Zupt's Inertial Survey Tools:

Metrology

Contents

Metrology surveys – we need to be:

Very ***efficient***

While delivering the required ***accuracy***

With known ***quality***.

Topics today:

Dimensional Control and offsets

Mechanical interfaces between instruments and structures

ROV operational issues

Bathymetry surveys

Quality control displays while collecting data

Offshore deliverables

Proven technology

Zupt has been in business since 2005, operating offshore since 2007 – first commercial client for metrology early 2008. To date we have commercially delivered **>100 inertial metrologies** in:

Regions:
West Africa rigs and survey vessels
U.S. Gulf of Mexico rigs and survey vessels
North Sea from rig
Bahamas (42" dia. spool) shallow water barge with divers

Fields worked:
Angola: Shenzi, Pazflor, Girassol, CLOV, Dahlia, Girri
Congo: Moho Bilondo
GoM: Mississippi Canyon, Green Canyon
North Sea: Pelican

Clients:
Total, BHP Billiton, Shell, LLOG, C&C Technologies, TAQA, Acergy, Statoil, Jan de Nul. Near term future work in Malaysia & Russia?

Inertial Metrology

Mature and fully proven – if you have a place to stab inertial will work

Accurate: +/- 25mm to 20m jumper/spool length
+/- 50mm to 50m jumper/spool length
+/- 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

One more time - what is needed?

Deliverables from a metrology:

When we look at ***accuracy***, ***efficiency*** and ***quality*** we have to understand the subtle issues associated with all of the deliverable components required of a metrology survey:

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

We spend more time acquiring the bathy than we do the distance or attitude data. We spend more time processing the bathy as well.

DC - Offsets and accuracy

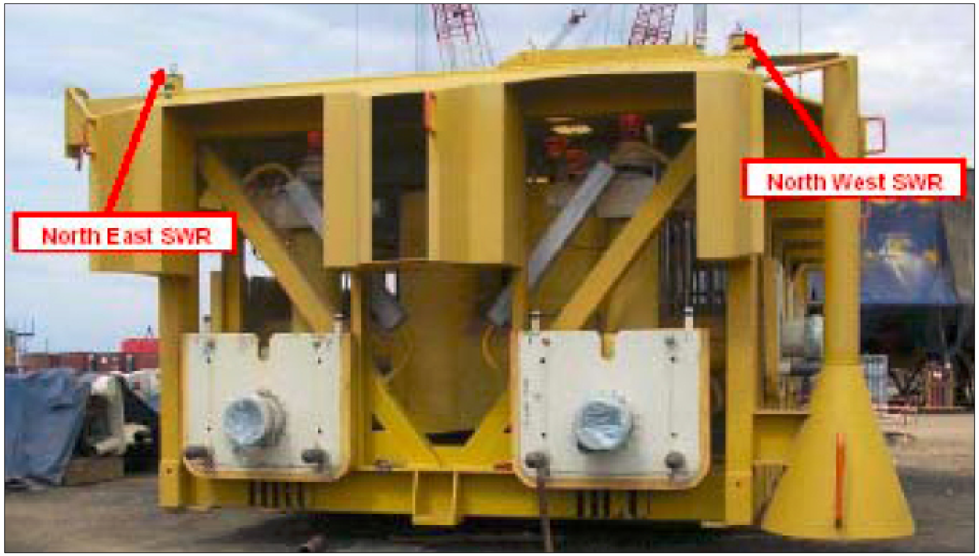
Sounds obvious – BUT!

Install receptacles or survey points close to hub

Make sure it is accessible

Make sure both linear and angular lever arms are measured.

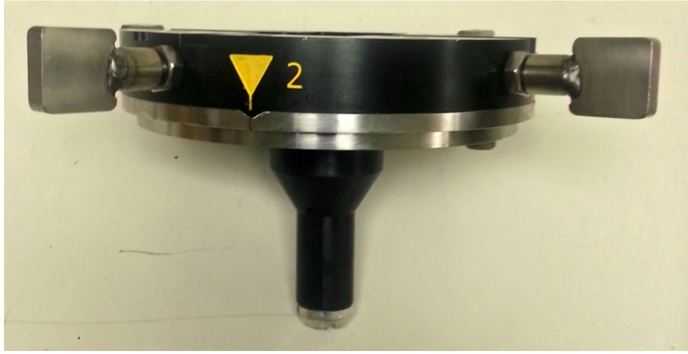
Is it better to have a fixed receptacle further away, or tooling that is installed onto the hub face? Both!

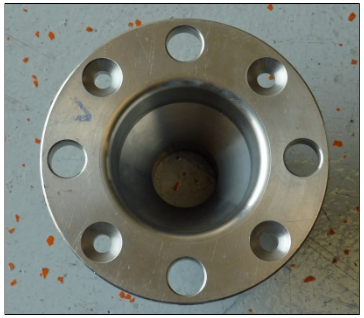


Tooling

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

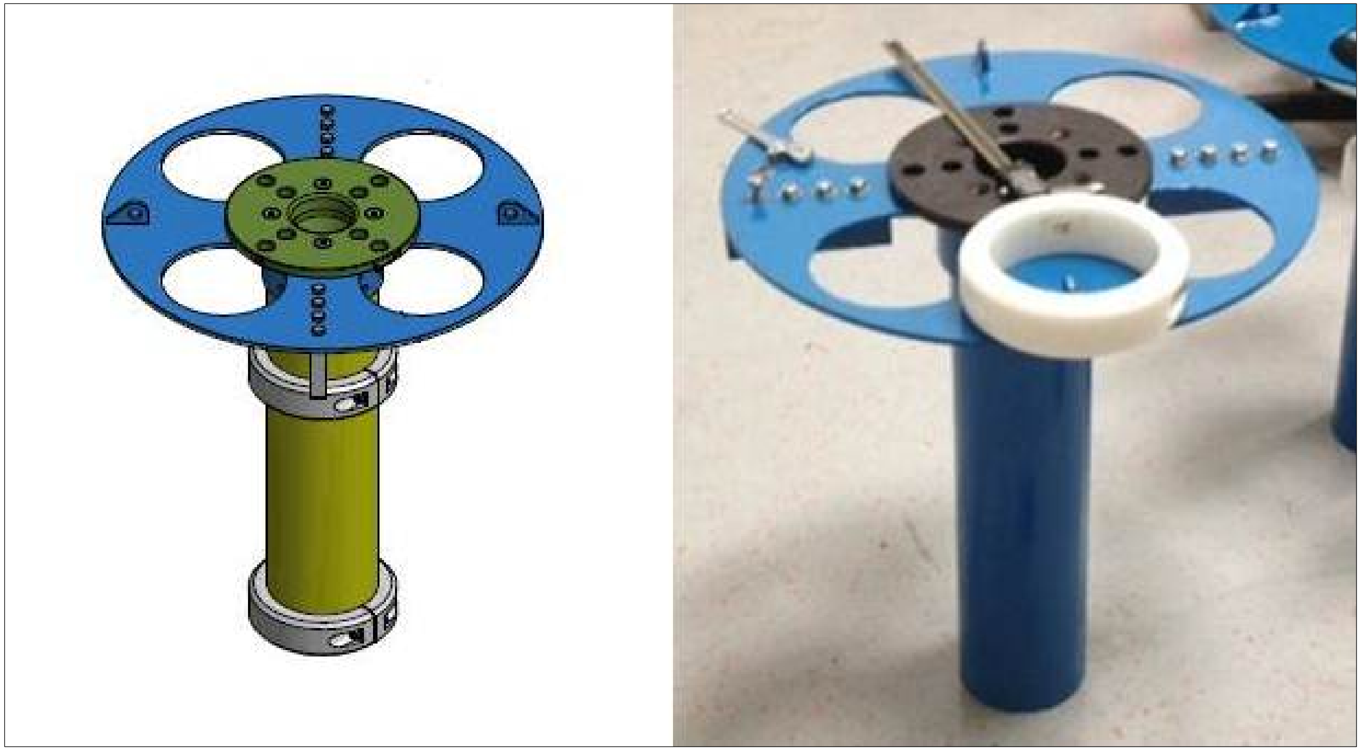
Good

Bad

Tooling

Do not make the tooling overly heavy – if it is going to be used in a "plastic receptacle" – it will break the receptacle!

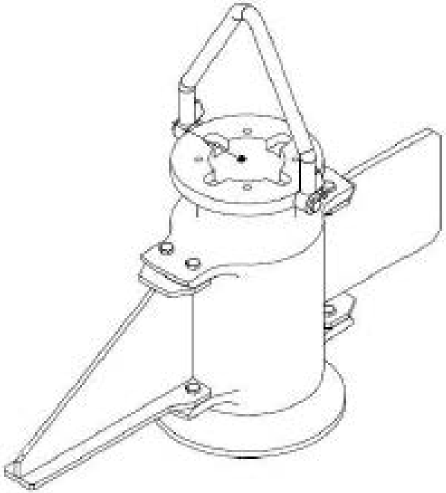
Tooling Examples



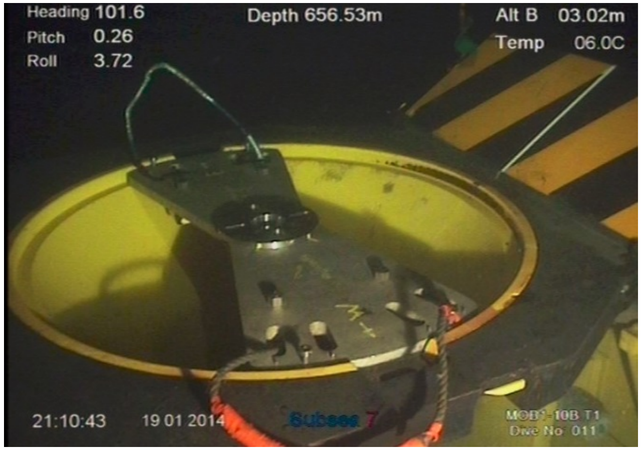
Aligning an inertial system in a Compatt frame - Bucket Stab

Tooling Examples

CLOV Tool



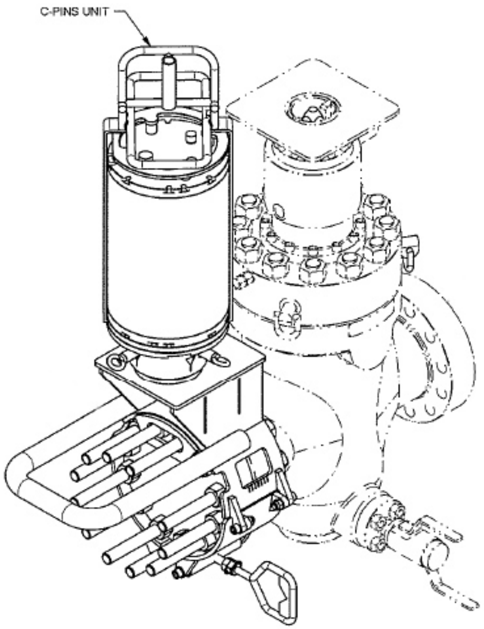
Trouser Plate



“Wine glass” and
“SRIP” plate

Tooling Examples

Vertical connector – pressure cap
No heading required



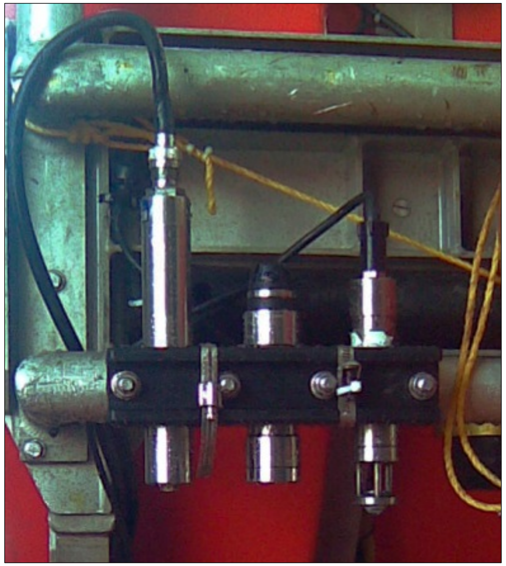
Brownfield measurements on
existing installations

ROV operational issues

Power: 24V dc, 75W (battery back up internal to our tool)

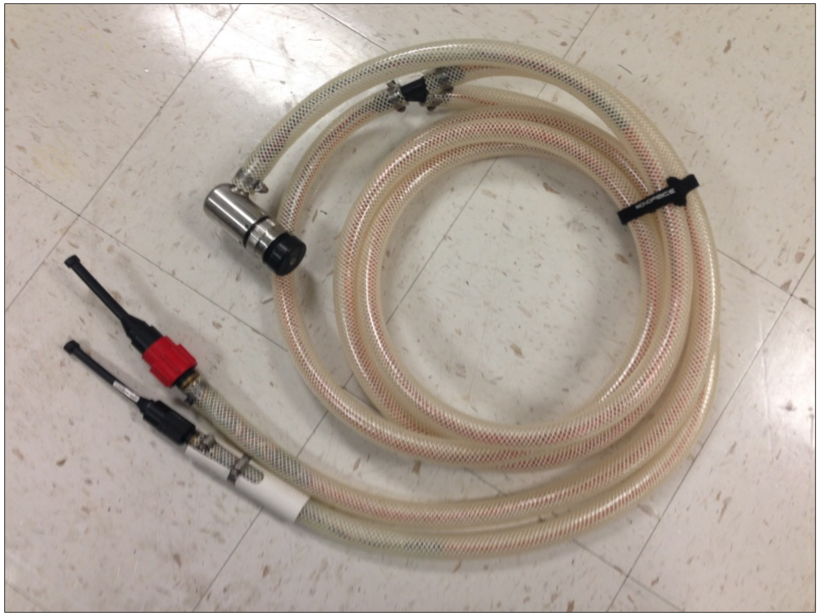
Communications: A single RS232 115,200 (can live with 38,400) baud rate com port.

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



ROV operational issues

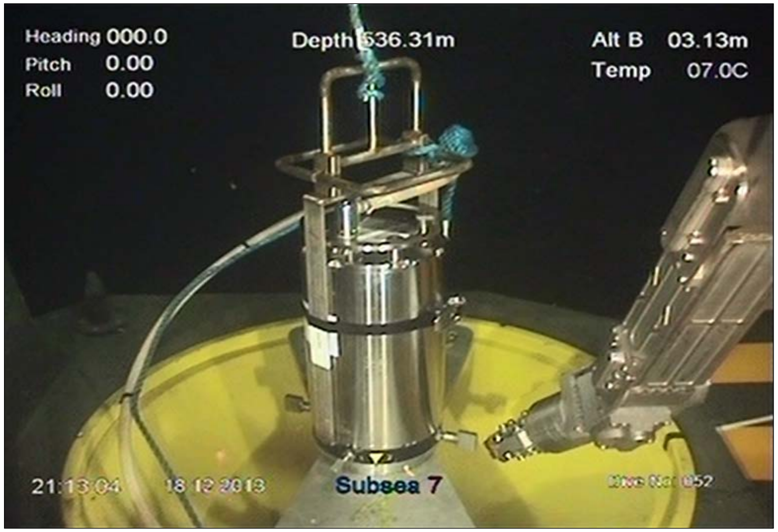
Cabling – ground faults and make up time!!

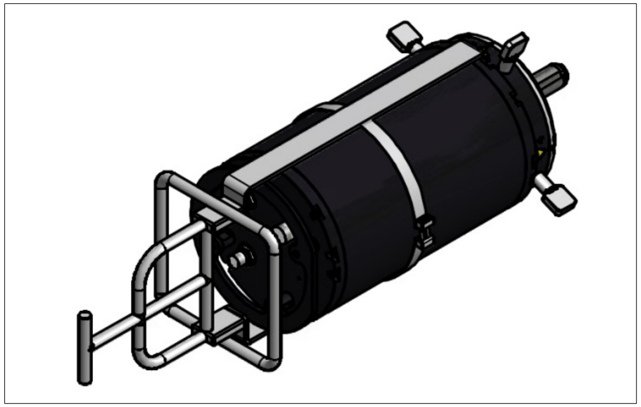


OR

ROV operational issues

Lifting and handling - T, Fishtail – manipulator compliant

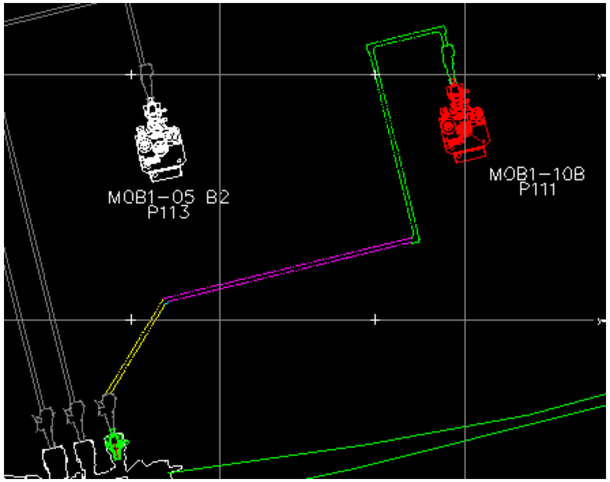


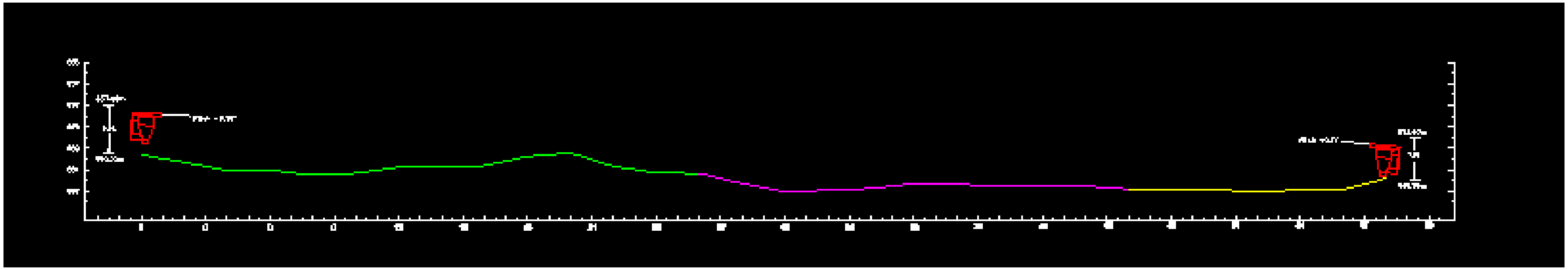


Bathy Survey - step or fly?

Step Bathymetric Survey (Digiquartz)
Log position every 2 m along jumper route with Digiquartz.

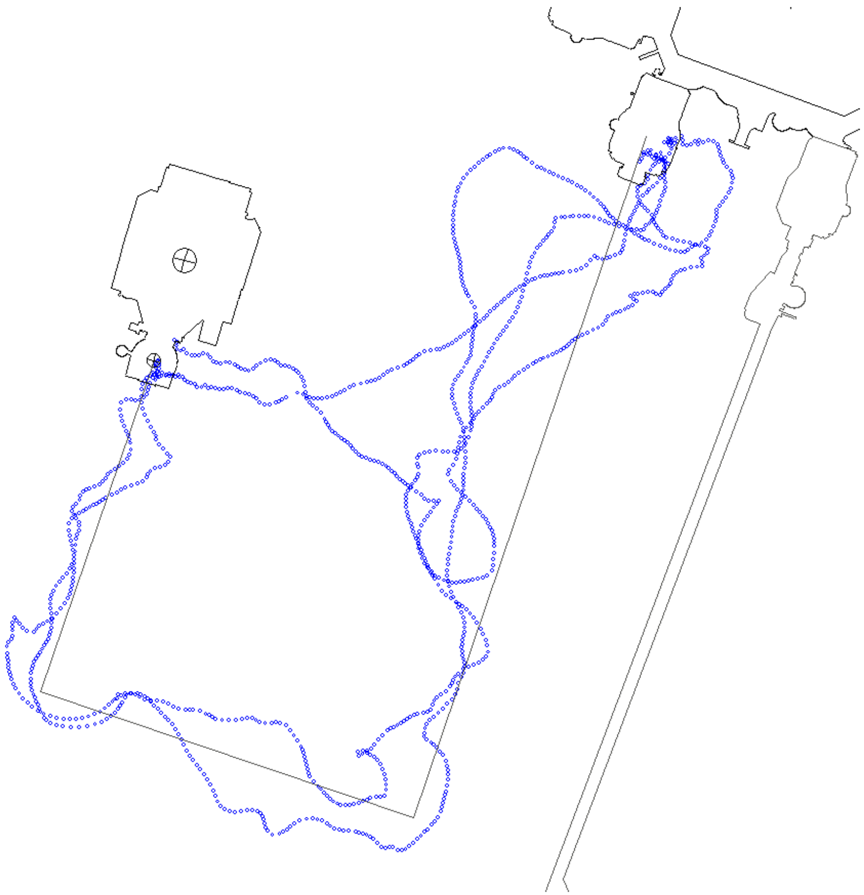
Fly
Using mini SVS and an Altimeter in addition to the Digiquartz we fly the route





Fly the route or Step the route?

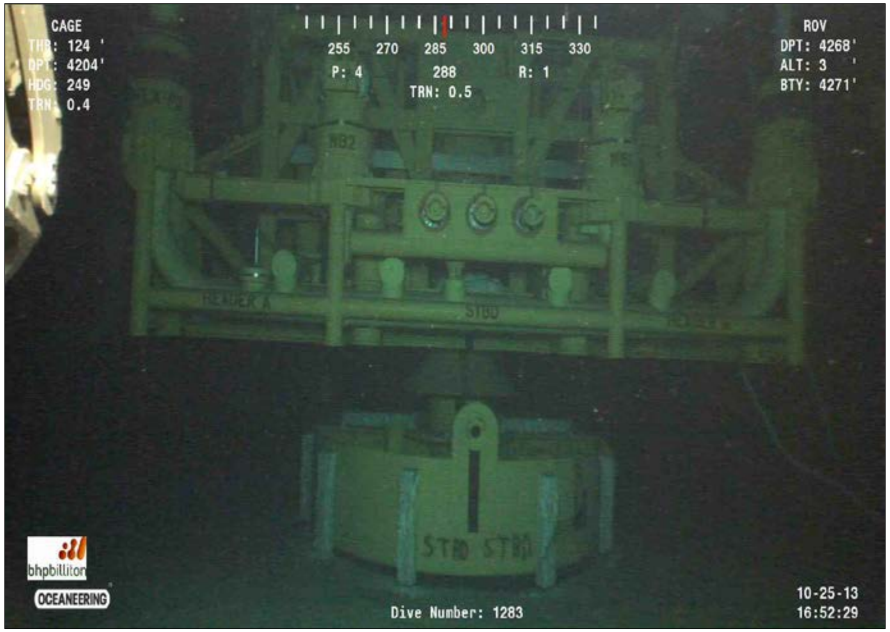
Why don't we always fly the route survey?



Step Height Survey

Step Height Survey

Top of hub to plant North mudline depth measurements



Step Height 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.

Quality required

Zupt uses our proprietary software for data acquisition and on-line QC - SSTT (Sub Sea Time Tag)

Our ***real time QC*** lets us know when we have a valid data set with the quality specified as we are working.

Accuracies we have within current contracts:

Hub to Hub Horizontal Range	+/- 50mm-+/- 75mm
Hub Attitude (Heading, Pitch, Roll)	+/- °0.5
Alpha / Beta Angles between Hubs	+/- °0.5
Hub Step Heights	+/- 75mm
Depth Difference between Hubs	+/- 50mm
Bathymetric Profile of Jumper Route	Not specified

Real-time quality control

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

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

Position loop selection on the left.

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

<u>*We know when we are done!*</u>

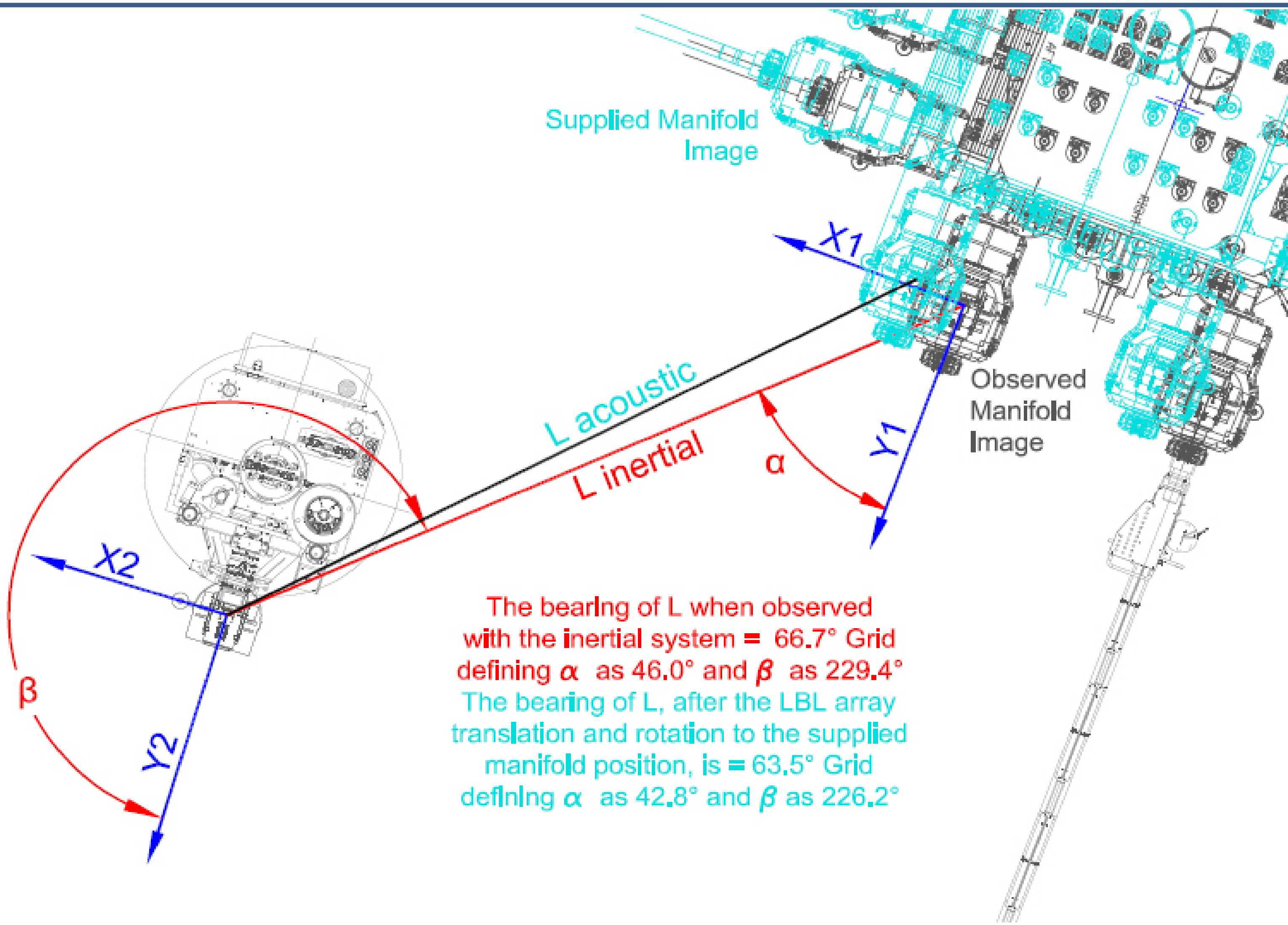
SD at ~65% of client spec.

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

Alpha and Beta angle quality



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 for jumper fabrication.

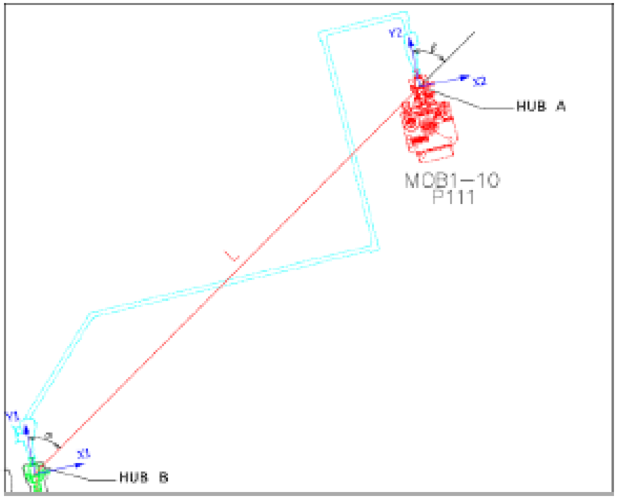
All of our data is sent emailed to Houston for QC during and immediately upon completion of survey(24/7/365). Client is issued raw data within an hour of survey completion.

Results delivered within min 12 hours, max 24 hours of data acquisition.

Offshore Deliverable

Metrology Result MOB1-10 P111 M11

	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

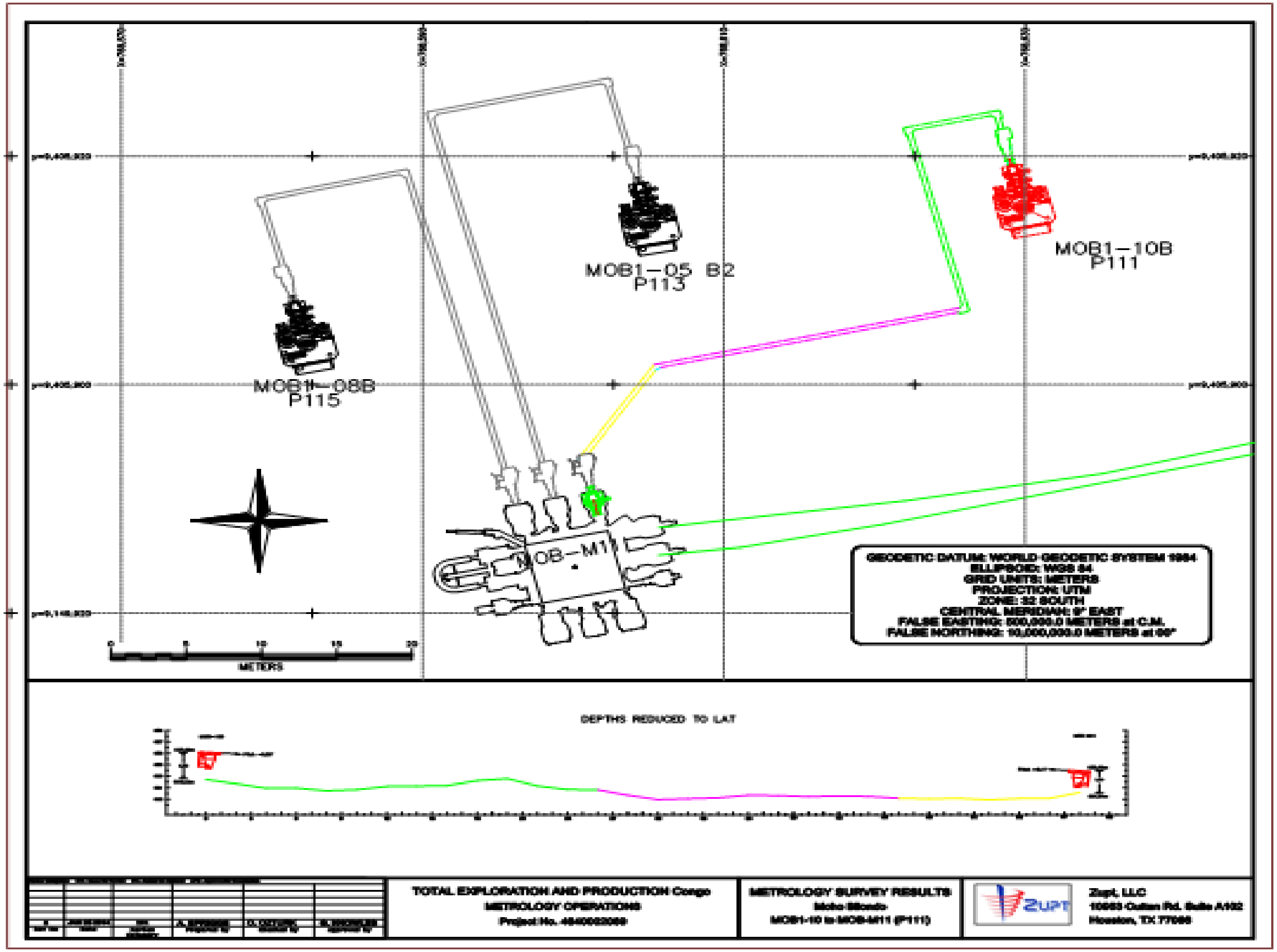
NOTES:
1. Data computed from C-PINS inertial navigation system
2. Data collected onboard the GSF135 Jan 24th and 25st 2014
3. Differential depths established using C-PINS inertial system
4. Bathymetry established using external Digiquartz pressure sensor

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

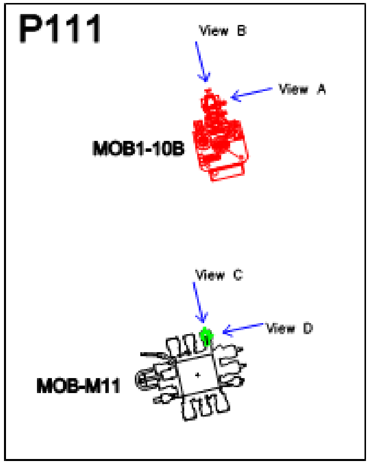
Offshore Deliverable

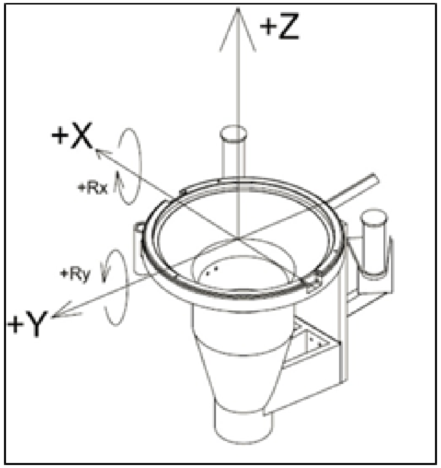
Bathymetry Data

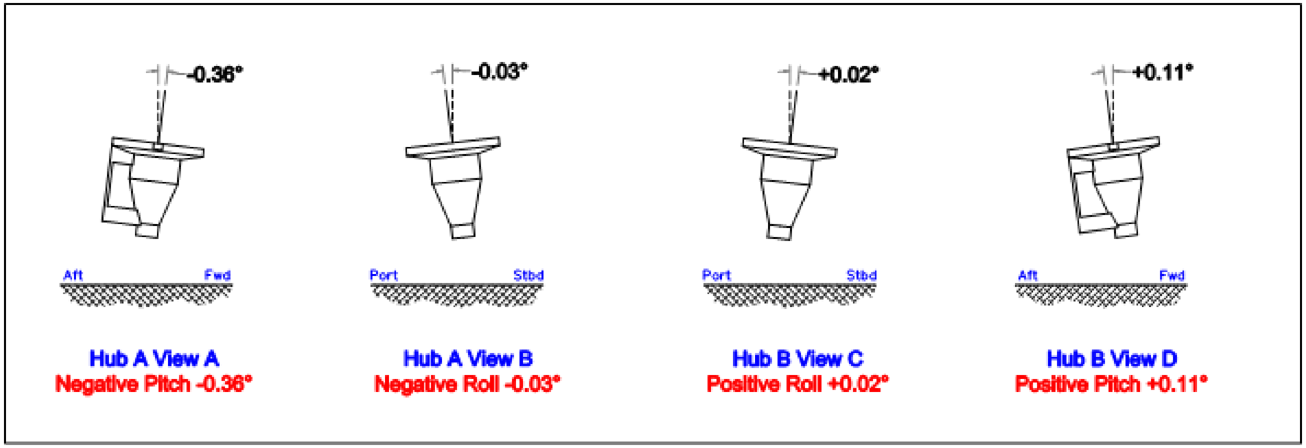


Offshore Deliverable

Attitude Data







Offshore Deliverable

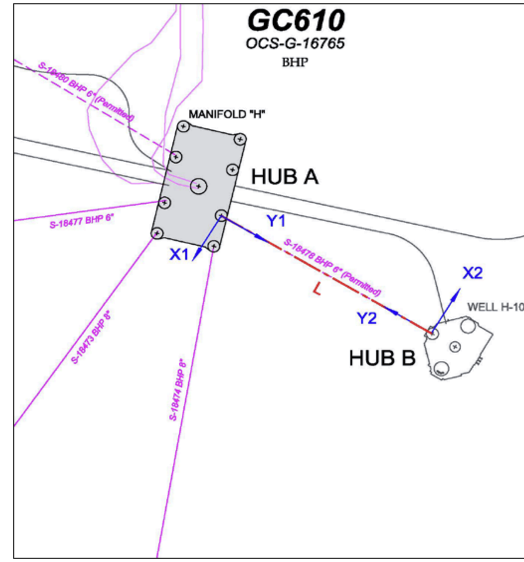
C&C Technologies

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

ZUPT

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

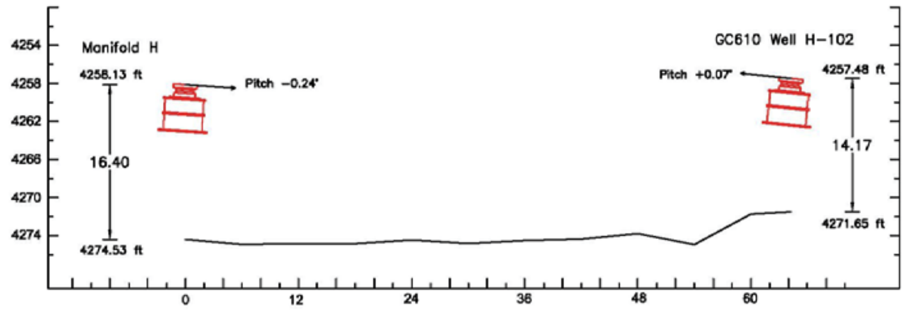
bhpbilliton	BHP BILLITON GC610 METROLOGY OPERATIONS PROJECT NO. 130946	METROLOGY SURVEY RESULTS GC610 Well H-102 BHP 6" - SEG NO. 18478	ZUPT, LLC 10963 CUTTEN RD, SUITE A102 HOUSTON, TX 77066

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

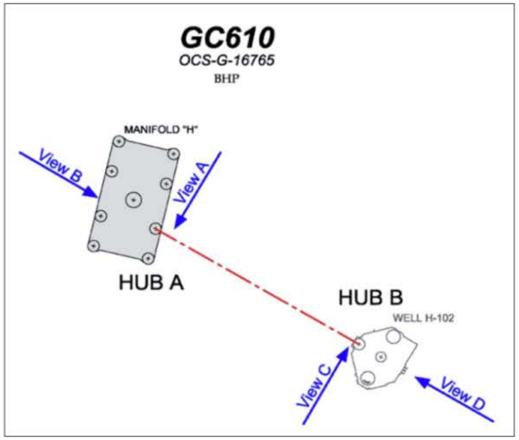
bhpbilliton	BHP BILLITON GC610 METROLOGY OPERATIONS PROJECT NO. 130946	METROLOGY SURVEY RESULTS GC610 Well H-102 BHP 6" - SEG NO. 18478	ZUPT, LLC 10963 CUTTEN RD, SUITE A102 HOUSTON, TX 77066

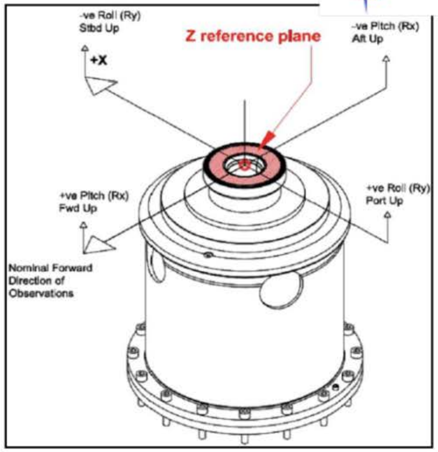
Offshore Deliverable

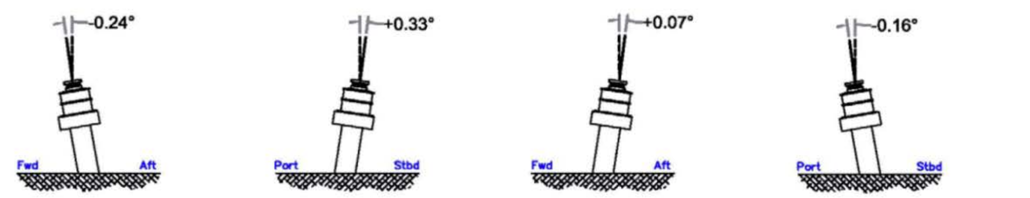
C&C Technologies

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

ZUPT







Manifold View A
Negative Pitch -0.24°

Manifold View B
Positive Roll +0.33°

Well View C
Positive Pitch +0.07°

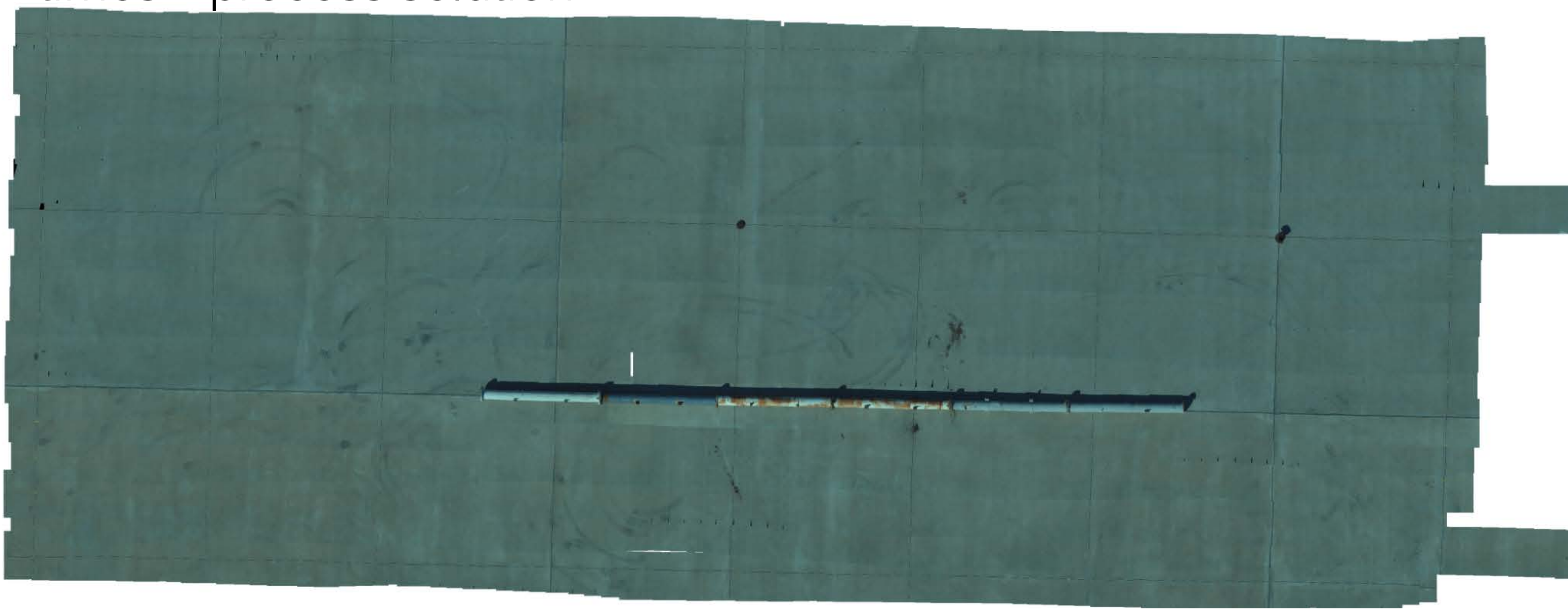
Well View D
Negative Pitch -0.16°

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

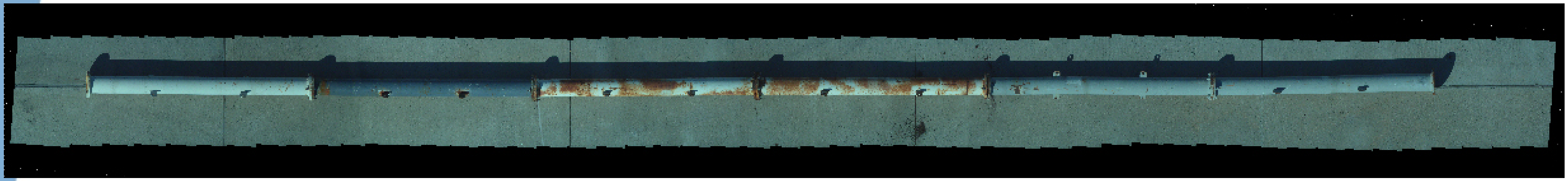
Metrology from imaging?

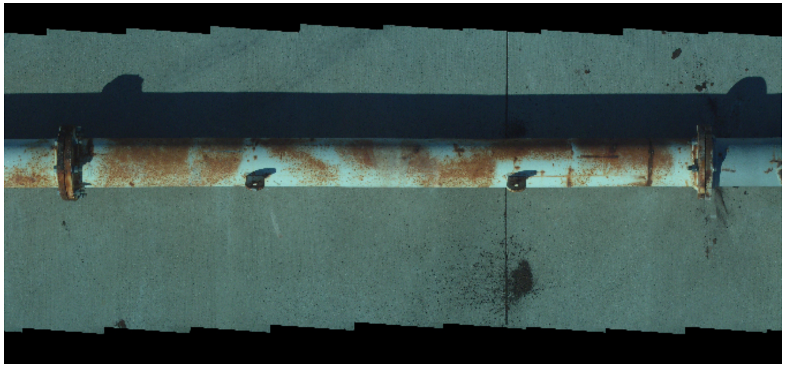
The next generation – "Fly by metrology"

Precise measurements made within photogrammetry like data collected by frame grabbing video imagery – fly the route a few times – process solution.



High resolution, geospatially correct





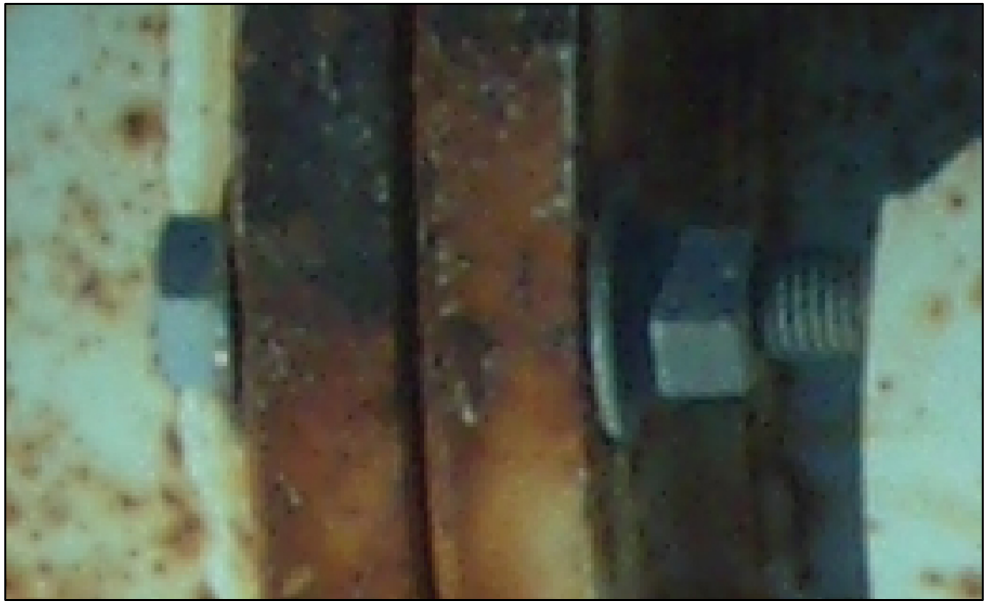
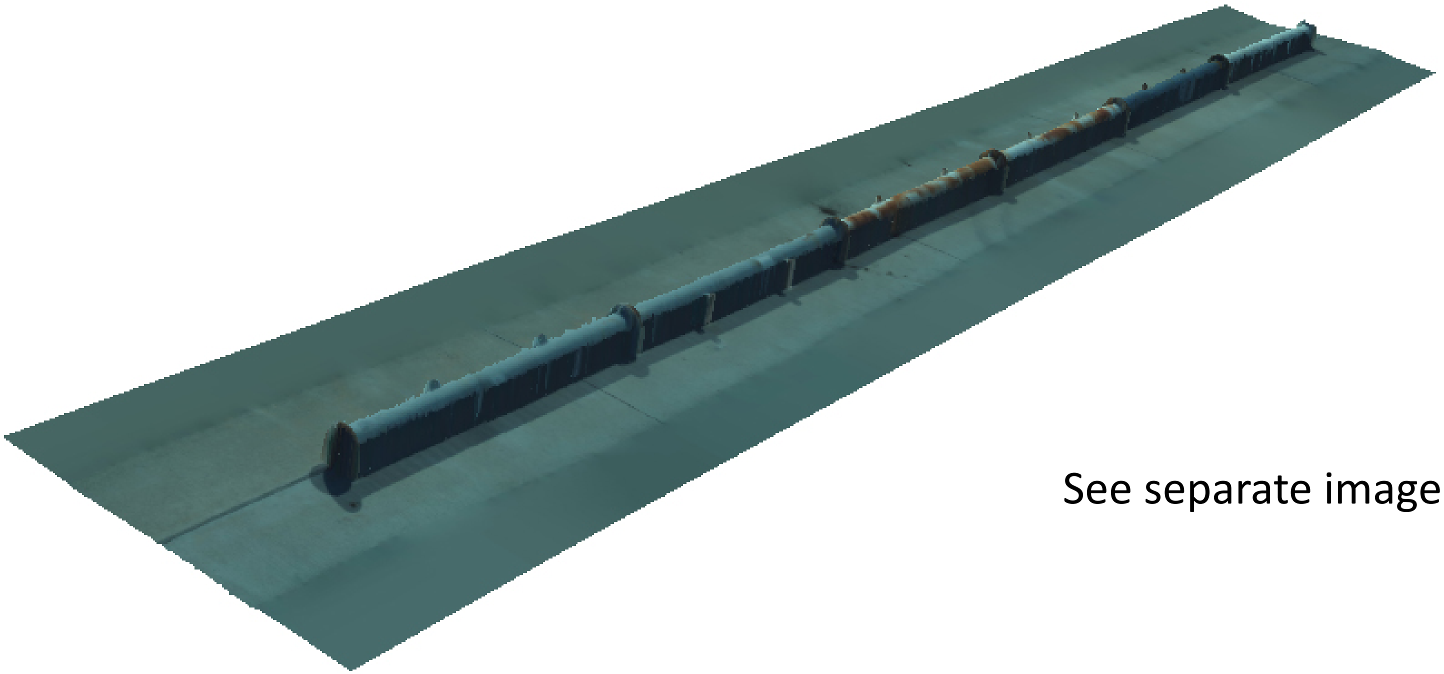
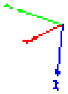


Image based metrology



See separate image



Thank You

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