Naval Research Laboratory
Stennis Space Center, MS 39529-5004

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Demonstrating a Moving-Map System With Electronic Charts for Improved Lane Navigation: Testing on AAVs in Gulfport, MS

Marlin L. Gendron
Stephanie A. Myrick
Stephanie S. Edwards
Richard A. Mang

Mapping, Charting, and Geodesy Branch
Marine Geosciences Division

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Marlin L. Gendron, Stephanie A. Myrick, Stephanie S. Edwards, and Richard A. Mang

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14. ABSTRACT

Amphibious landing operations that are being conducted in a mined environment require the use of navigation lanes that have been cleared of mines. The amount of time required to clear mines is determined by the width of the lanes to be cleared where lane width is determined by the ability of the assault craft to successfully navigate within a cleared lane (i.e., its lane navigation capability). Therefore, vehicles with stronger navigation capabilities allow more narrow lanes to be cleared. This project is based on the premise that a moving map (MM) capability will facilitate more precise lane navigation, thereby reducing aggregate lane width requirements for mine clearance.

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DEMONSTRATING A MOVING-MAP SYSTEM WITH ELECTRONIC CHARTS FOR IMPROVED LANE NAVIGATION: TESTING ON AAVs IN GULFPORT, MS

INTRODUCTION

Amphibious landing operations that are being conducted in a mined environment require the use of navigation lanes that have been cleared of mines. The amount of time required to clear mines is determined by the width of the lanes to be cleared where lane width is determined by the ability of the assault craft to successfully navigate within a cleared lane (i.e., its lane navigation capability). Therefore, vehicles with stronger navigation capabilities allow more narrow lanes to be cleared. This project is based on the premise that a moving map (MM) capability will facilitate more precise lane navigation, thereby reducing aggregate lane width requirements for mine clearance.

The Office of Naval Research (ONR) has funded the Naval Research Laboratory (NRL), Stennis Space Center, MS to equip amphibious assault vehicles with Differential GPS MM systems and electronic charting to test for improvements in lane navigation. These tests will be conducted on the Amphibious Assault Vehicle (AAV), the Landing Craft Utility (LCU), and the Landing Craft Air Cushion (LCAC). NRL will outfit each type of vehicle with the MM system and demonstrate its capabilities at Fleet Battle Experiment Juliet in July 2002 and Kernel Blitz 03 in FY-03Q2.

The NRL MM system is a relatively low cost commercial off-the-shelf (COTS) differential GPS (DGPS) moving-map navigation system that runs a government off-the-shelf (GOTS) moving-map software package figure 1). This system consists of a differential DGPS receiver and antenna capable of giving the vehicle's exact position within 5 meters. The DGPS is connected to a high performance, ruggedized, water-resistant Intel computer running the Portable Flight Planning System (PFPS) software suite that can display standard National Imagery and Mapping Agency (NIMA) navigational charts.

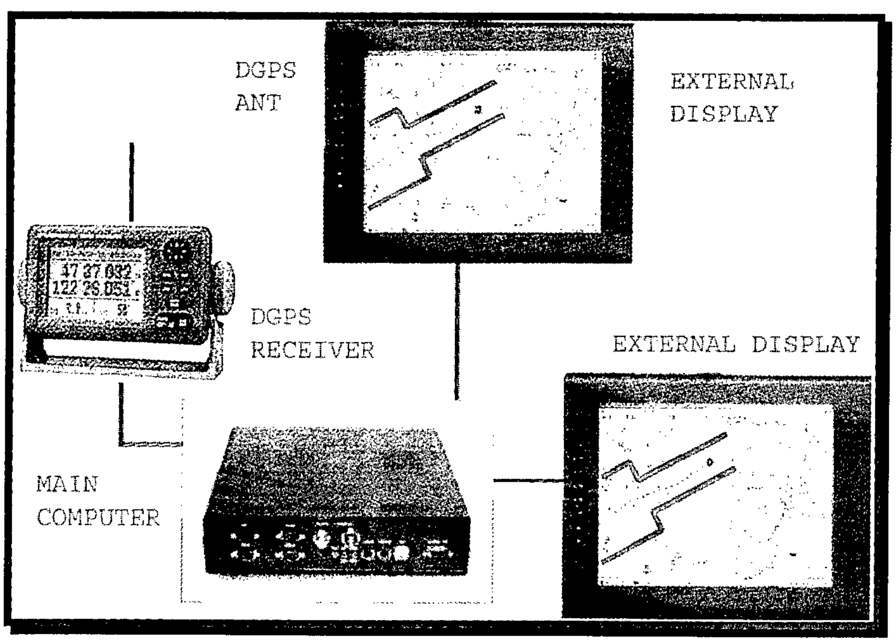

Figure 1. The NRL Moving Map system

Manuscript approved June 24, 2002.

BACKGROUND

In preparation for these demonstrations, NRL worked with the 3rd Platoon, Company A, 4th Assault Amphibian Battalion (AABN), US Marine Corp Reserve Unit in Gulfport, MS to test a prototype lane navigation system, and with the Coastal System Station (CSS), Panama City, FL for OPNAV N752 in support of their lane width study.

During May 7-9,2002; NRL and CSS jointly conducted lane navigation tests from the beach in Gulfport using AAVs and Marine Corp Reserve crews. Each vehicle was outfitted with an MM system by NRL, and a precise position-tracking device by CSS. CSS also supplied one of the vehicles with a Precision Lightweight GPS Receiver (PLGR). During these tests, one vehicle primarily ran MM while the other vehicle used the PLGR. This configuration was employed to compare results from the use of different navigation devices. The AAV crews were rotated between configurations to maximize their exposure with each. In addition, each vehicle was run through the course as many times as possible during the three days of testing. For comparison of position accuracy, some of the runs with the MM vehicle were using differential GPS (DGPS) and others used GPS.

PFPS was loaded with a 1:26K Topographic map of the Gulfport test area (figure 2). Figure 3 shows an overlay of a precisely surveyed test course possessing a 50-yard lane width. Drivers were instructed to steer their vehicles along the centerline within this lane. The direction the vehicles traversed the course, clockwise or counter-clockwise, was varied with each vehicle to help reduce course familiarity.

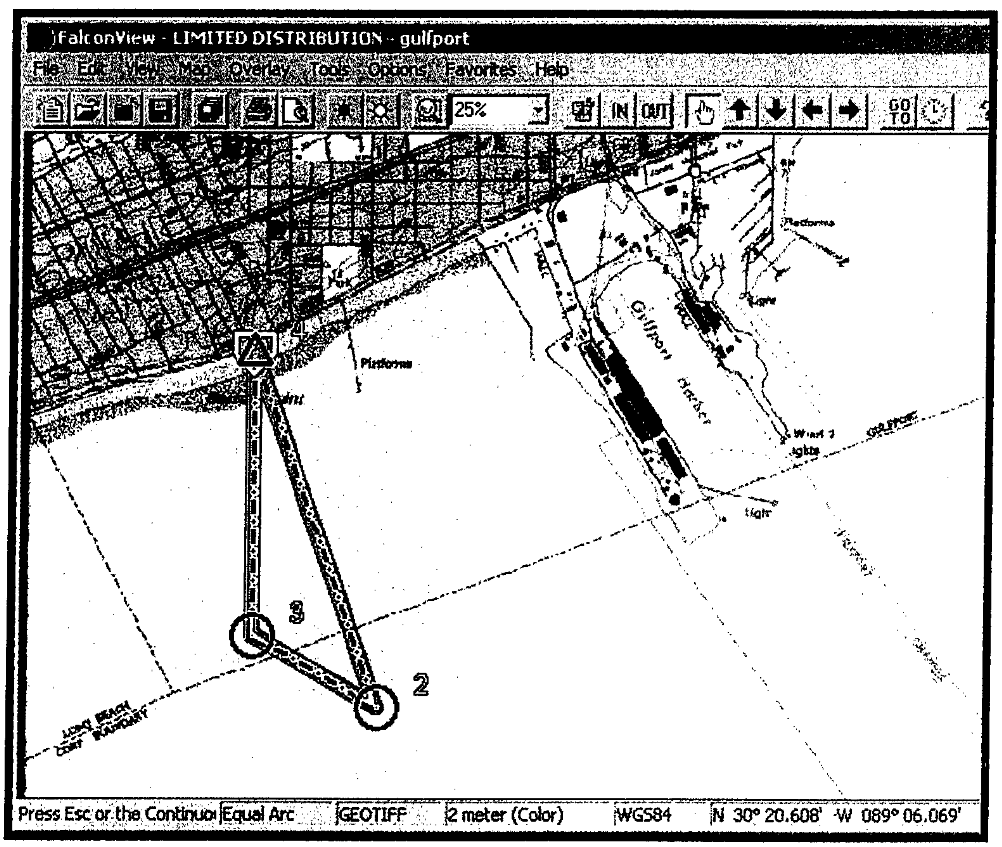

Figure 2. A topographic map of the Gulfport, MS test area

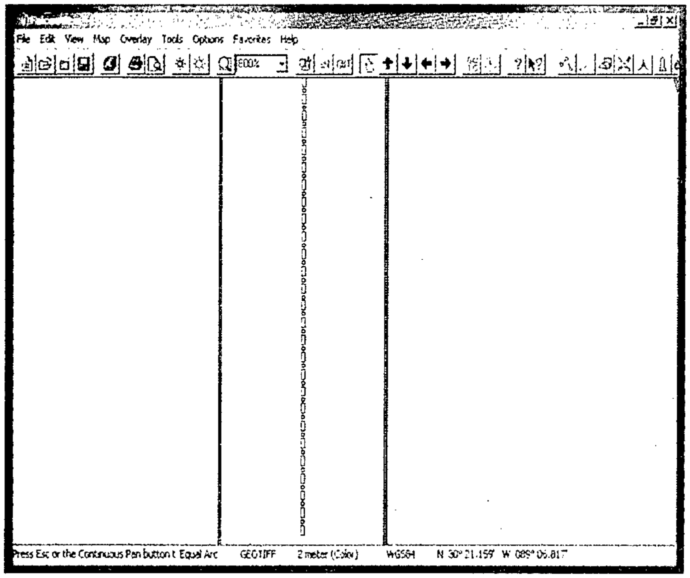

Figure 3. Topographic map with a 50-yard lane width test course overlay. The centerline is marked with a dashed line and a yellow symbol indicates the AAV position as it travels within the navigation lane.

One display was installed in the AAV directly in front of the driver. PFPS was run in the *track up* moving-map display mode where the vehicle position is always indicated at the bottom on the screen (with a yellow symbol) and pointed forward (up) in the direction of travel (figure 3). The map movement scrolls from top to bottom. Therefore, when the AAV is heading North, the top of the display is depicted as North, and when the AAV is heading South, the top of the display is depicted as South. This mode resembles driving an automobile - if the vehicle began drifting to the right, the driver would steer left to remain in the lane.

Figure 4 shows the driver and map display during the actual test in Gulfport. A second, smaller display was installed in the turret for the Crew Chief that showed the same view. PFPS gives the ability to zoom the map display in or out so, it could be adjusted to accommodate viewing preferences.

Figure 4. An AAV driver using the MM system during testing in Gulfport, MS.

MM SYSTEM TEST OPERATIONS

To reduce the risk of water damage to equipment, NRL constructed waterproof enclosures for the computer processors and installed the moving-map systems on each vehicle prior to the beginning of test operations. Equipment installation required 3 days of effort and was completed on Monday, May 6th. Installation time for the July demonstrations will be reduced to a single day because of the experience NRL gained and the availability of six pre-built waterproof systems. Also on Monday, NRL trained three full crews which consisted of new Reservists who had little or no prior water driving experience.

During the three-day test NRL saved all the DGPS/GPS positions that were recorded by the MM system for later analysis. Informal interviews with drivers and Crew Chiefs were conducted before and after each run to obtain performance feedback, address concerns and answer questions. NRL also videotaped the display that the driver viewed during each moving-map test. CSS tracked the PLGR data (i.e., precise location of each vehicle as it traversed the course) and recorded environmental conditions. Test results show that the MM system helped the driver to remain within the navigation lane. When DGPS was used, the drivers demonstrated an increase in accuracy since the CSS tracking data reveal that, in some cases, the vehicle's track was less than a meter from the center of the track.

Testing operations were very successful. A total of 34 test runs were completed with only two aborted runs. There were 16 runs made with the PLGR vehicle and 17 runs made with the MM vehicle. Note that the sea conditions during the duration of the testing were relatively calm with 1 to 2 foot choppy waves.

POST TEST BRIEFING

On Friday a briefing was held to identify strengths and weakness, address performance issues and conduct general discussions. Crew Chiefs, drivers, and scientists from NRL and CSS attended this meeting. Although NRL had conducted informal interviews during the tests, additional feedback and comments were solicited during the briefing to further identify areas for improvement and clarify feedback. Appendix A provides a summary of these questions. A brief synopsis of the briefing discussions follows.

- The drivers generally found the MM system easy to use, very helpful in maintaining position of the vehicles within the lanes, and a huge improvement over the PLGR system. The drivers commented that it "was much easier to get back into the lane using the MM than using the PLGR." The Crew Chief found the PLGR to be very "unforgiving" when calculating a vector to get back into the lane. The Crew Chief stated that, on average, it could take as long as 1 to 2 minutes to calculate the current position of the vehicle when using PLGR data. This process apparently produced driver fatigue. In one instance a Crew Chief reported feeling nauseated and dizzy from staring at the small PLGR display. The PLGR was mounted in the turret and its small display tended to move around considerably.

- When using the MM display, the drivers reported very little fatigue or distress. The mounting of the MM display was solid, and the drivers reported that the display did not move or vibrate.

- One problem drivers reported was that, when turning the vehicle, there was a lag time between the vehicle's actual position and the position noted on the MM screen. This was due to the 1 second GPS update rate. This lag occasionally caused the driver to overcompensate when trying to stay in the lane, and could cause a condition where the vehicle oscillates back and forth. To correct this, the driver would slow the vehicle, regain control, and then get back on course. It should be noted that this condition occurred infrequently, and was observed during the first test runs with inexperienced drivers. When this did occur, the vehicle remained within the lane. After the driver got used to the lag time, this was no longer a problem. A driver stated that experience, or "getting to know the system", completely solved the problem.

- Drivers using the MM system became quite proficient at staying in the lane.

- Prior to testing, drivers were instructed to view and rely on the MM display as the sole navigation aid and not look outside the window as they would normally do. At the debriefing, the drivers stated they did not look outside, but only at the MM screen or down at the vehicle's instruments. The drivers felt that it would be better to completely block the windows during an assault because this would reduce glare and prevent any light originating from the MM display to be emitted outside the vehicle.

- There was a smaller display located in the turret for use by the Crew Chief. One Crew Chief stated that he liked having the display so he could easily keep track of the vehicle's location and the driver's abilities. All of the Crew Chiefs stated that they did not have to aid the drivers in staying in the lane at anytime when the drivers used the MM. Sometimes the Crew Chiefs had to tell the inexperienced drivers to slow down when making turns to maintain vehicle control. These remarks were unrelated to the ability of the MM to aid the driver in staying within the lane.

- The Crew Chiefs recommend that, in the future, the driver's display and the turret display have independent zooming capabilities. This would allow the driver to "zoom in" and concentrate on the lane, while the Crew Chief could "zoom out" for better situational awareness. Other suggestions included using nautical charts instead of Topographic maps since the nautical charts show other information (e.g., water depth, contours, buoys) that would be helpful for better situational awareness.

MM SYSTEM EQUIPMENT PERFORMANCE

The MM equipment performed well and consistent. One test run was aborted because a faulty vehicle ground connection that was quickly and easily corrected. From the beginning, NRL was aware of the importance of using waterproof/water-resistant equipment. As a result, the main display in front of the driver was waterproof as was the container for the main computer processing unit. NRL had also planned to use a similar but smaller waterproof display in the Crew Chief position. Unfortunately, these smaller displays have only recently become available and are in high demand and short supply. NRL was unable to obtain a display in time for the Gulfport test however; several waterproof displays should be available for the July demonstrations.

A non-waterproof display was installed in the Crew Chief position for the Gulfport test and NRL was aware that unit was vulnerable to water damage. Approximately half of the MM runs where made with this display in the crew chief's position before it sustained excessive water damage and became unusable. Since half of the runs were made with the crew chief's display and half of the runs without it, a comparison set of results pertaining to the need for the second display were obtained. These results indicate that the Crew Chief display is very useful for situation awareness to the Crew Chief (but is not required for the driver to remain within the prescribed lane since he is using a separate display).

The MM system that was installed in the PLGR vehicle was tested on the last day of operations. The main computer processor of this system completely failed and NRL had anticipated that this might occur since there were earlier problems with that particular hardware vendor. None of the six MM systems that NRL will demonstrate in July will contain parts from this vendor. Ultimately, this problem did not affect testing in Gulfport, since the operational plan was to run only ONE MM system to compare it to the PLGR vehicle.

RESULTS

User feedback indicates that the drivers were extremely satisfied with the use of the moving map display. Training had adequately prepared the drivers and Crew Chiefs to use the MM system. Based on preliminary CCS findings, it was clear that without the MM system, the driver's visibility was so limited that it was difficult to remain in a predetermined lane. This was the case even when the drivers were receiving direction vectors based on radar returns. When using the MM display (which was physically located 6 inches away from the driver's face) the driver was able to remain very close to the center of the navigation lane (figure 5). The navigation lanes were intentionally not set to be perpendicular to the beach but instead, oriented at an angle that would make it very difficult to use visual references to maintain accurate navigation. One promising comment noted "this was the most accurate set of beach landings the drivers had done".

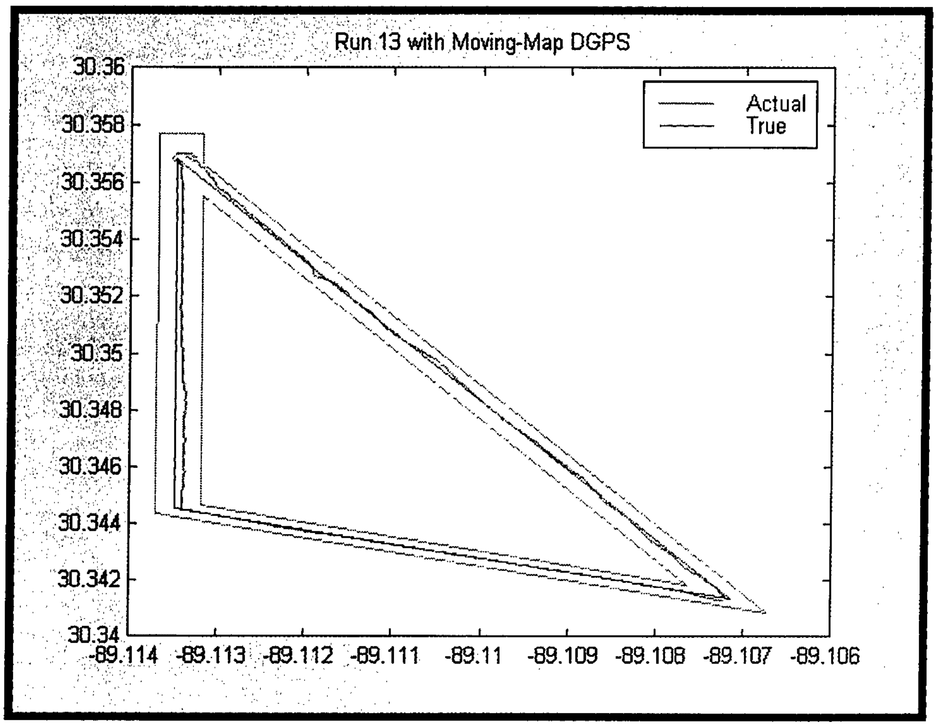

Figure 5. A lane navigation plot showing typical deviation of the AAV from the lane centerline.

Data collected during test runs show that drivers were normally capable of remaining within the track. Table 1 summarizes deviations between the lane centerline and actual track driven. The GPS data for this test area were very accurate. However, it should be noted that in the case of high GPS errors, even if the driver drove a straight course within the navigation lane, the vehicle could still be physically located outside of the navigation lane. Therefore, DGPS should also be used when it is available. Appendix B provides navigation plots for each test run. These plots show actual versus true navigational coordinates, where a green line outlines the entire 50-yard width of navigation lane, the true lane center is drawn in red, and the actual AAV track driven is drawn in blue. Course direction did not appear to affect results.

Run	Number of GPS points collected	Travel Direction (North-up)	Number of GPS points outside the lane	Percentage outside the lane
1	4619	CW	0	0
2	2265	CW	0	0
3	2318	CW	189	8.1
4	2064	CW	7	0.3
5	1311	CW	18	1.3
6	1441	CCW	123	8.5
7	4533	CCW	2	0
8	2163	CCW	36	1.6
9	2464	CCW	573	23.2
10	2960	CW	56	1.8
11	1963	CW	0	0
12	1645	CW	0	0
13	2633	CW	0	0
14	2851	CW	0	0
15	2931	CCW	0	0
16	2464	CCW	0	0
17	2691	CCW	0	0

Table 1. A lane navigation summary for each AAV test run. CW indicates Clockwise direction and CWW indicates a Counter-Clockwise direction.

Driver errors caused most of the navigation deviations during test runs:

- Runs 3, 6 and 8 reflect vehicle oscillations that resulted from the lag GPS update lag, as the driver overcompensated his steering when trying to stay in the lane. To correct the problem, the driver would slow the vehicle, regain control, and then get back on course. The use of inexperienced drivers was also a factor. Figure 5 shows the navigation plot for run 3.

- Deviations in run 5 are attributed to the driver cutting a corner of the course.

- Vehicle power fluctuations due to a vehicle ground connection was responsible for run 9 deviations.

- Deviations for run 10 are the consequences of a false start, and the resultant circle, that is located at the beginning of the run (figure 6).

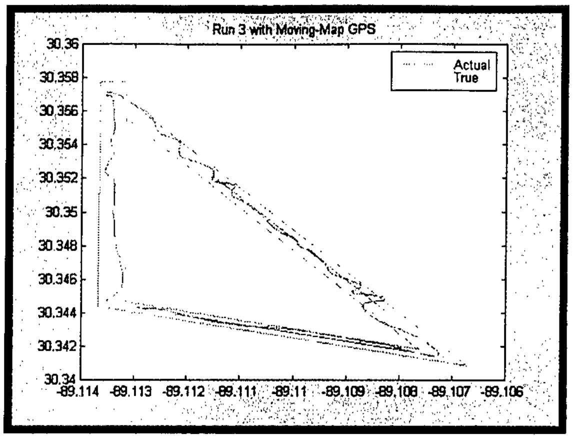

Figure 5. Navigation plot showing AAV oscillations

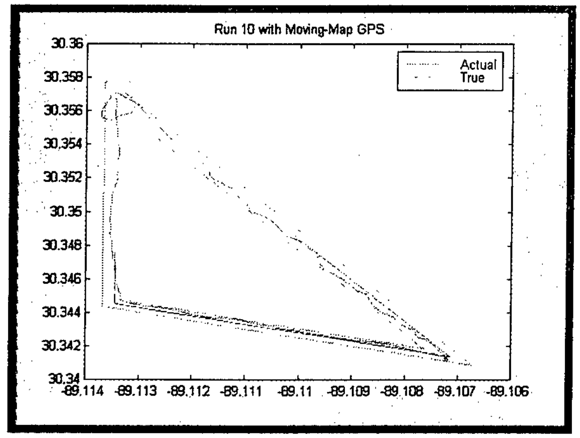

Figure 6. False start beginning in run 10

Based on MM performance and user feedback, the Gulfport tests were successful and demonstrated that the MM system aided lane navigation. Especially so, when considering this operation was the first test of equipment and software, and that all of the drivers were relatively inexperienced. The few problems encountered were inconsequential and minor. Part of this success may be attributable to the sea state's relative calmness (1 to 2 feet of choppy waves). These test operations will be compared to the results from the demonstrations in July where sea states are expected to be higher, and the drivers may be more experienced.

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Stephanie Edwards (Computer Scientist),
Richard Mang (Electronics Technician), and
Stephanie Myrick (Computer Scientist)

APPENDIX A

User Evaluation

Demonstrating DGPS Moving-Maps with Electronic Charting for Improved Lane Navigation

Gulfport, Mississippi

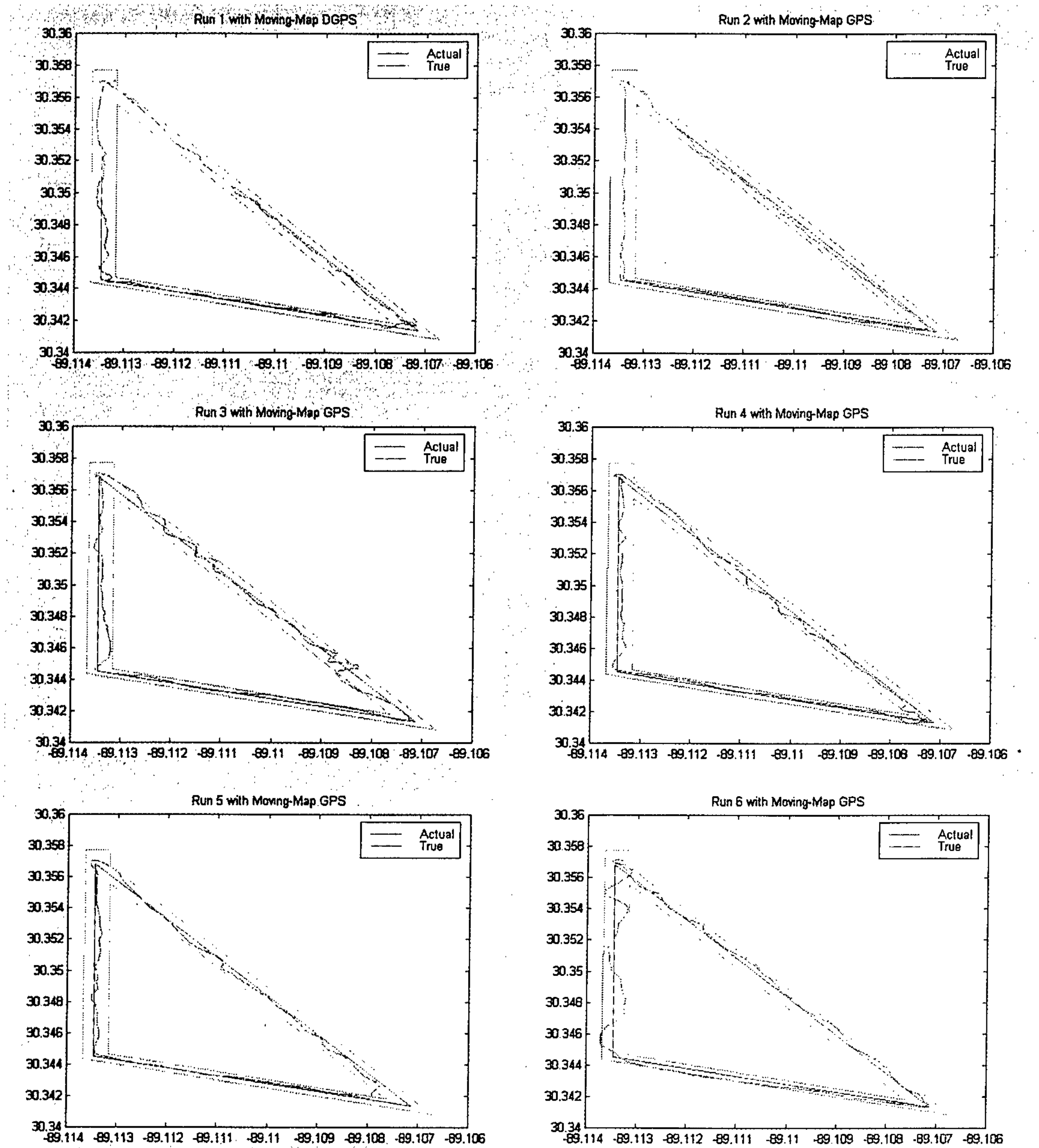
Rating system: 1---------------2---------------3---------------4---------------5

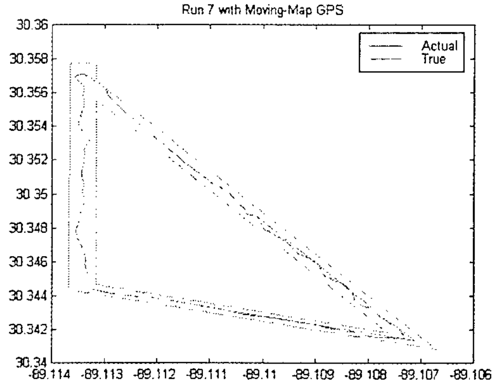
Poor Fair Average Good Outstanding

Element	Rating	Comments
Training Materials		
Training Length		
Demonstration Duration		
Display Monitor location		
Display Monitor Vibration		
Base Map		
Overlay Lane Width Markings		
Overlay Vehicle location		
Overlay Accuracy		
Overlay Colors		
Display Update Rate		
Display Clarity		
Display Colors		
Display Zoom In Feature		
Display Zoom Out Feature		
Overall Usefulness (Navigation/Driver)		
Overall Usefulness (Crew Chief)		

APPENDIX B

Plots showing actual versus true navigational coordinates for all test runs. Within each plot, a green line is used to outline the entire 50-yard width of navigation lane, the lane center is drawn in blue, and the AAV track is drawn in red. The beach was located in the northwest portion away from the plot




Run 7 with Moving-Map GPS
Actual
True
30.36
30.358
30.356
30.354
30.352
30.35
30.348
30.346
30.344
30.342
30.34
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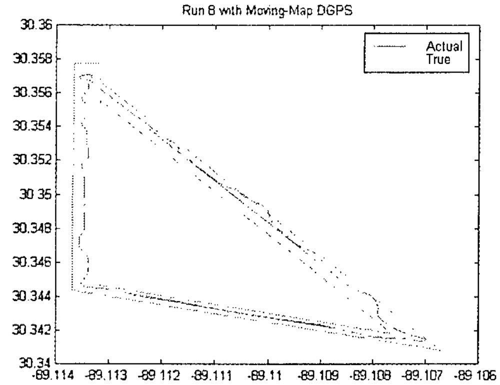
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Actual
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30.358
30.356
30.354
30.352
30.35
30.348
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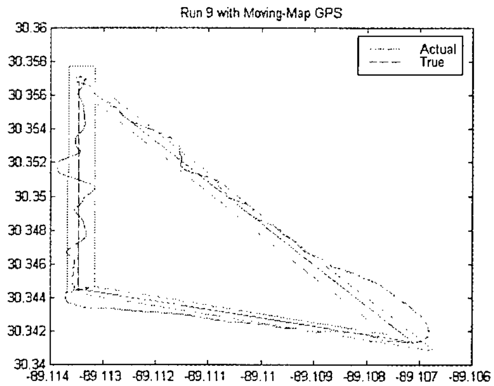
30.342
30.34
-89.114 -89.113 -89.112 -89.111 -89.11 -89.109 -89.108 -89.107 -89.106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30.358
30.356
30.354
30.352
30.35
30.348
30.346
30.344
30.342
30.34
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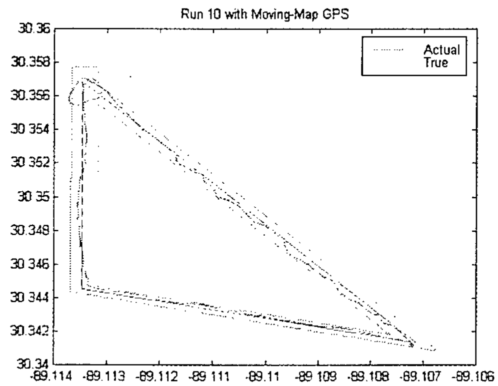
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Actual
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30.358
30.356
30.354
30.352
30.35
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30.342
30.34
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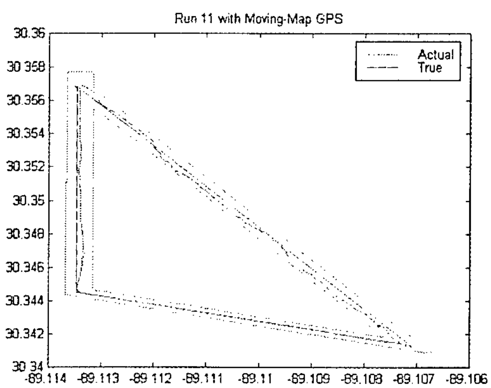
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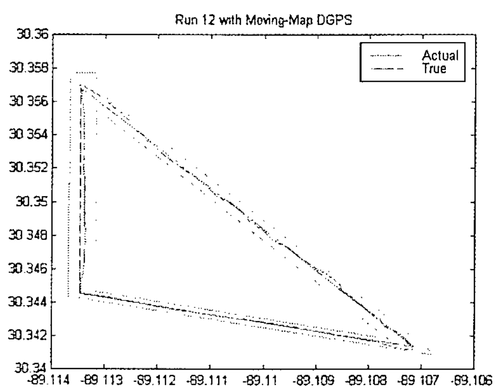
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Actual
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30.358
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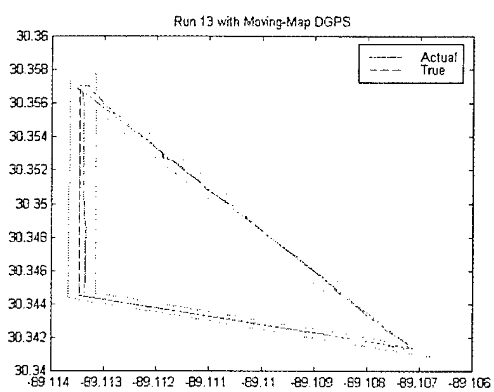
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Actual
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30.358
30.356
30.354
30.352
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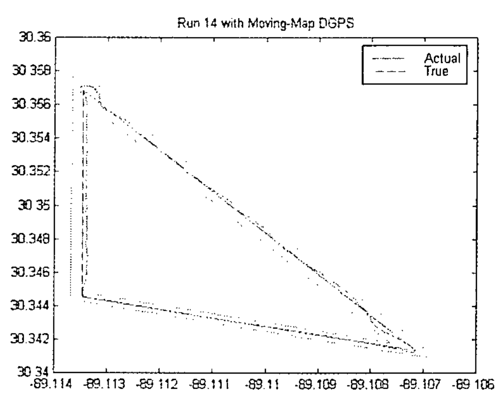
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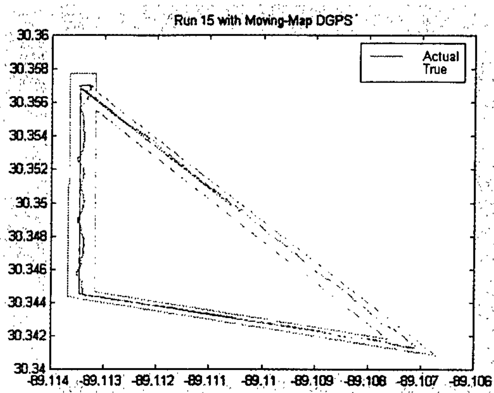
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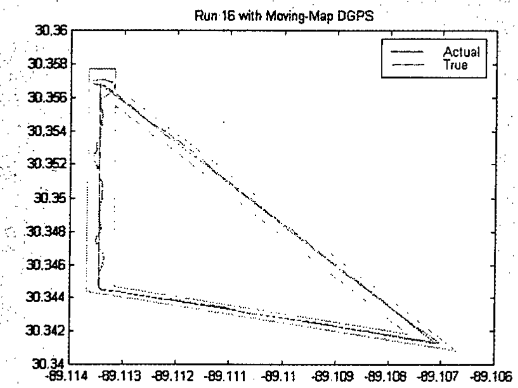
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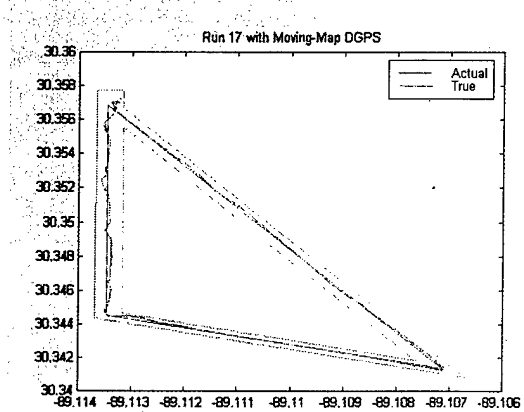
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30.358
30.356
30.354
30.352
30.35
30.348
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30.344
30.342
30.34
-89.114 -89.113 -89.112 -89.111 -89.11 -89.109 -89.108 -89.107 -89.106