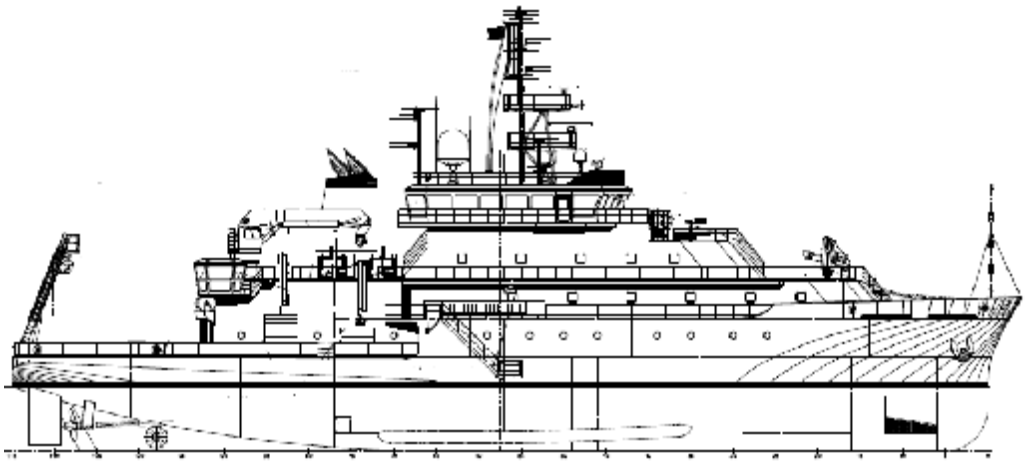
R/V NEIL ARMSTRONG (AGOR 27)
SENSOR ALIGNMENT & ORTHOGONAL COORDINATE SURVEY
JANUARY/FEBRUARY 2016

FINAL REPORT

February 8, 2016 Rev - 0



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PROJECT OVERVIEW

General Comments- Tasks performed

This report summarizes coordinate measurement data taken on the vessel Neil Armstrong, December 27, 2015 thru February 2, 2016. The vessel was in a graving dock at Detyens Shipyard, North Charleston SC.

Coordinate measurements were taken to characterize the vessel and create the required reference coordinate system for reporting azimuth, pitch, and roll and coordinate data.

Measurements were taken to determine the coordinate location specified elements. Benchmarks were installed.

Survey crew assisted shipyard personnel in aligning transducer frames prior to drilling hull.

3-D Coordinate Measurement Equipment

Temporary "benchmarks" or reference points were placed throughout the vessel as required to allow for re-locating the instrument to a new position or "Station" and tie all of the data to the common coordinate system for comparison.

The measuring system used for this final inspection report is one of several owned by The IMTEC Group, Ltd. The NET 1200 total station, S/N 110554 was calibrated, traceable to N.I.S.T. and in accordance with A.N.S.I. Z-540-1, at the Sokkia USA Factory Service Center November 17, 2015

Reference Coordinate System

The following parameters were used to define the reference coordinate system for reporting the survey data:

A Keel survey was performed determining the centerline near Frames 5,9,18,25,38,49,58,67,76,81,89,and 95. A best-fit line faired through was used as the ships zero heading (azimuth).

Athwart ship hull points were measured at the keel from Frame 5 to 58. The inclination of a best-fit plane through these points was used as the ships pitch and roll axis as docked.

WHOI coordinate system origin is at Forward Perpendicular at the Base Line.
The X-axis is positive aft, the Y-axis is positive port and the Z-axis is positive towards the keel.

Kongsberg coordinate system origin is at the Primary Granite Block. The X-axis is positive Forward, the Y-axis is positive Starboard and the Z-axis is positive towards the keel.

Measurement Procedure

Adhesive targets with retro reflective target face were used throughout the survey as temporary benchmarks for relocating the instrument to new stations. Kinematic (a target with a known offset) retro reflective targets such as the RT-50M swivel targets used to measure some of the features defining the specified elements to be reported. Where possible, a retro reflective surface target was used to eliminate any offsets.

3-D X, Y, Z coordinates, Post Processing

In some cases, the features or targets defining the elements required by the survey were made to a kinematic target with a known offset orthogonal to the vessel’s final reference coordinate system. After the each survey was complete, these offsets were applied to report the final X, Y, Z value of the element.

Data files

One measurement file was used to perform the survey.

All measurement files were backed up at the completion of a set of observations from a particular station and on a daily basis.

This vessel coordinate system was created from the initial characterization file.

Station transformations are used to bring a new instrument location into the current vessel coordinate system. The result produces some residuals.

Measurement Precision and Uncertainty

Point to Point, any element or target within the vessel survey to another element or feature in the survey

$X, Y, \& Z \leq 2.3$ mm

Region to Region, i.e., keel features to DGPS antenna

$X \leq 3$ mm
$Y \leq 3$ mm
$Z \leq 4$ mm

Angular precision is based on analysis of features measured and calculation of the mathematical relationship of these features.

The angular measurement precision of the NET1200 is < 1 arc second in azimuth and zenith. There can be some error introduced by targeting. Random and systematic errors can be introduced by the working environment.

The expected angular precision is analyzed to be:

Azimuth:	≤ 00° 00' 30"
Pitch:	≤ 00° 01' 00"
Roll:	≤ 00° 01' 00"

PROJECT DATA

Element and benchmark coordinates are reported in two coordinate systems. The Kongsberg system has origin at the Primary Granite Block; the WHOI system has the origin at the intersection of the forward perpendicular at the base line. All coordinates are in meters.

The draft mark table is reported in feet.

FWD DRAFT MARKS (FT)			AFT DRAFT MARKS (FT)		
MARK	STBD	PORT	MARK	STBD	PORT
10	10.0	10.0	10	10.1	10.1
11	11.0	11.0	11	11.1	11.1
12	12.0	12.0	12	12.1	12.1
13	13.0	13.0	13	13.1	13.1
14	14.0	14.0	14	14.1	14.1
15	15.0	15.0	15	15.1	15.1
16	16.0	16.0	16	16.1	16.1
17	17.0	17.0	17	17.1	17.1

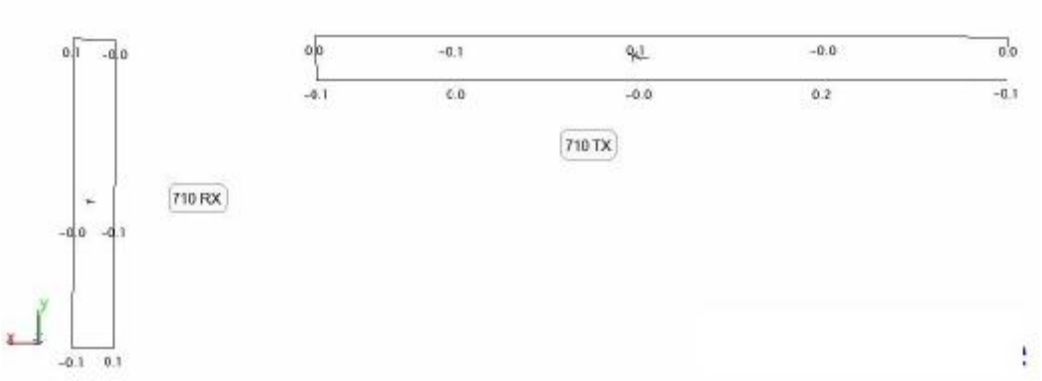
PLIMSOLL DRAFT MARKS		
MARK	STBD	PORT
AB	16.3	16.3
TF	16.9	16.9
F	16.6	16.5
S	16.3	16.2
W	15.9	15.9
WNA	15.8	15.7

WHOI ELEMENT TABLE-ORIGIN AT FORWARD PERPENDICULAR AT BASELINE						
ELEMENT	COORDINATE (METERS)			INCLINATION		HEADING
	X	**Y**	**Z**	**Pitch**	**Roll**	**Azimuth**
122TX @ Array	23.408	0.548	-0.188	0.008 Bow Up	0.01 Stbd Dn	0.01 Stbd
122RX @ Array	27.823	0.017	-0.115	0.173 Bow Dn	0.025 Stbd Up	.058 Stbd Aft
710TX @ Array	25.126	-0.285	-0.113	0.008 Bow Dn	0.083 Stbd Dn	.077 Port
710RX @ Array	26.552	-0.629	-0.115	0.027 Bow Up	0.051 Stbd Dn	0.008 Stbd Aft
HIPAP @ Split	29.288	-0.598	0.621	0.026 Top Fwd	0.177 Top Stbd	3.127 Stbd
Port Seachest	29.267	2.436	-0.153	0.032 Bow Dn	0.021 Stbd Dn	8.932 Stbd
Mid Seachest	29.270	1.220	-0.154	0.009 Bow Dn	0.06 Stbd Up	9.542 Port
Stdb Seachest	29.270	-2.434	-0.151	0.11 Bow Dn	0.11 Stbd Dn	9.322 Stbd
Port Camera	27.747	2.267	0.061	N/A	N/A	N/A
Stbd Camera	27.750	-2.259	0.062	N/A	N/A	N/A
18KHZ	26.832	-2.430	-0.167	0.096 Bow Dn	0.071 Stbd Dn	12.477 Stbd
ADCP 300	19.223	-0.606	-0.080	0.412 Bow UP	0.048 Stbd Dn	10.643 Stbd
ADCP 150	18.909	2.441	-0.122	0.482 Bow Up	0.296 Stbd Up	0.602 Port
ADCP 38	18.553	1.223	-0.121	.065 Bow Up	.098 Stbd Dn	3.593 Stbd
DP MRU	42.105	0.337	-8.746	.204 Bow Dn	.493 Stbd Up	.721 Stbd
SBP	22.290	-1.063	-0.045	.001 Bow Dn	.076 Stbd Up	.159 Stbd
120KHZ	24.703	-2.895	-0.081	0.007 Bow Up	0.059 Stbd Dn	.067 Port
38KHZ	23.793	-2.450	-0.032	0.242 Bow Up	0.461 Stbd Up	0.090 Stbd
70KHZ	25.312	-2.509	-0.081	0.244 Bow Dn	0.131 Stbd Up	.425 Stbd
200KHZ	24.702	-2.208	-0.069	0.418 Bow Up	0.096 Stbd Dn	.190 Stbd
Winch MRU	47.943	-3.674	-10.182	0.275 Bow Dn	0.007 Stbd Dn	1.056 Stbd
Main IMU	27.914	-0.008	-1.172	0.028 Bow Up	0.005 Stbd Up	0.351 Port
PHINS IMU	25.619	-0.164	-4.062	N/A	N/A	N/A
Speedlog	17.999	-0.610	0.006	N/A	N/A	N/A
Moon Pool Top	54.248	1.825	-6.761	N/A	N/A	N/A
Moon Pool Bottom	54.252	1.822	-1.075	N/A	N/A	N/A
Main Granite Block	21.948	0.000	-1.102	0.066 Bow Up	0.027 Stbd Up	Scribe 0.094 Port
Secondary Block	63.992	0.021	-3.834	.016 Bow Up	0.032 Stbd Up	N/A
Port C-NAV	30.776	6.791	-22.874	On Center, Top of Base		
Port POSMV	26.382	1.709	-20.903	On Center, Top of Base		
Stbd POSMV	26.400	-2.045	-20.913	On Center, Top of Base		
Stbd Fwd Kongsberg	30.778	-6.814	-22.709	On Center, Top of Base		
Stbd NOVATEL	34.082	-5.842	-20.654	Phase Center		
JRC DGPS	36.352	-1.106	-20.916	On Center, Top of Base		
Port Windbird	33.467	0.895	-30.040	On Center, Top of Base		
Stbd Windbird	33.456	-1.063	-29.994	On Center, Top of Base		

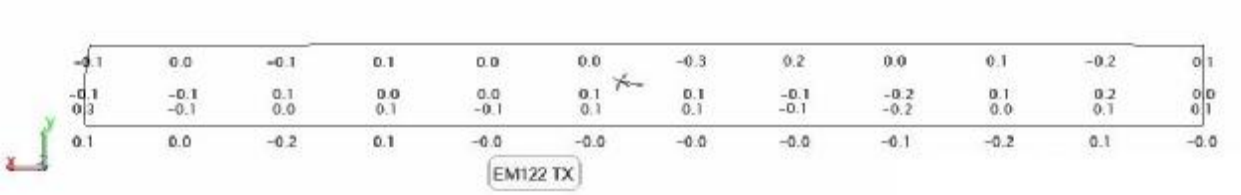
WHOI BENCH MARK TABLE-ORIGIN AT FORWARD PERPENDICULAR AT BASE LINE			
LOCATION	COORDINATE (METERS)		
	X	**Y**	**Z**
01 LEVEL 1	10.489	-5.491	-12.2342
01 LEVEL 2	10.490	5.477	-12.227
01 LEVEL 3	10.393	-0.005	-12.2198
02 LEVEL 1	23.779	-4.388	-16.3384
02 LEVEL 2	23.771	4.864	-16.3022
A FRAME/WORKING DECK 1	52.724	-6.398	-6.7705
A FRAME/WORKING DECK 2	66.738	-6.402	-6.7911
A FRAME/WORKING DECK 3	66.735	-0.002	-6.7967
A FRAME/WORKING DECK 4	66.732	6.400	-6.7899
A FRAME/WORKING DECK 5	57.191	7.307	-6.7797
CRANE 1	52.489	-1.205	-12.5733
DUCER ROOM 1	19.090	0.067	-2.6746
DUCER ROOM 2	24.201	-3.634	-2.6635
DUCER ROOM 3	29.868	-1.036	-3.0231
DUCER ROOM 4	26.218	3.634	-2.6997
FLYING BRIDGE 1	31.046	-6.689	-19.0932
FLYING BRIDGE 2	26.238	-1.822	-19.2519
FLYING BRIDGE 3	40.581	-2.057	-19.0843
FLYING BRIDGE 4	31.024	6.705	-19.0801
FOC DECK 2	7.998	-0.001	-10.5224
MAIN LAB 1	31.117	4.166	-6.8422
MAIN LAB 2	41.960	0.819	-6.7913
MAIN LAB 3	48.524	4.191	-6.8517
MAIN LAB 4	42.021	7.390	-6.8477
TRANSCEIVER 1	22.588	-2.221	-4.2842
TRANSCEIVER 2	26.526	-3.636	-5.5211
TRANSCEIVER 3	29.865	-2.912	-5.4117
TRANSCEIVER 4	25.582	-0.007	-5.6434
AFT LOWER WINCH 1	58.166	-0.011	-4.0475

KONGSBERG ELEMENT TABLE-ORIGIN AT PRIMARY GRANITE BLOCK						
ELEMENT	COORDINATE (METERS)			INCLINATION		HEADING
	X	**Y**	**Z**	**Pitch**	**Roll**	**Azimuth**
122TX @ Array	-1.459	-0.548	0.914	0.008 Bow Up	0.01 Stbd Dn	0.01 Stbd
122RX @ Array	-5.874	-0.017	0.987	0.173 Bow Dn	0.025 Stbd Up	.058 Stbd Aft
710TX @ Array	-3.177	0.285	0.989	0.008 Bow Dn	0.083 Stbd Dn	.077 Port
710RX @ Array	-4.604	0.629	0.987	0.027 Bow Up	0.051 Stbd Dn	0.008 Stbd Aft
HIPAP @ Split	-7.340	0.598	1.723	0.026 Top Fwd	0.177 Top Stbd	3.127 Stbd
Port Seachest	-7.319	-2.436	0.949	0.032 Bow Dn	0.021 Stbd Dn	8.932 Stbd
Mid Seachest	-7.321	-1.220	0.948	0.009 Bow Dn	0.06 Stbd Up	9.542 Port
Stdb Seachest	-7.322	2.434	0.951	0.11 Bow Dn	0.11 Stbd Dn	9.322 Stbd
Port Camera	-5.799	-2.267	1.163	N/A	N/A	N/A
Stbd Camera	-5.801	2.259	1.164	N/A	N/A	N/A
18KHZ	-4.883	2.430	0.935	0.096 Bow Dn	0.071 Stbd Dn	12.477 Stbd
ADCP 300	2.726	0.606	1.022	0.412 Bow UP	0.048 Stbd Dn	10.643 Stbd
ADCP 150	3.040	-2.441	0.980	0.482 Bow Up	0.296 Stbd Up	0.602 Port
ADCP 38	3.395	-1.235	0.981	.065 Bow Up	.098 Stbd Dn	3.593 Stbd
DP MRU	-20.157	-0.336	-7.644	.204 Bow Dn	.493 Stbd Up	.721 Stbd
SBP	-0.342	1.063	1.057	.001 Bow Dn	.076 Stbd Up	.159 Stbd
120KHZ	-2.754	2.895	1.021	0.007 Bow Up	0.059 Stbd Dn	.067 Port
38KHZ	-1.845	2.450	1.070	0.242 Bow Up	0.461 Stbd Up	0.090 Stbd
70KHZ	-3.364	2.509	1.021	0.244 Bow Dn	0.131 Stbd Up	.425 Stbd
200KHZ	-2.753	2.208	1.033	0.418 Bow Up	0.096 Stbd Dn	.190 Stbd
Winch MRU	-25.995	3.673	-9.080	0.275 Bow Dn	0.007 Stbd Dn	1.056 Stbd
Main IMU	-5.966	0.007	-0.070	0.028 Bow Up	0.005 Stbd Up	0.351 Port
PHINS IMU	-3.671	0.164	-2.960	N/A	N/A	N/A
Speedlog	3.950	0.610	1.108	N/A	N/A	N/A
Moon Pool-Top	-32.300	-1.825	-5.659	N/A	N/A	N/A
Moon Pool-Bott	-32.304	-1.821	0.027	N/A	N/A	N/A
Main Granite Block	0.000	0.000	0.000	0.066 Bow Up	0.027 Stbd Up	Scribe 0.094 Port
Secondary Block	-42.044	-0.021	-2.732	.016 Bow Up	0.032 Stbd Up	N/A
Port C-NAV	-8.828	-6.791	-21.772	On Center Top of Base		
Port POSMV	-4.434	-1.709	-19.801	On Center Top of Base		
Stbd POSMV	-4.451	2.045	-19.811	On Center Top of Base		
Stbd Fwd Kongsberg	-8.830	6.814	-21.607	On Center Top of Base		
Stbd NOVATEL	-12.134	5.842	-19.552	Phase Center		
JRC DGPS	-14.404	1.106	-19.814	On Center Top of Base		
Port Windbird	-11.519	-0.895	-28.938	On Center Top of Base		
Stbd Windbird	-11.507	1.063	-28.892	On Center Top of Base		

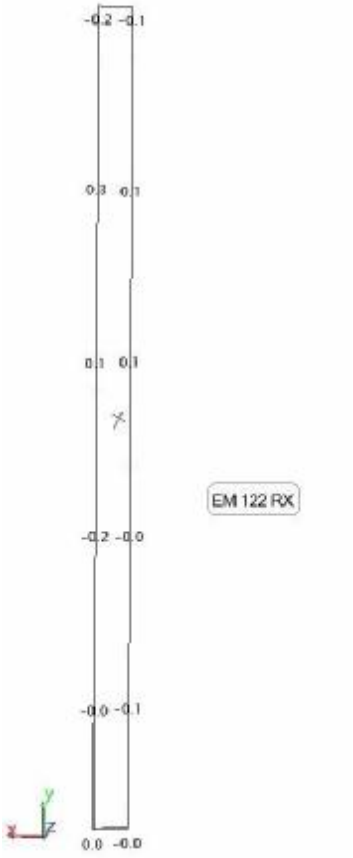
KONGSBERG BENCH MARK TABLE-ORIGIN AT PRIMARY GRANITE BLOCK			
LOCATION	COORDINATE (METERS)		
	X	**Y**	**Z**
01 LEVEL 1	-10.4891	5.491	-11.132
01 LEVEL 2	-10.4903	-5.4766	-11.125
01 LEVEL 3	-10.3932	0.0048	-11.118
02 LEVEL 1	-23.7789	4.3878	-15.236
02 LEVEL 2	-23.7711	-4.8637	-15.200
A FRAME/WORKING DECK 1	-30.776	6.398	-5.668
A FRAME/WORKING DECK 2	-44.79	6.402	-5.689
A FRAME/WORKING DECK 3	-44.787	0.002	-5.695
A FRAME/WORKING DECK 4	-44.784	-6.4	-5.688
A FRAME/WORKING DECK 5	-35.242	-7.307	-5.678
CRANE 1	-30.541	1.205	-11.471
DUCER ROOM 1	2.858	-0.067	-1.573
DUCER ROOM 2	-2.253	3.634	-1.561
DUCER ROOM 3	-7.92	1.036	-1.921
DUCER ROOM 4	-4.27	-3.634	-1.598
FLYING BRIDGE 1	-9.098	6.689	-17.991
FLYING BRIDGE 2	-4.289	1.822	-18.150
FLYING BRIDGE 3	-18.632	2.057	-17.982
FLYING BRIDGE 4	-9.075	-6.705	-17.978
FOC DECK 2	13.95	0.001	-9.420
MAIN LAB 1	-9.169	-4.165	-5.740
MAIN LAB 2	-20.011	-0.819	-5.689
MAIN LAB 3	-26.576	-4.191	-5.750
MAIN LAB 4	-20.073	-7.39	-5.746
TRANSCEIVER 1	-0.64	2.221	-3.182
TRANSCEIVER 2	-4.578	3.636	-4.419
TRANSCEIVER 3	-7.916	2.912	-4.310
TRANSCEIVER 4	-3.633	0.007	-4.541
AFT LOWER WINCH 1	-36.218	0.011	-2.945



FLATNESS- EM 710 TX/RX AS INSTALLED (MM)



FLATNESS EM122 TX AS INSTALLED (MM)



FLATNESS EM 122 RX AS INSTALLED

Certificate of Calibration

Item No. / Model: NET 1200

Manufacturer: SOKKIA

Serial No.: 110554 Certificate Number: 50997

This certifies that the above instrument has been inspected and calibrated by the Sokkia Corporation Service Department. This inspection was performed using the procedures set forth in the NET SERIES INSTRUMENT CALIBRATION AND CERTIFICATION MANUAL (August 15, 2005 Rev. 6). At the time of completion of this service, Sokkia Corporation certifies that the above stated instrument meets or exceeds all factory specifications and tolerances for instrument parameters and performance of this instrument model. The certification is effective for a 12 month period from the calibration date shown below.

All distance measurement parameters were tested and adjusted using factory calibration jigs and with the 10 Meter Calibration Rail whose accuracy is traceable to the National Institute of Standards and Technology (N.I.S.T) via Mutual Recognition Agreement. All angle measurement parameters were tested with a NIST traceable optical collimation system, using accepted collimation and adjustment procedures

The quality system addresses and conforms to ANSI/NCSL Z540-1-1994 and ISO/IEC 17025-1999
(and, as a result ISO 9001-1994 or ISO 9002-1994)

This certificate shall not be reproduced except in full, without the written approval of Sokkia Corporation

Customer Name: IMTEC GROUP, Ltd

Customer Address: 19004 E. RINGO CIR.

Customer City/State/Zip: INDEPENDENCE, MO 64057

See individual sets of data for temperature and pressure

Date Calibrated: 11/17/2015 Date Recalibration Due: 11/17/2016

Signed: _____ Date: 11/17/2015

Yes	No	
___	X	Is this a new instrument?

Answer the following questions only if the above answer is "No".

___	X	Is this the first NIST calibration we have performed on this instrument?
X	___	Were the calibration seals intact when the instrument was received?
___	X	Were the initial collimation inspection results within tolerance?
___	X	Were the initial EDM inspection results within tolerance?
___	X	Was the instrument damaged/defective and unable to have an initial inspection?
___	X	Corrective action recommended?

* See page 2 for a list of primary standards

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