

NOAA FAIRWEATHER (S 220)
SENSOR ALIGNMENT & ORTHOGONAL COORDINATE SURVEY
NOVEMBER – DECEMBER 2014

FINAL REPORT

January 7, 2015 - Rev "1"



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CONTENTS

Page 2	Project Overview Purpose General Comments 3-D Coordinate Measurement Equipment Reference Coordinate Systems
Page 3	Coordinate System Definition – Kongsberg Figure 1- Vessel Coordinate System
Page 4	(2) Additional Coordinate System Definitions (per NOAA Representative) Measurement Procedure Gondola Installation
Page 5	EM710 Tx and EM710 Rx Transducer Installation
Page 6	Vessel Benchmarks and Navigation Elements Figure 2 – Granite Block Figure 3 – IMU Figure 4 – Gyros
Page 7	Figure 5 – POS/MV GPS Antenna and Benchmark locations
Page 8	Figure 6 – Transom Reference Point Stbd Side Figure 7 – Transom Reference Point Port Side Figure 8 – Stern Centerline Reference Point Figure 9 – Bow Centerline Reference point
Page 9	Figure 10 – Waterline Elevation Punchmarks on E Deck Handrails
Page 10	Measurement Precision and Uncertainty Project Data
Page 11	Table 1 – NOAA Fairweather Benchmark Table (Meters) Table 2 – NOAA Fairweather- Specified Element Coordinates (Meters)
Page 12	Table 3 – NOAA Fairweather Azimuth, Pitch, Roll Specified Elements (Degrees) Table 4 – NOAA Fairweather Draft Marks (Feet)
Page 13	Certificate of Calibration, Total Station, NET 1200 S/N 110554
Page 14	Appendix 1 – Data wrt NOAA-specified Granite Block coordinate system Table 1 – NOAA Fairweather Benchmark Table (Meters) Table 2 – NOAA Fairweather- Specified Element Coordinates (Meters)
Page 15	Appendix 1 – Data wrt NOAA-specified Granite Block coordinate system Table 3 – NOAA Fairweather Azimuth, Pitch, Roll Specified Elements (Degrees) Table 4 – NOAA Fairweather Draft Marks (Meters)
Page 16	Appendix 2 – Data wrt NOAA-specified EM710TX coordinate system Table 1 – NOAA Fairweather Benchmark Table (Meters) Table 2 – NOAA Fairweather- Specified Element Coordinates (Meters)
Page 17	Appendix 2 – Data wrt NOAA-specified EM710TX coordinate system Table 3 – NOAA Fairweather Azimuth, Pitch, Roll Specified Elements (Degrees) Table 4 – NOAA Fairweather Draft Marks (Meters)

PROJECT OVERVIEW

Purpose

The purpose of this commentary is to summarize the procedures and analytical methods employed to perform the 3-D coordinate total station inspection that produced the data in this report for those unfamiliar with the equipment and process.

Dimensional data resulting from the inspection is included with the report.

General Comments

This report summarizes coordinate measurement data taken on the vessel NOAA Fairweather November 24 and 25, 2014 and December 9, 2014. The vessel was located in a floating dry dock at Bay Ship and Yacht Company, Alameda, CA.

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

Coordinate measurements were then taken to define elements and features as requested by NOAA representatives in support of the EM710 Multi-Beam Sounding system transducer installation.

Locations of existing draft marks were measured and recorded.

3-D Coordinate Measurement Equipment

A Sokkia NET 1200 enhanced electronic total station operated through a notebook computer running New River Kinematics Spatial Analyzer™ measurement and analysis software was utilized. This system measures 3-D spherical coordinates by recording an azimuth and zenith angle simultaneously with the near infrared distance coaxial with the telescope line of sight for each observation. Spatial Analyzer measurement and analysis software converts the spherical coordinate data to a Cartesian coordinate system that can be defined by the user. Measurements are made to either adhesive or kinematic targets that have a retro-reflective target face.

Temporary "benchmarks" or reference points were placed throughout the dry-dock area and on 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 January 2, 2014.

Reference Coordinate Systems

The following parameters were used to define the reference coordinate system for reporting the survey data (See Page 9) per Kongsberg representatives.

Survey data with respect to 2 additional coordinate systems was requested by NOAA representatives.

Note that since the vessel was located in a floating drydock, gravity reference could not be used.

Kongsberg requested coordinate system:

- Origin: Center of Granite Block: $X=0.000$, $Y=0.000$, $Z=0.000$ (intersection of etched lines)
- Pitch: Pairs of points were surveyed at frames 20, 32, 40, 52, 60, 70 on main keel plate and frames 79, 88 and 95 on the skeg. A best-fit plane was derived using all pairs except those at frames 52 and 79 where the keel had a severe amount of distortion as compared to the rest of the points.
- Roll: The 4 (port/stbd and fwd/aft) 12' draft marks were used to define the roll.
- X Axis: Single points were taken at frames 10 and 107 on the centerline of keel and midpoints were constructed from the pairs of points used to define the keel plane. These points were then projected onto the keel plane and used to construct a best fit line to define the ship's heading (Azimuth).

Thus the coordinate system is depicted as shown:

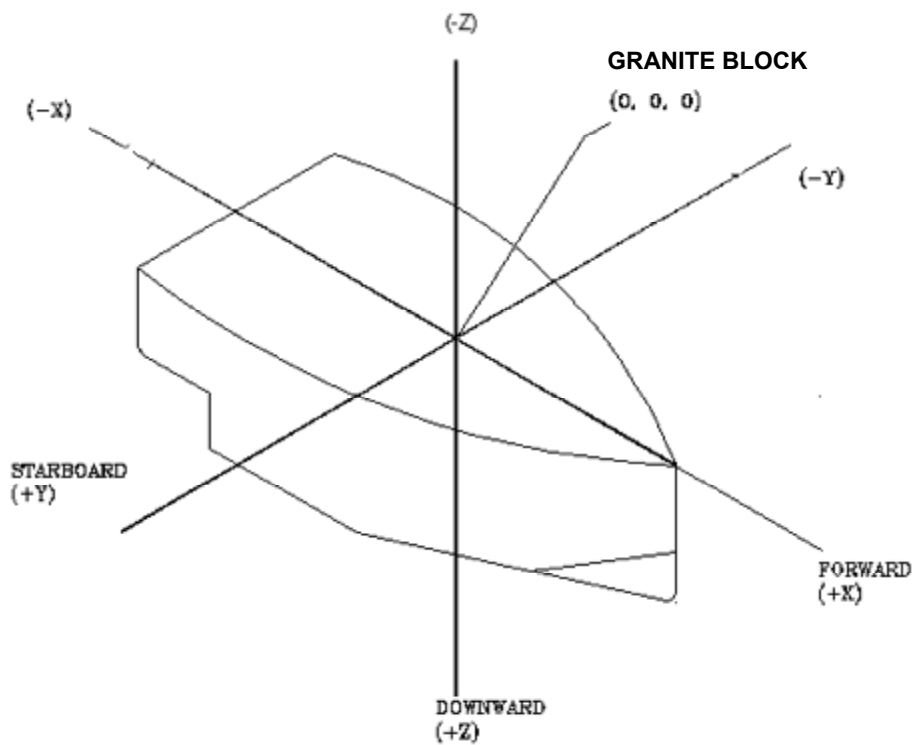


Figure 1 – Vessel Coordinate System

The first coordinate system requested by NOAA is defined as follows:

Origin: Center of Granite Block: X=0.000, Y=0.000, Z=0.000 (intersection of etched lines)

Pitch: Plane of Granite Block.

Roll: Plane of Granite Block.

X Axis: Etched Azimuth line on Granite Block.

Granite Block therefore completely defines the vessel coordinate system.

The second coordinate system requested by NOAA is defined as follows:

Origin: Center of EM710 TX Transducer Face: X=0.000, Y=0.000, Z=0.000

Pitch: Plane of EM710 TX Transducer frame

Roll: Plane of EM710 TX Transducer frame

X Axis: Line constructed from midpoints fwd/aft on EM710 TX transducer frame rails.

EM710 TX Transducer therefore completely defines the vessel coordinate system.

NOAA Representative requested that all survey data be presented in these two coordinate systems including the draft marks.

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 were frequently used as a temporary benchmark.

The Sokkia NET 1200 total station operated through a notebook computer running Spatial Analyzer™ industrial measurement software was used to measure the targets and record observations.

Gondola Installation

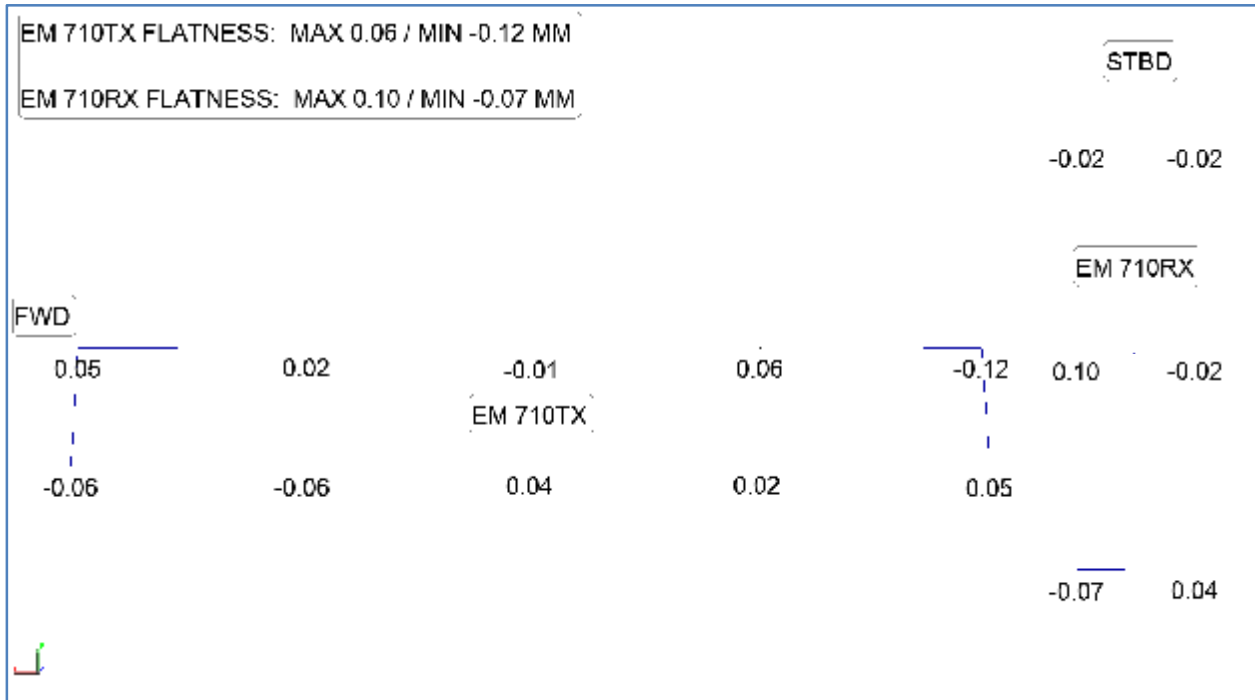
At the request of shipyard and NOAA personnel, IMTEC assisted with proper positioning of the gondola to within the azimuth, pitch and roll tolerances required by Kongsberg prior to welding.

The gondola was first characterized on the drydock floor to establish centerline, pitch and roll. Centerline with respect to the ship was marked on the keel to facilitate correct alignment and during fit-up, the gondola TX and RX mounting surfaces were monitored for Pitch and Roll respectively while adjustments were made to achieve required gondola alignment tolerances:

Pitch 0.341 (spec 0° to 1°) forward up and Azimuth 0.180° and Roll 0.365° (spec to within 1/2°).

EM 710TX and EM 710RX Transducers

After the transducer frames were installed, data points were surveyed at each of the bolt locations to determine overall flatness. With a tolerance of 0.20 mm, shim values were provided to Kongsberg to meet the flatness requirement. After shims were added and bolts final torqued, the frames were again surveyed to document final flatness.



Final location (X, Y, Z), pitch, roll and azimuth of the Kongsberg transducer frames with respect to the vessel coordinate system are found in Tables 2 & 3.

Vessel Benchmarks and Navigation Elements

Existing benchmarks and elements were surveyed as part of this effort and values for each are reported in the vessel orthogonal coordinate system. The Benchmarks are summarized in Table 1 of this report. Vessel elements are summarized in Table 2.

The coordinates, azimuth & inclination of the Granite Block, IMU and Gyros were measured and recorded as shown in the following figures 2 – 4.



Fig. 2 – Granite Block located in Fwd Closet of C05 Stateroom Lounge

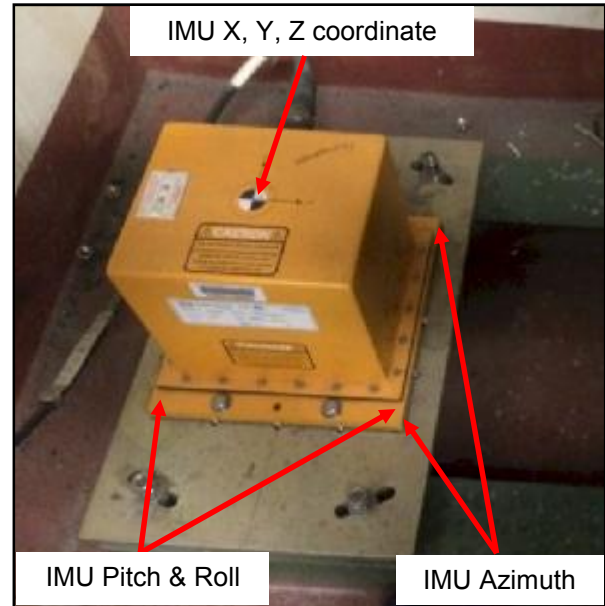


Fig. 3 – IMU, adjacent to Granite Block (4 corners of base used for Pitch & Roll)

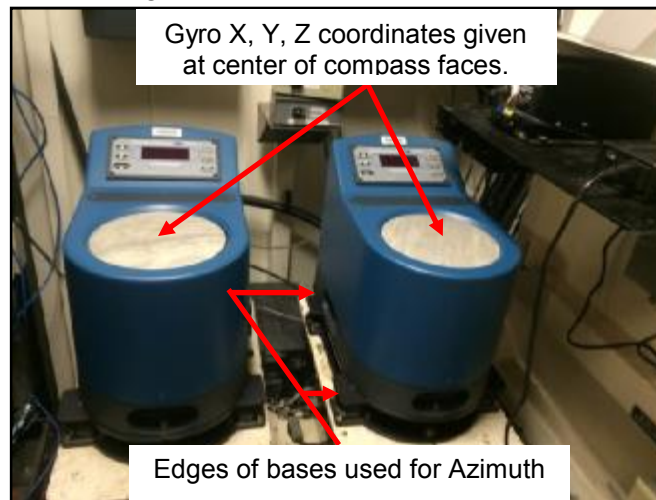


Fig. 4 - Gyros

The location and lever-arm (parallax coordinate) of the POS/MV GPS antennae were measured and recorded:

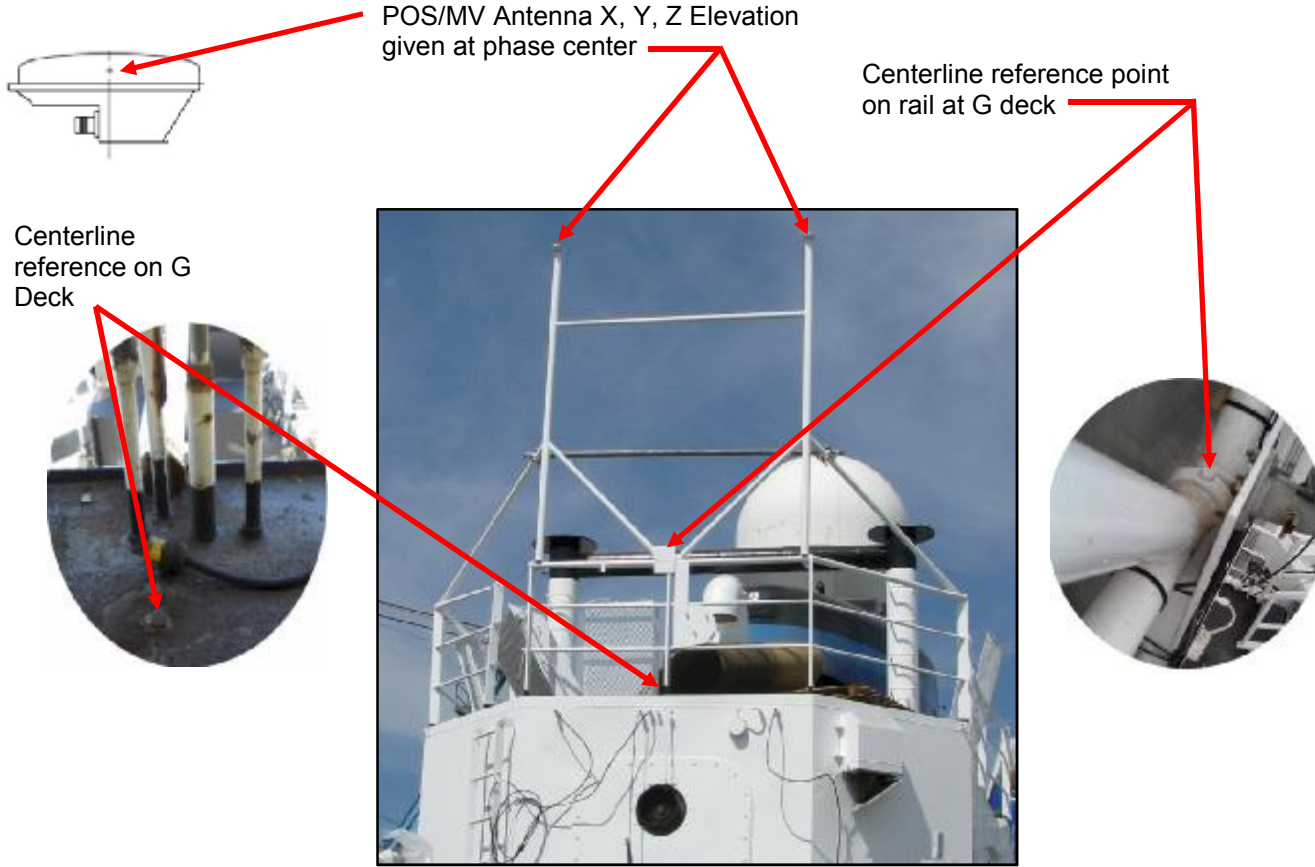


Figure 5 – POS/MV GPS Antenna and Benchmark Locations



Fig. 6 – Transom Reference Point Stbd Side



Fig. 7 – Transom Reference Point Port Side



Fig. 8 – Stern Centerline Reference Point



Fig. 9 – Bow Centerline Reference point

Per request of NOAA representative, punchmarks made on the E-Deck handrail/bulwark at the approximate longitudinal center value of the EM710 Tx Transducer were surveyed.

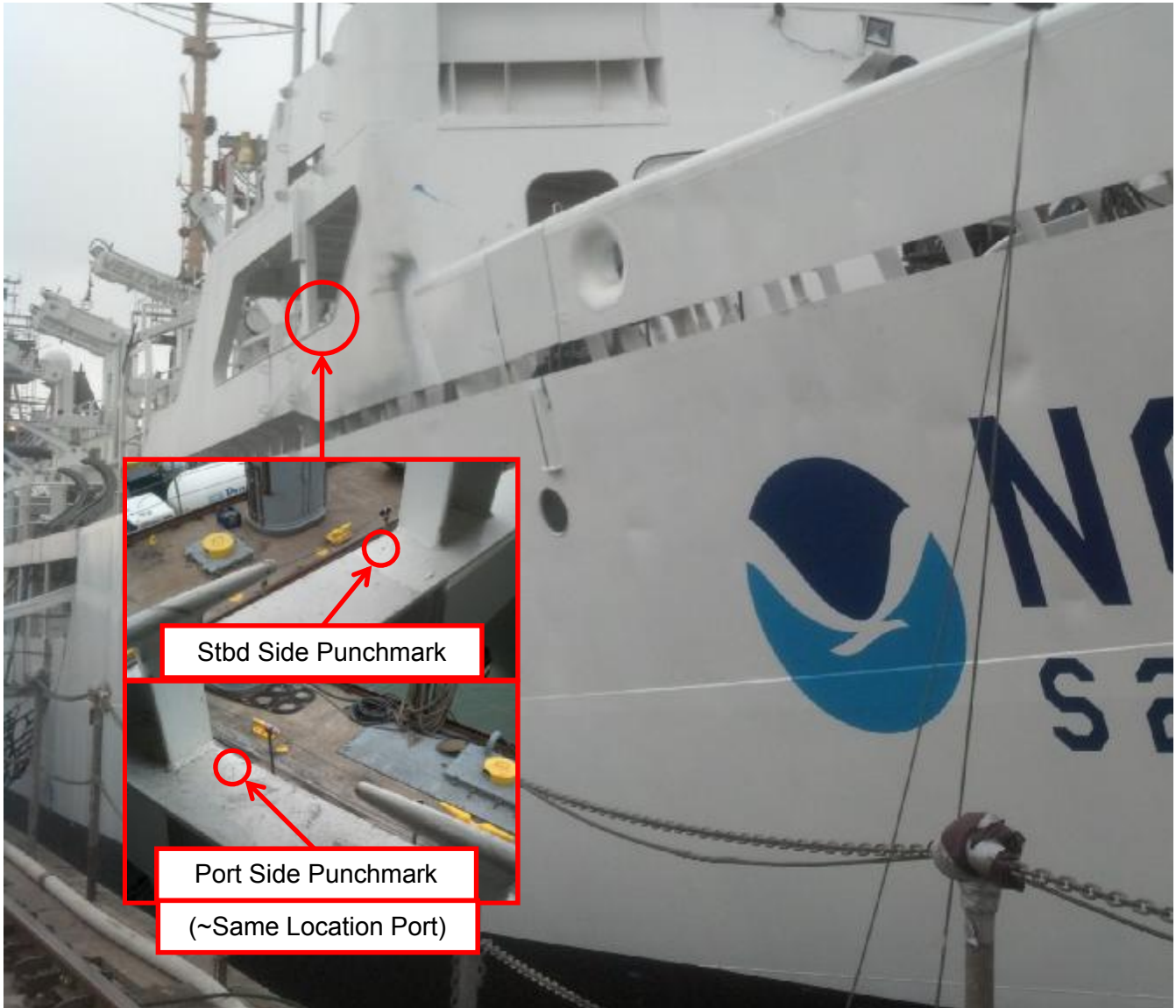


Fig. 10 – Waterline Elevation Punchmarks on E Deck Handrail

Measurement Precision and Uncertainty

Uncertainties are reported to be:

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

$$X, Y, \text{ \& } Z \leq 1.5 \text{ mm}$$

Region to Region, i.e., GPS antenna to EM710 RX/TX features:

$$X \leq 2.0 \text{ mm}$$

$$Y \leq 2.0 \text{ mm}$$

$$Z \leq 2.0 \text{ mm}$$

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 of the survey is analyzed to be:

$$\text{Azimuth, Pitch, Roll: } \leq 00^{\circ} 00' 30''$$

PROJECT DATA

The required data is summarized in tabular form on the following pages. The units of measure for reporting are indicated on each table.

Table 1 reports the X, Y and Z, values for specified benchmarks in units of meters and in the final vessel coordinate system.

Table 2 reports the X, Y and Z, values for specified elements in units of meters and in the final vessel coordinate system.

Table 3 reports the Azimuth, Pitch and Roll of specified elements.

Table 4 reports the summarized data for the draft mark survey and is presented with Feet as the unit of measure to correlate with the specific draft mark number. Draft marks were measured for elevation only, and at the bottom of the weld. Draftmark elevations are reported above the best-fit keel as surveyed. The gondola projection is not reflected by any set of draft marks and projects 1.9341 feet below the keel.

Appendix 1 is a copy of all 4 tables with the data presented with respect to the 1st coordinate system requested by NOAA: Granite Block as Origin and also defining Az, Pitch and Roll.

Appendix 2 is a copy of all 4 tables with the data presented with respect to the 2nda coordinate system requested by NOAA: EM710 Tx Transducer Center as Origin and defining Az, Pitch & Roll.

TABLE 1 - NOAA FAIRWEATHER BENCHMARK TABLE (METERS)

BENCHMARK	X	Y	Z
GRANITE BLOCK	0.0000	0.0000	0.0000
BOW BENCHMARK	28.4121	1.3606	-7.7727
G-DECK CENTERLINE BENCHMARK	-11.7440	1.3695	-9.5527
E-DECK PORT HANDRAIL/BULWARK	7.5889	-4.9564	-6.1073
PORT TRANSOM PIVOT	-16.3096	11.5008	-4.6196
POS/MV BENCHMARK	-11.9527	1.3815	-10.6261
E-DECK STBD HANDRAIL/BULWARK	7.5769	7.6991	-6.1227
STBD TRANSOM PIVOT	-39.7177	3.1794	-2.7963
STERN BENCHMARK	-40.3032	1.3449	-2.6774

TABLE 2 - NOAA FAIRWEATHER ELEMENT COORDINATES (METERS)

DESCRIPTION	X	Y	Z
GRANITE BLOCK	0.0000	0.0000	0.0000
IMU	0.0003	-0.4830	-0.0997
POS/MV GPS STBD	-11.8037	2.4058	-13.2788
POS/MV GPS PORT	-11.8098	0.4080	-13.2864
GYRO 1 STBD	-1.0794	0.6861	-3.3263
GYRO 2 PORT	-1.0556	0.2452	-3.3245
GONDOLA PROJECTION *			4.5624
710 TX FACE CENTER	8.4280	1.2836	4.5618
710 RX FACE CENTER	7.2046	1.3905	4.5614
TRANSDUCER 4	0.9830	1.6716	4.0052
TRANSDUCER 5	0.9839	1.0577	4.0002
TRANSDUCER 6	-0.6302	0.6461	3.9805
TRANSDUCER 7	-0.0988	0.6325	3.9732
TRANSDUCER 10	-0.6248	1.5469	4.0026
TRANSDUCER 93	-0.5791	-0.1383	3.9402
USBL	-28.3814	1.3865	4.1862

*Note lowest measured Gondola projection at Aft Port Corner of EM710 RX

**TABLE 3 - NOAA FAIRWEATHER - AZIMUTH, PITCH, & ROLL OF SPECIFIED ELEMENTS
 (DECIMAL DEGREES)**

ELEMENT	AZIMUTH		PITCH		ROLL	
	VALUE	DIRECTION	VALUE	DIRECTION	VALUE	DIRECTION
GRANITE BLOCK	0.10930	STBD	0.22347	FWD DOWN	0.15816	STBD DOWN
IMU	0.13332	PORT	0.07217	FWD UP	0.08096	STBD UP
GYRO 1 STBD	0.07749	STBD	-	-	-	-
GYRO 2 PORT	0.10667	PORT	-	-	-	-
EM710 TX FRAME	0.17592	PORT	0.07214	FWD UP	0.15802	STBD UP
EM710 RX FRAME	0.15001	STBD	0.19881	FWD UP	0.04755	STBD UP

TABLE 4 - NOAA FAIRWEATHER DRAFT MARKS

DRAFT MARK	PORT		DRAFT MARK	STARBOARD	
	LOCATION AS SURVEYED			LOCATION AS SURVEYED	
	FWD	AFT		FWD	AFT
7	7.234	N/A	7	7.258	N/A
8	8.199	8.103	8	8.273	8.131
9	9.201	9.108	9	9.257	9.136
10	10.196	10.126	10	10.273	10.141
11	11.188	11.121	11	11.248	11.138
12	12.178	12.143	12	12.259	12.127
13	13.170	13.122	13	13.242	13.117
14	14.187	14.147	14	14.269	14.088
15	15.179	15.117	15	15.239	15.074
16	16.185	16.022	16	16.257	16.087
17	17.179	17.082	17	17.260	17.095

Certificate of Calibration

Item No. / Model: NET1200
Manufacturer: Sokkia Co., LTD
Serial No.: 110554 Certificate Number: CL31782

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 18, 2005 Rev. 8). 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/NCCL 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: The Imtec Group, LTD

Customer Address: 19004 E Ringo Circle

Customer City/State/Zip: Independence, MO 64057

See individual sets of data for temperature and pressure

Date Calibrated: 01/02/2014 Date Recalibration Due: 01/02/2015

Signed: Larry W. Taylor Date: 01/02/2014

Yes No
 Is this a new instrument?

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

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

* See page 2 for a list of primary standards

Appendix 1 – NOAA Requested Coordinates wrt Granite Block

TABLE 1 - NOAA FAIRWEATHER BENCHMARK TABLE (METERS)

BENCHMARK	X	Y	Z
GRANITE BLOCK	0.0000	0.0000	0.0000
BOW BENCHMARK	28.3841	1.2847	-7.8872
G-DECK CENTERLINE BENCHMARK	-11.7785	1.3657	-9.5106
E-DECK PORT HANDRAIL/BULWARK	7.5555	-4.9877	-6.1232
PORT TRANSOM PIVOT	-16.3056	11.5193	-4.5876
POS/MV BENCHMARK	-11.9914	1.3752	-10.5832
E-DECK STBD HANDRAIL/BULWARK	7.5676	7.6677	-6.1734
STBD TRANSOM PIVOT	-39.7222	3.2479	-2.6502
STERN BENCHMARK	-40.3107	1.4148	-2.5239

TABLE 2 - NOAA FAIRWEATHER ELEMENT COORDINATES (METERS)

DESCRIPTION	X	Y	Z
GRANITE BLOCK	0.0000	0.0000	0.0000
IMU	-0.0010	-0.4833	-0.0984
POSMV STBD	-11.8509	2.3919	-13.2393
POSMV PORT	-11.8608	0.3941	-13.2413
GYRO 1 STBD	-1.0911	0.6790	-3.3240
GYRO 2 PORT	-1.0681	0.2381	-3.3210
GONDOLA			4.5320
710 TX FACE CENTER	8.4482	1.3892	4.5294
710 RX FACE CENTER	7.2250	1.2800	4.5253
TRANSDUCER 4	1.0018	1.6808	3.9967
TRANSDUCER 5	1.0016	1.0669	3.9934
TRANSDUCER 6	-0.6134	0.6582	3.9811
TRANSDUCER 7	-0.0821	0.6437	3.9717
TRANSDUCER 10	-0.6062	1.5591	4.0007
TRANSDUCER 93	-0.5639	-0.1263	3.9428
USBL	-28.3621	1.4524	4.2930

*Note lowest measured Gondola projection at Aft Port Corner of EM710 RX Frame

Appendix 1 – NOAA Requested Coordinates wrt Granite Block

**TABLE 3 - NOAA FAIRWEATHER - AZIMUTH, PITCH, & ROLL OF SPECIFIED ELEMENTS
 (DECIMAL DEGREES)**

ELEMENT	AZIMUTH		PITCH		ROLL	
	VALUE	DIRECTION	VALUE	DIRECTION	VALUE	DIRECTION
GRANITE BLOCK	0.00000	-	0.00000	-	0.00000	-
IMU	0.24342	PORT	0.29609	FWD UP	0.23856	STBD UP
GYRO 1 STBD	0.03482	PORT	-	-	-	-
GYRO 2 PORT	0.21692	PORT	-	-	-	-
EM710 TX FRAME	0.06583	STBD	0.29622	FWD UP	0.31561	STBD UP
EM710 RX FRAME	0.04096	STBD	0.42267	FWD UP	0.20490	STBD UP

TABLE 4 - NOAA FAIRWEATHER DRAFT MARKS (METERS)

DRAFT MARK	PORT		DRAFT MARK	STARBOARD	
	LOCATION AS SURVEYED			LOCATION AS SURVEYED	
	FWD	AFT		FWD	AFT
7	1.6778	N/A	7	1.6696	N/A
8	1.3838	1.6361	8	1.3599	1.6122
9	1.0788	1.3297	9	1.0597	1.3058
10	0.7759	1.0197	10	0.7499	0.9996
11	0.4738	0.7166	11	0.4527	0.6954
12	0.1721	0.4056	12	0.1440	0.3934
13	-0.1299	0.1090	13	-0.1559	0.0901
14	-0.4396	-0.2020	14	-0.4691	-0.2072
15	-0.7418	-0.4970	15	-0.7648	-0.5086
16	-1.0481	-0.7723	16	-1.0755	-0.8180
17	-1.3509	-1.0948	17	-1.3817	-1.1258

Appendix 2 – NOAA Requested Coordinates wrt EM710 TX Transducer

TABLE 1 - NOAA FAIRWEATHER BENCHMARK TABLE (METERS)

BENCHMARK	X	Y	Z
GRANITE BLOCK	-8.4262	-1.2451	-4.5759
BOW BENCHMARK	19.9998	0.0496	-12.3090
G-DECK CENTERLINE BENCHMARK	-20.1537	0.1868	-14.1396
E-DECK PORT HANDRAIL/BULWARK	-0.8448	-6.2079	-10.6873
PORT TRANSOM PIVOT	-24.6945	10.3185	-9.1843
POS/MV BENCHMARK	-20.3610	0.2024	-15.2132
E-DECK STBD HANDRAIL/BULWARK	-0.8179	6.4475	-10.6678
STBD TRANSOM PIVOT	-48.1303	2.0640	-7.4135
STERN BENCHMARK	-48.7216	0.2310	-7.3003

TABLE 2 - NOAA FAIRWEATHER ELEMENT COORDINATES (METERS)

DESCRIPTION	X	Y	Z
GRANITE BLOCK	-8.4262	-1.2451	-4.5759
IMU	-8.4272	-1.7278	-4.6770
POSMV STBD	-20.2056	1.2335	-17.8629
POSMV PORT	-20.2178	-0.7642	-17.8760
GYRO 1 STBD	-9.4992	-0.5465	-7.9017
GYRO 2 PORT	-9.4768	-0.9875	-7.9010
GONDOLA PROJECTION *			0.0001
710 TX FACE CENTER	0.0000	0.0000	0.0000
710 RX FACE CENTER	-1.2231	0.1107	-0.0016
TRANSDUCER 4	-7.4432	0.4125	-0.5648
TRANSDUCER 5	-7.4440	-0.2014	-0.5715
TRANSDUCER 6	-9.0594	-0.6081	-0.5945
TRANSDUCER 7	-8.5281	-0.6232	-0.6011
TRANSDUCER 10	-9.0513	0.2927	-0.5699
TRANSDUCER 93	-9.0106	-1.3924	-0.6368
USBL	-36.8084	0.2170	-0.4216

*Note lowest measured Gondola projection at FWD Center of EM710 TX

Appendix 2 – NOAA Requested Coordinates wrt EM710 TX Transducer

**TABLE 3 - NOAA FAIRWEATHER - AZIMUTH, PITCH, & ROLL OF SPECIFIED ELEMENTS
 (DECIMAL DEGREES)**

ELEMENT	AZIMUTH		PITCH		ROLL	
	VALUE	DIRECTION	VALUE	DIRECTION	VALUE	DIRECTION
GRANITE BLOCK	0.06742	PORT	0.29658	FWD DOWN	0.31527	STBD DOWN
IMU	0.30922	PORT	0.00021	FWD DOWN	0.07705	STBD DOWN
GYRO 1 STBD	0.09622	PORT	-	-	-	-
GYRO 2 PORT	0.28243	PORT	-	-	-	-
EM710 TX FRAME	0.00000	-	0.00000	-	0.00000	-
EM710 RX FRAME	0.02598	PORT	0.12632	FWD UP	0.11086	STBD DOWN

TABLE 4 - NOAA FAIRWEATHER DRAFT MARK SURVEY

DRAFT MARK	PORT		DRAFT MARK	STARBOARD	
	LOCATION AS SURVEYED			LOCATION AS SURVEYED	
	FWD	AFT		FWD	AFT
7	-2.778	N/A	7	-2.784	N/A
8	-3.072	-3.120	8	-3.093	-3.113
9	-3.378	-3.426	9	-3.393	-3.419
10	-3.681	-3.736	10	-3.702	-3.725
11	-3.984	-4.040	11	-4.000	-4.029
12	-4.286	-4.352	12	-4.308	-4.330
13	-4.589	-4.652	13	-4.607	-4.630
14	-4.899	-4.966	14	-4.919	-4.925
15	-5.202	-5.262	15	-5.215	-5.224
16	-5.508	-5.539	16	-5.525	-5.532
17	-5.812	-5.862	17	-5.831	-5.839