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Report No. CG-D-06-00

Positioning Tool Validation Report

FINAL REPORT
NOVEMBER 1999

Prepared for:

U.S. Department of Transportation
United States Coast Guard
Operations (G-O)
Washington, DC 20593-0001

N O T I C E

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Technical Report Documentation Page

1. Report No. CG-D-06-00	2. Government Accession Number	3. Recipient's Catalog No.
4. Title and Subtitle Positioning Tool Validation Report		5. Report Date November 1999 6. Performing Organization Code Project No. 2790
7. Author(s) Jay Spalding		8. Performing Organization Report No. R&DC-439-99
9. Performing Organization Name and Address U.S. Coast Guard Research and Development Center 1082 Shennecossett Road Groton, CT 06340-6096		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Organization Name and Address U.S. Department of Transportation United States Coast Guard Operations (G-O) Office of Aids to Navigation Washington, DC 20593-0001		13. Type of Report & Period Covered Final 14. Sponsoring Agency Code Commandant (G-OPN) U.S. Coast Guard Headquarters Washington, DC 20593-0001

15. Supplementary Notes

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16. Abstract (MAXIMUM 200 WORDS)

The aids to navigation positioning programs AAPS 3.4, ATONIS/AAPS 4.0, and ECPINS/ATON 1.73 were tested for the accuracy of determining range and bearing when used to position floating aids to navigation. These calculations are the key element in determining when an aid is on station, so these programs must yield consistent and correct results. The USCG R&D Center in Groton, CT, conducted the tests by comparing the program output to independently calculated results developed using algorithms obtained from the National Geodetic Survey. Test points at various places around the world were generated to test all possible combinations of quadrants and hemispheres. Both ATONIS/AAPS 4.0 and AAPS 3.4 were found to be accurate to within 0.5 inches in range and within .01 degrees in bearing to the calculated truth measurements. ECPINS/ATON 1.73 was found to be accurate within five inches in range, and .01 degrees in bearing. The Differential Global Positioning System receivers used to position are accurate to two yards so these small differences in range would not be noticeable. All three positioning programs can effectively be used interchangeably and achieve equivalent results.

17. Key Words navigational aids, position finding	18. Distribution Statement This document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161

19. Security Class (This Report) UNCLASSIFIED	20. Security Class (This Page) UNCLASSIFIED	21. No of Pages 16	22. Price

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Executive Summary

In spring 1999, the U. S. Coast Guard aids-to-navigation program (G-OPN) determined that testing and evaluation was required on various aid to navigation software tools used for positioning floating and fixed short range aids. As part of the Coast Guard's migration to standard workstation III (Windows NT environment), and as a result of upgrades in the electronic chart navigation software of the new seagoing and coastal buoy tenders, the program expected to have three different software applications in use over the next several years. Questions arose regarding the accuracy and consistency between these applications in positioning aids. The program asked the USCG R&D Center to test and evaluate the existing system, AAPS 3.4, its successor ATONIS/AAPS 4.0, and the aids-to-navigation enhancement to the buoy tender's electronic chart navigation system, ECPINS/ATON 1.71.

A proposal and test plan were developed to determine the accuracy of range and bearing functions used to position floating aids to navigation. These calculations are the key elements in determining when an aid is on station. The R&D Center conducted the tests by comparing the programs' outputs to independently calculated outputs developed using algorithms obtained from the National Geodetic Survey. Test points at various places around the world were generated to test all possible combinations of quadrants and hemispheres. AAPS 3.4 and ATONIS/AAPS 4.0 were tested at the R&D Center with assistance from G-OPN for operation and set-up of ATONIS/AAPS 4.0. ECPINS/ATON 1.71 was tested at the USCG Command and Control Engineering Center in Portsmouth, Virginia, in September, 1999, with the help of the WLB/WLM Land Based Support Facility. ECPINS/ATON 1.73 was tested by the WLB/WLM Land Based Support Facility in December, 1999, to determine if this new revision corrects the discrepancies found in version 1.71. Both sets of data are included in this report.

In order to judge the impact of any calculation differences found; we developed an error budget for positioning that includes all of the relevant error sources involved in the positioning process. The range and bearing calculations (subject of this test), data precision, positioning system accuracy (DGPS), position translation accuracy, and vessel maneuvering accuracy were included in the error budget. When examined in this systematic fashion, the driving factors are the DGPS accuracy and the vessel's maneuvering accuracy. At the accuracy levels found in the testing, the positioning programs themselves are virtually interchangeable with no effect on the positioning performance. The specific results were as follows: both AAPS 3.4 and ATONIS/AAPS 4.0 applications were found to be accurate to within 0.5 inches in range and within .01 degrees in bearing to the calculated truth measurements. ECPINS/ATON 1.73 was found to be accurate within five inches in range and within .01 degrees in bearing to the calculated truth measurements. The errors in version 1.71 were clearly corrected. All three positioning programs can now effectively be used interchangeably and achieve identical results.

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List of Acronyms

AAPS	Automated AtoN Positioning System
ANT	Aids to Navigation Team
APR	Aid Positioning Report
ATONIS	Aids to Navigation Information System
C2CEN	Command and Control Engineering Center
DGPS	Differential Global Positioning System
DPS	Dynamic Positioning System
ECPINS	Electronic Chart Precision Integrated Navigation System
EECEN	Electronic Engineering Center
GPS	Global Positioning System
LBSF	Land Based Support Facility
MEA	Mission Essential Application
NGS	National Geodetic Survey
NMEA	National Marine Electronics Association
OOD	Officer Of the Deck
OSC	Operations Systems Center
OSL	Offshore Systems Limited
SWIII	Standard Workstation III
WLB	Seagoing buoy tender
WLM	Coastal buoy tender

Introduction

Several AtoN buoy positioning systems are expected to be in use in the Coast Guard in 1999-2000. In this time frame, AtoN operations will be transitioning from the AAPS 3.4 to the ATONIS/AAPS 4.0 (ANTs and older cutters) or the ECPINS/ATON (WLM (keeper class), WLB (Juniper class)). Testing was required to determine that all of these applications properly position aids to navigation by delivering consistent and accurate results.

AAPS 3.4 - Originally written by R&D Center as the final deliverable from the AAPS R&D project, delivered for fleet use in 1991, maintained by EECEN and later OSC. Tested in June 1999

ATONIS/AAPS 4.0 (MEA) - The combination of the ATONIS database and the AAPS positioning function being implemented under the SWIII MEA conversion contract with Anteon, Inc. under G-OPN supervision. Tested in July 1999.

ECPINS/AtoN - Created by Offshore Systems Limited under contract to G-OCU to allow the new WLB/WLM fleet to use the ECPINS system for AtoN positioning. Tested in September 1999 by RDC and in December 1999 by C2Cen.

Objective

Conduct a test of each of the three AtoN positioning support systems expected to in use by the Coast Guard in 1999-2000. This test was designed to treat each system as a "black box," with no specific knowledge of its internal workings. Calculated positions in the form of NMEA 0183 GPS receiver output were input to each system and compared to the known result as calculated using algorithms developed by the National Geodetic Survey. Any differences are documented and analyzed for impact on the AtoN mission. Impact is evaluated through the use of an error budget that accounts for all of the various errors involved in positioning aids with DGPS. This effort has also produced a standard test that can be executed to validate revisions to these or other future positioning systems.

Benefit

Proven accuracy and consistency of the Coast Guard's AtoN positioning tools will ensure that aids are positioned on station when any of the available tools are used. This will give the Coast Guard a solid technical basis to defend its positioning procedures during marine investigations.

Error budget

As part of this effort to measure and evaluate the accuracy and differences in various AtoN positioning tools we felt it was important to put the results in context with the rest of the positioning system. This is done through the determination of an error budget that considers the various error sources in placing an aid on station. This error budget considers everything from the standpoint of the ship positioning to the point that the decision is made to set the buoy. It does not consider other factors such as what happens to the buoy sinker when it is released from the chain stopper, i.e. whether it falls straight down.

Errors in Yards	AAPS 3.4	ATONIS/AAPS4.0	ECPINS/WLM	ECPINS/WLB
Range and Bearing accuracy	0.008	0.008	0.140	0.140
NMEA 0183 Precision	0.2	0.2	0.2	0.2
DGPS accuracy	5	5	2	2
Translation error	0.5	0.5	0.5	0.5
Maneuvering accuracy	2	2	2	5
Total positioning error	5.41	5.41	2.88	5.41

Range and bearing accuracy

The accuracy of each system's ability to calculate range and bearing from the most probable position (MPP) to the assigned position (AP) is the first element in this error budget and the subject of this test. This element of the error budget was unknown until this test.

NMEA 0183 precision

While the precision of positions in the NMEA 0183 GGA format is not explicitly defined, the maximum overall length of the GGA message practically limits it to a reasonable number. The Trimble NT200CG , Leica 9212 and 9412 receivers use four digits of precision i.e. the least significant digit is .0001 minutes of Latitude or Longitude which is 0.2 yards in Latitude.

DGPS accuracy

DGPS accuracy is directly dependent on the precision and accuracy of the GPS measurements and therefore is a function of the type of GPS receiver in use. Trimble NT200CG is nominally 5 yards 95 percent, Leica 9212 (early JUNIPER and KEEPER class tenders) has been measured to 2 yards 95 percent, Leica 9412 (later JUNIPER and KEEPER class tenders) would be expected to perform at close to 1 yard 95% (based on manufacturer's data) and the new WLB/WLM Starlink Invicta 210M would be expected to perform at 2-4 yards 95%.

Translation error

This value is an approximation of a typical error involved in translating the GPS antenna position down to the buoy deck and over to the chain stopper. It was derived as follows: assume one degree of gyro error, take the sin of this angle and multiplying by a typical distance from the GPS to the chain stopper, 30 yards, to yield 0.5 yards.

Maneuvering accuracy

Maneuvering accuracy is the biggest variable in this error budget. Environmental factors such as wind and current play a large role in the accuracy of both manual and automatic (DPS) positioning. This is essentially an estimate of how precisely the operators or dynamic positioning system (DPS) can maneuver the ship to where the positioning program shows the assigned position. JUNPIER class DPS was measured as performing at 10 Meters 95 percent in difficult conditions, but typical results are within 5yds (QM1 Kvistad USCGC JUNPER). KEEPER class DPS was measured closer to 5 meters 95 percent in similar difficult conditions.

Interviews with field operators (CWO John Haley, CO of USCGC KATHERINE WALKER) show typical automatic and manual WLM performance to be closer to 2 meters 95 percent.

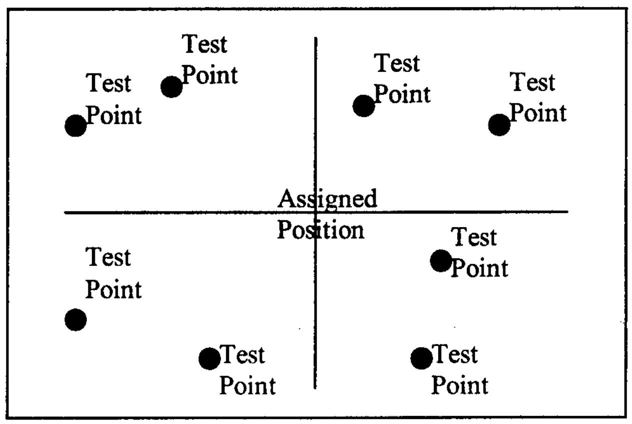
Total positioning error

Total positioning error is the square root of the sum of the squares of each element in the error budget. This analysis shows that AtoN positioning errors are dominated by the two most significant error sources, positioning errors from DGPS and maneuvering errors by the automatic systems or the vessel operators. Other sources of error such as the algorithms used in positioning software or vessel offsets are insignificant in the final outcome.

Test Development

The tests to evaluate the positioning capabilities were created to thoroughly evaluate range and bearing functions for every possible trigonometric case. This section is divided into test concept, preparation and procedure.

Test concept



R&D Center created specific scenarios to test the positioning function of these systems to validate the algorithms and methods implemented. The test scenarios included testing in northern, southern, eastern, and western hemispheres, and in all four quadrants using a variety of test points. These test points and the actual range and bearing to their associated assigned position was determined using software algorithms from National Geodetic Survey. These test points were created as files of NMEA-0183 data that is "played" into each system to be indistinguishable from its normal DGPS input. The antenna and buoyport shipboard offsets and excursion functions will also be tested similarly for geometric accuracy.

Test Preparation

To prepare for the testing of these systems there were several tasks to be performed. First were to layout the Assigned Position and test points in MS Excel. AP was chosen to be representative of an area where the Coast Guard works aids to navigation. Test point alpha was in North latitude and West Longitude, Bravo was North and East, Charlie was South and West and Delta was South and East. Eight points of range and bearing were randomly chosen about each imaginary AP. The NGS derived routines were used to determine the latitude and longitude of each of these eight points about each AP. These eight positions then had to be turned into input for the positioning programs. The latitudes and longitudes were truncated to the precision of the NMEA 0183 data (0.0001 min). The "True" range and bearing was then calculated using these truncated values to obtain a number to compare to the positioning program output. This process was laid out in the following spreadsheet.

Test Point ALPHA, AP = 41 00' 00.000" N, 072 00' 00.000" W											
						NMEA Lat Input		NMEA Lon Input		"True"	
AP Lat	AP Long	Range	Bearing	GPS Latitude	GPS Longitude	Lat Deg	Lat Min	Lon Deg	Lon Min	Range	Bearing
41	-72	100	30	41.00071307147730	-71.99945658187910	41	0.0428	71	59.9674	100.024	29.987
		75	59	41.00031805405470	-71.99930130380560	41	0.0191	71	59.9581	74.989	58.965
		60	110	40.99983102970260	-71.99938723297110	40	59.9899	71	59.9632	60.023	109.914
		20	157	40.99984841388920	-71.99991506896050	40	59.9909	71	59.9949	20.011	156.994
		87	182	40.99928409090140	-72.00003299842060	40	59.9570	72	0.0020	87.093	182.018
		300	241	40.99880240889900	-72.00285162283950	40	59.9281	72	0.1711	300.047	240.985
		640	294	41.00214319133490	-72.00635453295600	41	0.1286	72	0.3813	640.046	294.000
		31	345	41.00024655206540	-72.00008720049950	41	0.0148	72	0.0052	31.001	345.094

This extra step of controlling the precision of the numbers was crucial to getting accurate and consistent results from these tests. At this point we had the assigned positions to input into AAPS 3.4, ATONIS/AAPS 4.0 and ECPINS/ATON-DB respectively. We now needed a way to input the simulated vessel positions at the eight points around each AP.

To do this we created simulated DGPS output for input into AAPS 3.4 and ATONIS/AAPS 4.0. NMEA 0183 data was recorded from a Trimble NT200CG DGPS receiver. This one data file was then manipulated by changing the latitude and longitude of the position in the $GPGGA message to correspond to the NMEA lat input and NMEA lon input values in the example spreadsheet. This manipulation was done using a program that could reconstruct the proper check sum value for the $GPGGA message. Four test points each yielded eight files of test data, one for each test case for a total of 32 test files. These files of data were then "played" into the two AAPS programs using another program as if the data were coming from the DGPS in real time. For ECPINS/ATON we used the Offshore Systems NVES simulator to input the positions at the test points. Each Aid Positioning Report was carefully checked to ensure that there were no data entry errors.

Test Procedure

Test procedures were developed for each of the systems under test. The tests were conducted in three parts, range and bearing to AP, antenna offsets, and excursion. The tests were separated so that any error in one of these would not effect the others.

AAPS 3.4

AP for Alpha, Bravo, Charlie and Delta were entered into AAPS 3.4 as new aids. The system was configured to position at Short Stay with no antenna or buoy port offsets. AP Alpha was selected and all eight test cases were played into the system. The Found and Set functions were exercised and an Aid Position Report (APR) was printed for each test case. The same was done for test points Bravo, Charlie and Delta. To test the antenna offset calculations test case Alpha 1 was used to provide data input. The Alpha 1 position was also input as the AP. Various headings were manually input to AAPS 3.4 and the results were recorded on more APRs. Offsets of 17 yards and 917 yards were used to test for any sensitivity to distance. Excursion was similarly tested and confirmed through inspection.

ATONIS/AAPS 4.0

AP for Alpha, Bravo, Charlie and Delta were entered into ATONIS/AAPS 4.0 as new aids. The system was configured to position at Short Stay with no antenna or buoy port offsets. AP Alpha was selected and all eight test cases were played into the system. The Found and Set functions were exercised and an Aid Position Report (APR) was printed for each test case. The same was done for test points Bravo, Charlie and Delta. To test the antenna offset calculations test case Alpha 1 was used to provide data input. The Alpha 1 position was also input as the AP. Various headings were manually input to the AAPS 4.0 routine and the results were recorded on more APRs. Offsets of 17 yards and 917 yards were used to test for any sensitivity to distance. Excursion was similarly tested and confirmed through inspection.

ECPINS/ATON-DB

AP for Alpha, Bravo, Charlie and Delta were entered into ATON-Database as new aids. The ECPINS system was configured to position at Short Stay with no antenna or buoy port offsets. AP Alpha was selected and all eight test cases were manually entered into NVES. The Found and Set functions were exercised and an Aid Position Report (APR) was saved and printed for each test case. The same was done for test points Bravo, Charlie and Delta. To test the antenna offset calculations test case Alpha 1 was used to provide data input. The Alpha 1 position was also input as the AP. Various headings were manually input to the ECPINS and the results were recorded on more APRs. Offsets of 17 yards and 317 yards were used to test for any sensitivity to distance. 317 yards was used instead of the 917 yards used in AAPS because 917 yards did not work in ECPINS. It accepted the value but produced results that were clearly in error. Both 317 and 917 yards far exceed any realistic value for Coast Guard ships. Excursion was tested at various angles, again using the Alpha 1 AP. ECPINS/ATON 1.73 was tested later by C2Cen WLB/WLM Land Based Support Facility.

Test Results

Range and bearing to AP data

Range and bearing are crucial data for positioning aids-to-navigation. They are used for maneuvering by manual and automatic means and to determine when an aid is on station. It is very important that AtoN positioning programs obtain equivalent results for range and bearing. It would not be desirable for one application to find an aid on station and another finds it off station. Test results for each of the four test points are presented on the following two pages in the form of spreadsheets.

AAPS 3.4 and ATONIS/AAPS 4.0 obtained equal results that are consistent with the truth calculations to the limits of round off error. AAPS 3.4 rounded bearings off to 0.01 degrees and range to 0.01 yards. ATONIS/AAPS 4.0 rounded bearings off to 0.1 degrees and range to 0.01 yards. This difference in bearing round off represents the only difference in the results between these two systems and truth. This consistency is not surprising as AAPS 3.4 was built using the same NGS algorithms and ATONIS/AAPS 4.0 is intended to be the functional equivalent of AAPS 3.4. As the range or distance to AP is the determining value for ON/OFF station calculations further statistical analysis was done to determine the standard deviation to contribute to the positioning error budget. The standard deviation for both AAPS 3.4 and 4.0 was 0.008 yards, about 1/4 of an inch.

Test Point ALPHA, AP = 41 00' 00.000" N, 072 00' 00.000" W

NMEA Lat Input		NMEA Lon Inpu		"True"		"AAPS 3.4"		"AAPS 4.0"		"ECPINS 1.71"		"ECPINS 1.73"	
Lat	Lat Min	Lon I	Lon Min	Range	Bearing	Range	Bearing	Range	Bearing	Range	Bearing	Range	Bearing
41	0.0428	71	59.9674	100.024	29.987	100.02	29.99	100.02	30.00	100.06	31.96	100.06	29.99
41	0.0191	71	59.9581	74.989	58.965	74.99	58.97	74.99	59.00	75.02	60.93	75.02	58.97
40	59.9899	71	59.9632	60.023	109.914	60.02	109.91	60.02	109.90	60.05	111.88	60.05	109.92
40	59.9909	71	59.9949	20.011	156.994	20.01	156.99	20.01	157.00	20.02	158.96	20.02	157.00
40	59.9570	72	0.0020	87.093	182.018	87.09	182.02	87.09	182.00	87.13	180.05	87.13	182.02
40	59.9281	72	0.1711	300.047	240.985	300.05	240.99	300.05	241.00	300.16	239.02	300.16	240.98
41	0.1286	72	0.3813	640.046	294.000	640.05	294.00	640.05	294.00	640.29	292.03	640.29	293.99
41	0.0148	72	0.0052	31.001	345.094	31.00	345.09	31.00	345.10	31.01	343.13	31.01	345.09

Test Point BRAVO, AP = 13 00' 00.000" N, 144 00' 00.000" E

NMEA Lat Inpu		NMEA Lon Inpu		"True"		"AAPS 3.4"		"AAPS 4.0"		"ECPINS 1.71"		"ECPINS 1.73"	
Lat I	Lat Min	Lon I	Lon Min	Range	Bearing	Range	Bearing	Range	Bearing	Range	Bearing	Range	Bearing
13	0.0429	144	0.0253	99.929	30.041	99.93	30.04	99.93	30.00	100.02	30.72	100.02	30.04
13	0.0192	144	0.0325	75.025	58.933	75.02	58.93	75.02	58.90	75.09	59.61	75.09	58.93
12	59.9898	144	0.0285	59.990	110.051	59.99	110.05	59.99	110.00	60.05	110.73	60.05	110.05
12	59.9909	144	0.0040	19.982	156.682	19.98	156.68	19.98	156.70	20.00	157.36	20.00	156.68
12	59.9569	143	59.9985	86.959	181.955	86.95	181.95	86.95	182.00	87.04	181.28	87.04	181.95
12	59.9279	143	59.8673	299.979	241.010	299.98	241.01	299.98	241.00	300.25	240.34	300.25	241.01
13	0.1291	143	59.7043	640.029	294.001	640.03	294.00	640.03	294.00	640.61	293.33	640.61	294.00
13	0.0148	143	59.9959	30.925	344.802	30.92	344.80	30.92	344.80	30.95	344.13	30.95	344.80

Test Point CHARLIE, AP = 60 00' 00.000" S, 087 00' 00.000" W

NMEA Lat Input		NMEA Lon Inpu		"True"		"AAPS 3.4"		"AAPS 4.0"		"ECPINS 1.71"		"ECPINS 1.73"	
Lat [	Lat Min	Lon	Lon Min	Range	Bearing	Range	Bearing	Range	Bearing	Range	Bearing	Range	Bearing
59	59.9574	86	59.9508	99.938	30.047	99.94	30.05	99.94	30.00	99.90	30.05	99.90	30.05
59	59.9810	86	59.9368	74.969	59.026	74.97	59.03	74.97	59.00	74.94	59.03	74.94	59.03
60	0.0101	86	59.9446	59.962	110.002	59.96	110.00	59.96	110.00	59.94	110.00	59.94	110.00
60	0.0091	86	59.9923	20.070	157.033	20.07	157.03	20.07	157.00	20.06	157.03	20.06	157.03
60	0.0428	87	0.0030	86.967	182.011	86.97	182.01	86.97	182.00	86.93	182.01	86.93	182.01
60	0.0716	87	0.2580	299.987	241.007	299.99	241.01	299.99	241.00	299.87	241.01	299.87	241.01
59	59.8718	87	0.5748	639.968	293.999	640.01	294.00	640.01	294.00	639.71	294.00	639.71	294.01
59	59.9853	87	0.0079	30.914	344.935	30.91	344.93	30.91	344.90	30.90	344.94	30.90	344.94

Test Point DELTA, AP = 10 00' 00.000" S, 170 00' 00.000" E

NMEA Lat Input		NMEA Lon Input		"True"		"AAPS 3.4"		"AAPS 4.0"		"ECPINS 1.71"		"ECPINS 1.73"	
Lat	Lat Min	Lon [	Lon Min	Range	Bearing	Range	Bearing	Range	Bearing	Range	Bearing	Range	Bearing
9	59.9570	170	0.0250	100.055	29.955	100.05	29.96	100.05	30.00	100.03	29.78	100.03	29.96
9	59.9808	170	0.0322	75.093	58.971	75.09	58.97	75.09	59.00	75.07	58.80	75.07	58.97
10	0.0102	170	0.0282	59.989	110.047	59.99	110.05	59.99	110.00	59.97	109.87	59.97	110.05
10	0.0091	170	0.0039	19.933	156.983	19.93	156.98	19.93	157.00	19.93	156.81	19.93	156.98
10	0.0431	169	59.9985	86.943	181.976	86.94	181.98	86.94	182.00	86.92	181.80	86.92	181.98
10	0.0721	169	59.8687	299.959	241.014	299.96	241.02	299.96	241.00	299.88	240.84	299.88	241.02
9	59.8709	169	59.7074	640.037	293.994	640.04	293.99	640.04	294.00	639.88	293.82	639.88	294.00
9	59.9851	169	59.9960	31.084	345.099	31.08	345.10	31.08	345.10	31.08	344.93	31.08	345.10

ECPINS/ATON 1.71 results show some differences with respect to the truth numbers. The standard deviation of the range values was 0.14 yards, about 5 inches. The difference is attributed to the way OSL models the area around AP. We believe they use a different mathematical approach versus the NGS spherical geometry approach. When this value is included in the positioning error budget it is clearly insignificant. Throughout the ECPINS 1.71 testing there were some anomalous bearing adjustments being performed by the ECPINS that could not be accounted for with the technical personnel at the LBSF/C2CEN. At the Alpha test point the system seemed to be adding 1.969 degrees to the bearing to AP for values between 0-180 and subtracting 1.969 for values between 180-360 degrees. Alpha had the largest bias, but the others exhibited biases of 0.68 (Bravo), 0.18 (Delta) and test point Charlie had no apparent bearing bias. These anomalous bearing adjustments do not effect the positioning of aids as the range values are the determining factor in on/off station calculations. In December 1999, the LBSF/C2CEN ran these same tests on ECPINS/ATON version 1.73. The results, as shown in the spreadsheets, indicates that the bearing bias has been eliminated resulting in small bearing errors, less than .01 degree. With this bearing problem isolated and corrected ECPINS/ATON version 1.73 yields bearing performance that is quite comparable to the NGS values.

Antenna Offset data

AAPS 3.4 and ATONIS/AAPS 4.0 delivered error free consistent results when performing antenna offsets on the vessel. ECPINS/ATON 1.71 had some slight differences from the truth calculations. In all cases, however the offsets were found to be within about 3 inches. Again, this difference is considered insignificant and will be a small part of the translation errors, which are most sensitive to gyro compass errors of bias or lag when heading is changing. While performing the antenna offsets the ECPINS still exhibited the anomalous bearing bias at test point Alpha. In this case it again seemed to add this bearing adjustment to the actual bearing to the offset position. It did not cause an error or a problem, it just presents this adjusted bearing instead of the actual bearing between the points. This was resolved in ECPINS/ATON 1.73.

Excursion data

AAPS 3.4 and ATONIS/AAPS 4.0 delivered error free consistent results when performing excursion calculations to account for distance from the vessel to calculate the most probable position. ECPINS/ATON version 1.71 was found to be in error due to the anomalous bearing adjustment being performed by ECPINS. While this anomaly was not a significant problem in earlier tests it caused significant errors in excursion. In the four excursion calculations run, the ECPINS was found to be off by 26-30 inches. When we compensated our input for the 1.969 degree bias we found the results to be within 2 inches. As this bearing problem has been corrected in ECPINS version 1.73, the excursion function is now working properly.

Conclusions

1. We developed an effective means for evaluating the positioning accuracy of AtoN positioning systems. This was demonstrated in C2Cen's ability to reproduce the test without R&D Center assistance.

2. An error budget for determining the statistical significance of the results of these tests was developed and should prove useful for other AtoN positioning issues.

3. AAPS 3.4 and ATONIS/AAPS 4.0 are effectively equivalent to the National Geodetic Survey algorithms in all test cases. The sole recommendation is: In order to maintain consistency with AAPS 3.4, ATONIS/AAPS 4.0 should have its presentation of bearing to AP changed from 0.1 to 0.01 degrees resolution on the APR.

4. The ECPINS/ATON version 1.71 we tested had a problem where it introduced biases into the bearing between positions. This was not generally a problem except in the excursion function where it caused significant errors. Later testing of ECPINS/ATON version 1.73 by LBSF/C2CEN shows that this bearing bias has been corrected and that ECPINS/ATON now produces acceptable results.

5. The end result of this testing is that AAPS 3.4, ATONIS/AAPS 4.0 and ECPINS/ATON 1.73 can be used interchangeably for positioning aids to navigation and achieve equivalent operational results.