex subsea stands

Contact Info

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