REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
13-FEB-2003	Conference Proceedings, (refereed)	

4. TITLE AND SUBTITLE
Demonstration Of A Moving-Map System For Improved Lane Navigation Of Amphibious Vehicles

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
0603782N

6. AUTHOR(S)
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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
74-M009-03

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Research Laboratory
Marine Geoscience Division
Stennis Space Center, MS 39529-5004

8. REPORTING ORGANIZATION REPORT NUMBER
NRL/PP/7440--03-1009

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217

10. SPONSOR/MONITOR'S ACRONYM(S)
ONR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release,distribution is unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The Naval Research Laboratory (NRL) is testing and demonstrating a prototype moving-map system on amphibious vehicles and landing craft to aid the location, neutralization, and navigation around mines and obstacles in the surf and beach zone. NRL proposed that a moving-map would improve crew situational awareness and communications, thereby improving precise lane navigability (and reducing the requisite lane width). Two platforms were targeted for moving-map tests: Landing Craft Utility and Amphibious Assault Vehicles.

15. SUBJECT TERMS
moving-map system, amphibious vehicles, landing craft

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON / 19b. TELEPHONE NUMBER *(Include area code)*
unclassified	unclassified	unclassified	Unlimited	10	Ms. Maura Lohrenz / 228-688-4611

Demonstration of a Moving-Map System for Improved Lane Navigation of Amphibious Vehicles

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Naval Research Laboratory Code 7440.1

Introduction

The Naval Research Laboratory (NRL) is testing and demonstrating a prototype moving-map system on amphibious vehicles and landing craft to aid the location, neutralization, and navigation around mines and obstacles in the surf and beach zone. NRL proposed that a moving-map would improve crew situational awareness and communications, thereby improving precise lane navigability (and reducing the requisite lane width). Two platforms were targeted for moving-map tests: Landing Craft Utility (LCU) and Amphibious Assault Vehicles (AAV).

Background

Standard navigation procedures for LCU and AAV

The LCU is operated by three crewmembers: navigator, craftmaster, and helmsman. The navigator and helmsman are stationed below decks with a limited outside view, while the craftmaster is situated topside with a 360° view of the surrounding area (figure 1). The navigator provides range and bearing information to the craftmaster, who instructs the helmsman to make appropriate course corrections. All communication between the craftmaster and the other two crewmembers is accomplished via sound tube. The navigator has access to paper charts, radar, and (in some cases) an electronic chart display.

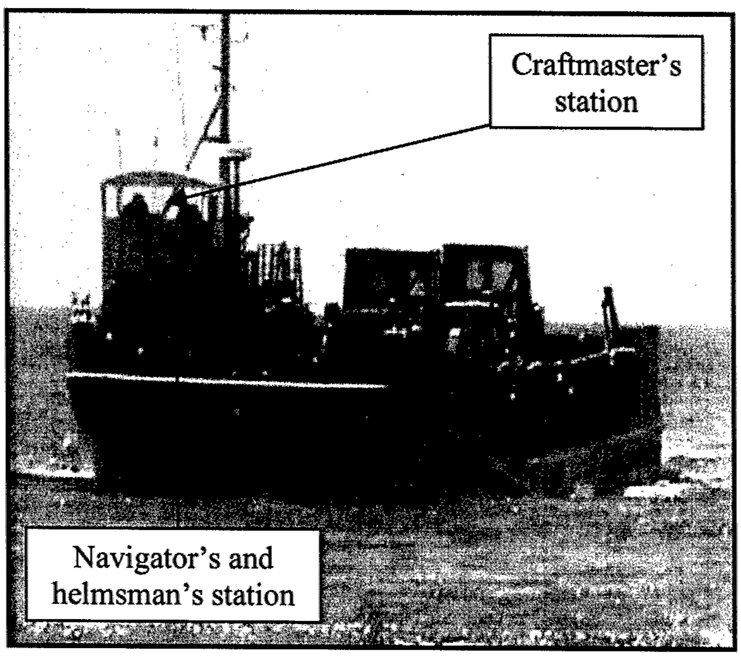

Figure 1. A Landing Craft Utility (LCU) showing primary crew locations.

The AAV (figure 2) is equipped with few navigational aids, and the crew has limited visibility from inside the vehicle. The crew chief uses a periscope – or intermittently pops the hatch – for improved visibility. The driver has limited visibility through small windows, which are often obscured by sea spray, so the driver must rely heavily on the crew chief for direction. In some cases, the crew chief is issued a Precision Lightweight GPS Receiver (PLGR), which displays vehicle location as latitude and longitude coordinates on a small handheld device, but the PLGR is not available on all AAVs, and many crew chiefs (including several who participated in our demonstrations) are unfamiliar with its operation. Many crew do not even have a compass. Some AAVs may be equipped with a thermal imaging display in the future, but this is not installed in any vehicles to date.

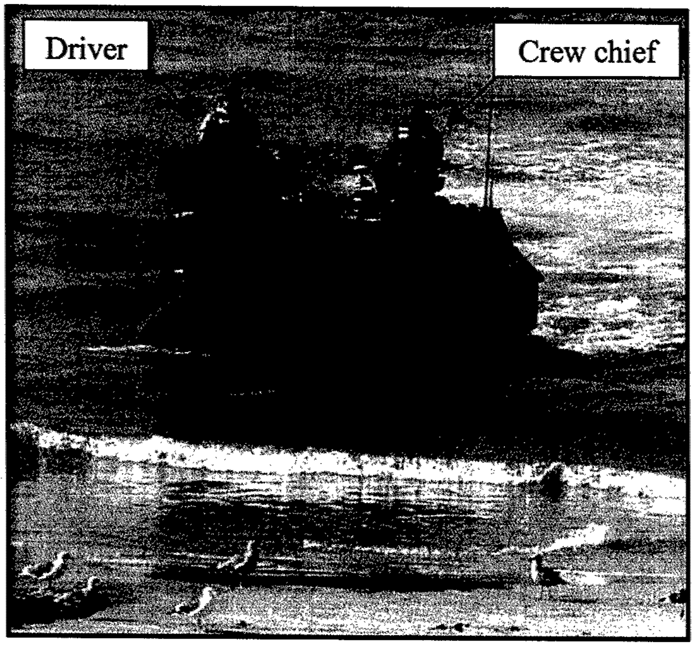

Figure 2. An AAV coming onto the beach (note: crew chief and driver are often partially or completely inside vehicle; communications are hampered by surf and engine noise).

In both the LCU and AAV, one crewmember is responsible for navigation while another actually drives the vehicle. Communication among the crew is crucial to successful navigation, yet hampered by the fact that the responsible crewmembers are located remotely from one another. A tool that would both improve communications and facilitate shared situational awareness (SA) among the crewmembers should also improve their ability to precisely navigate assault lanes.

Overview of NRL moving-map project for amphibious vehicles

In FY02, the Office of Naval Research (ONR) funded NRL Code 7440.1 to test and demonstrate a prototype moving-map system on LCU and AAV platforms in conjunction with a precise lane navigation study being conducted by the Coastal Systems Station (CSS) in Panama City, FL. NRL selected the government off-the-shelf (GOTS) FalconView software, which is the moving-map module of the Portable Flight Planning System (PFPS) widely used by the Naval Air Systems Command for map and mission planning. FalconView is free of charge with no licensing restrictions within the U.S. Department of Defense. FalconView supports all standard digital map and chart products distributed by the National Imagery and Mapping Agency (NIMA) and National Oceanic and Atmospheric Administration (NOAA), as well as the GeoTIFF image format, providing virtually unlimited digital map and chart sources. FalconView provides both track-up and north-up orientations; simple graphical overlay capabilities (e.g., to superimpose battlefield geometry and lane boundaries on the underlying map display); a "breadcrumb trail" to represent the vehicle's track, and a smooth scroll function (such that the map moves beneath a stationary vehicle icon). Range and bearing information can be displayed as needed.

The NRL moving-map (NRL-MM) system hosts the FalconView software on relatively low cost, commercial off-the-shelf (COTS) hardware, including a rugged, water-resistant computer, monitors, and Global Positioning System (GPS) / Differential GPS (DGPS) antenna and receiver capable of recording positions to 5m accuracy. When possible, NRL utilizes existing computers, monitors, and GPS receivers on-board the test vehicles, to minimize cost and space requirements. Figure 3 illustrates the NRL-MM configuration for the LCU, and Figure 4 shows the moving-map display installed in the LCU navigator's and craftmaster's stations. Figure 5 illustrates the configuration for the AAV, and Figure 6 shows the display installed in the AAV driver's station.

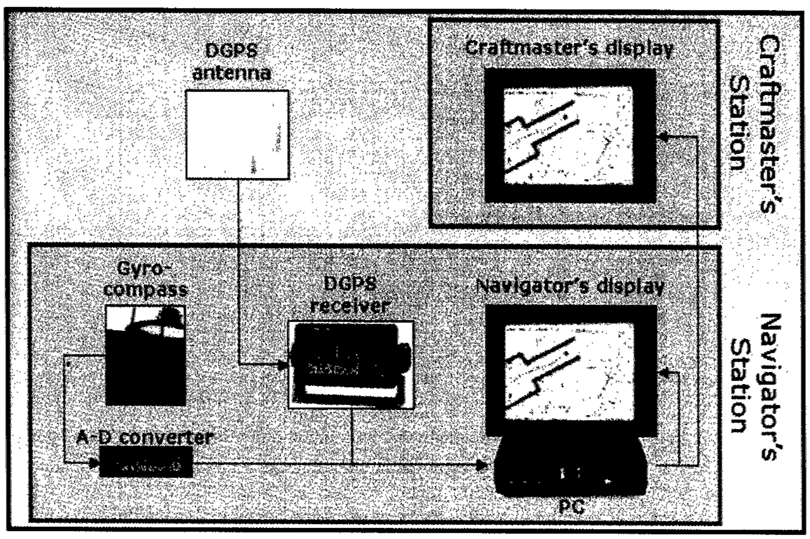

Figure 3. The NRL-MM system: LCU configuration.

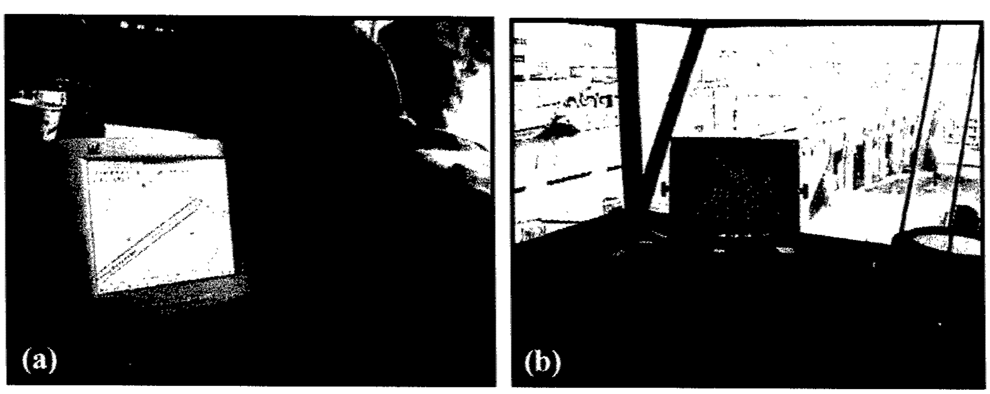

Figure 4. The NRL-MM display installed in a LCU: (a) Navigator's station; (b) Craftmaster's station. Note: both crew see the same view on both displays.

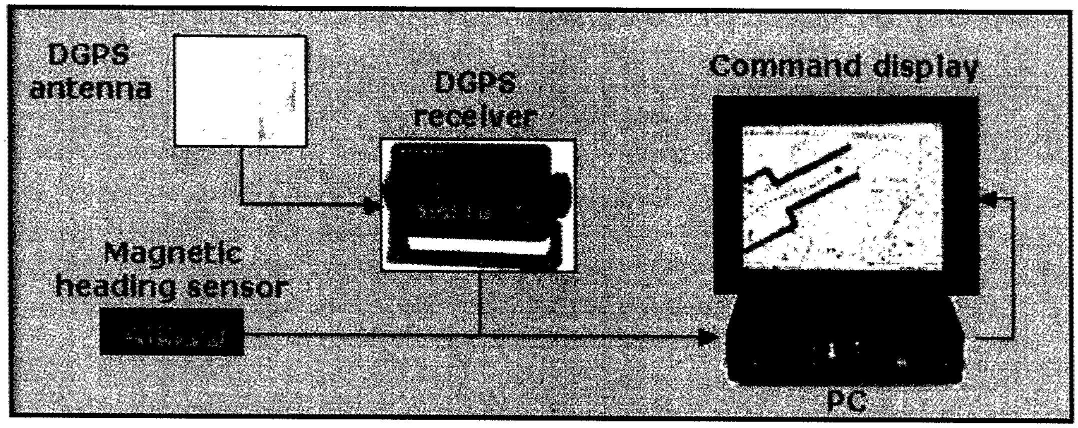

Figure 5. The NRL-MM system: AAV configuration.

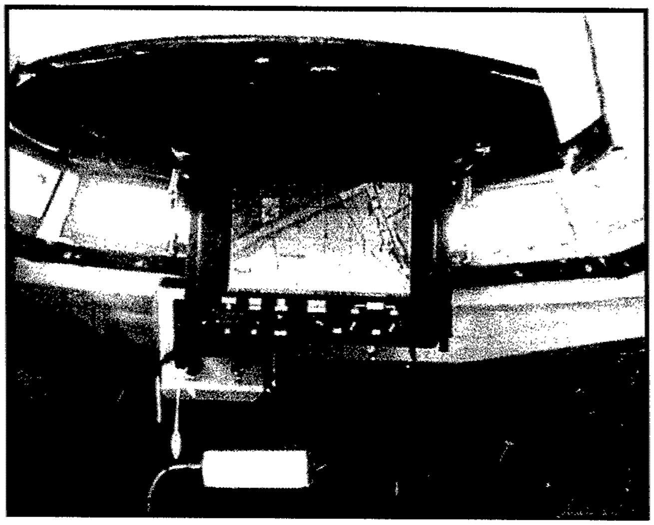

Figure 6. View from inside the AAV showing the driver's station with NRL-MM display and windows to outside view.

Initial tests and demonstrations

NRL first tested its MM system on AAVs in May 2002 with the 3rd Platoon, Company A, 4th Assault Amphibian Battalion Reserve Unit at the CB Base in Gulfport, MS (Gendron, et al., 2002). Preliminary data from these tests (collected by both NRL and CSS) suggested that the NRL-MM supports improved lane navigation performance, compared with use of a PLGR. Crew feedback was also very positive: AAV crewmembers reported that the moving-map system was easy to operate with minimal training and very effective in helping operators keep the vehicle within the lane. As one operator put it, "This is a step in the right direction!"

Follow-on demonstrations were conducted on AAV, LCU, and Landing Craft Air Cushion (LCAC) platforms during Fleet Battle Experiment-Juliet at Camp Pendleton, CA (July 2002). Crewmembers provided several recommendations for improvement to the moving-map displays, including integration of an independent heading sensor to stabilize the map when the vehicle is motionless. Without any heading information coming from the GPS receiver, the map on a track-up display (or the vehicle icon on a north-up display) will spin, which crewmembers reported was annoying and temporarily disorienting.

In late FY02, ONR funded NRL to integrate a heading sensor with the moving-map display and test the resulting system on both LCU and AAV platforms. LCU tests were conducted at Little Creek, VA, in October 2002. During those tests, we determined that the magnetic heading sensor was ineffective on the LCU due to the abundance of metal on the craft. A far better (and less expensive) solution was to integrate the NRL-MM system with the LCU's own gyrocompass, via an analog to digital converter, which successfully eliminated the spinning display problem and improved crew situation awareness. Tests of the NRL-MM system with independent heading sensor were conducted on AAVs at Gulfport in October and the Amphibious Vehicle Test Base (AVTB) at Camp Pendleton in November 2002. During those tests, we determined that the magnetic heading sensor was effective on the AAV, despite an abundance of metal on the craft, and successfully stabilized the map display.

Final tests and demonstrations of the NRL-MM system took place on LCU and AAV platforms during the Transparent Hunter 2003 (TH03) exercise in January. This paper presents preliminary TH03 results from the LCU and AAV moving-map tests.

TH03 Demonstration Operations

During both LCU and AAV demonstrations, NRL collaborated with a Mine Warfare Readiness and Effectiveness Measuring (MIREM) observation team from the Surface Warfare Development Group, which provided an independent assessment of our experimental procedures and observations. Our experimental design called for comparing the current (or baseline) mode of operations for each craft with operations using the NRL-MM system to determine whether the moving-map could reduce the required width of assault lanes.

LCU operations

The baseline mode of LCU operations called for the navigator to use a paper chart and verbally relay positional (range and bearing) information to the craftmaster, who then instructed the helmsman to make course corrections. In a second test, which is more similar to current LCU operations, the navigator referred to the NRL-MM display and again verbally relayed positional information to the craftmaster. In a third test, both the navigator and the craftmaster used the NRL-MM display. The navigator still communicated with the craftmaster, but in this case, both crewmembers shared the same display, which we assumed would improve communications and minimize navigational errors. In a fourth test, NRL collaborated with Technology Services, Inc. (TSI) in a joint demonstration of the NRL-MM system with TSI's Augmented Reality Visualization for the Common Operation Picture (ARVCOP), which overlays navigation data onto a ship pilot's field of view, displaying both navigational and tactical data on a bridge-mounted display. Eight LCU runs using this joint configuration were included in the experimental plan.

AAV operations

The baseline mode of AAV operations chosen for this study called for the crew chief to use a hand-held PLGR and relay positional information to the driver, who then made course corrections. For our comparison case, the driver could view the moving-map display directly, and the PLGR was not used.

Data collection

DGPS positions and starting / ending timestamps were recorded by the NRL-MM system computer along the tracks traversed during demonstration runs. Informal interviews with craftmasters and navigators were conducted before and after each run to obtain crew feedback, address concerns and answer questions.

Preliminary Results

LCU test runs

Figure 7 presents recorded DGPS tracks of a sample LCU run for each test condition:

a. Paper chart for the navigator, with no moving-map display;
b. Moving-map display for the navigator only;
c. Moving-map display for the navigator and craftmaster;
d. Moving-map display for both crew and 3-d heads-up display for the craftmaster.

The yellow line in each figure represents the planned route; the red and dark blue sections represent turns (red = starting half of turn, dark blue = finishing half of turn), and the bright turquoise sections represent the straight portions of the track.

Figure 8 presents a graph comparing LCU cross-track error (CTE) for each of these runs. CTE is calculated as the perpendicular distance between the planned route and the actual track (recorded as a series of latitude and longitude points from the DGPS receiver):

$$\mathbf{CTE_P} = \text{ABS}\,[(Y_E-Y_S)(X2M)(Y2M)(X_P-X_S) - (X_E-X_S)(X2M)(Y2M)(Y_P-Y_S)] \,/\, \text{SQRT}\,[\,(X2M(X_E-X_S))^2 + (Y2M(Y_E-Y_S))^2]$$

Where (X_P, Y_P) = longitude (X) and latitude (Y) of the DGPS point along the actual track,
(X_S, Y_S) = longitude and latitude of the starting point of the planned route segment,
(X_E, Y_E) = longitude and latitude of the ending point of the planned route segment,
X2M = constant to convert longitude into meters (for the average latitude of the course),
Y2M = constant to convert latitude into meters (which is independent of longitude).

The CTE for the entire track is calculated as the average of the CTE_P's for all points recorded along the track. The track is broken into turns and straight sections, and average CTE values are calculated separately for each section, for comparison purposes. Figure 8 shows that the average CTE is highest under the paper chart condition. The CTE is slightly higher for the single moving-map display (when only the navigator is given the display) than under either of the other two test conditions (when both navigator and crew chief have a display). The final report for this project will include a complete statistical analysis of all runs for each test condition.

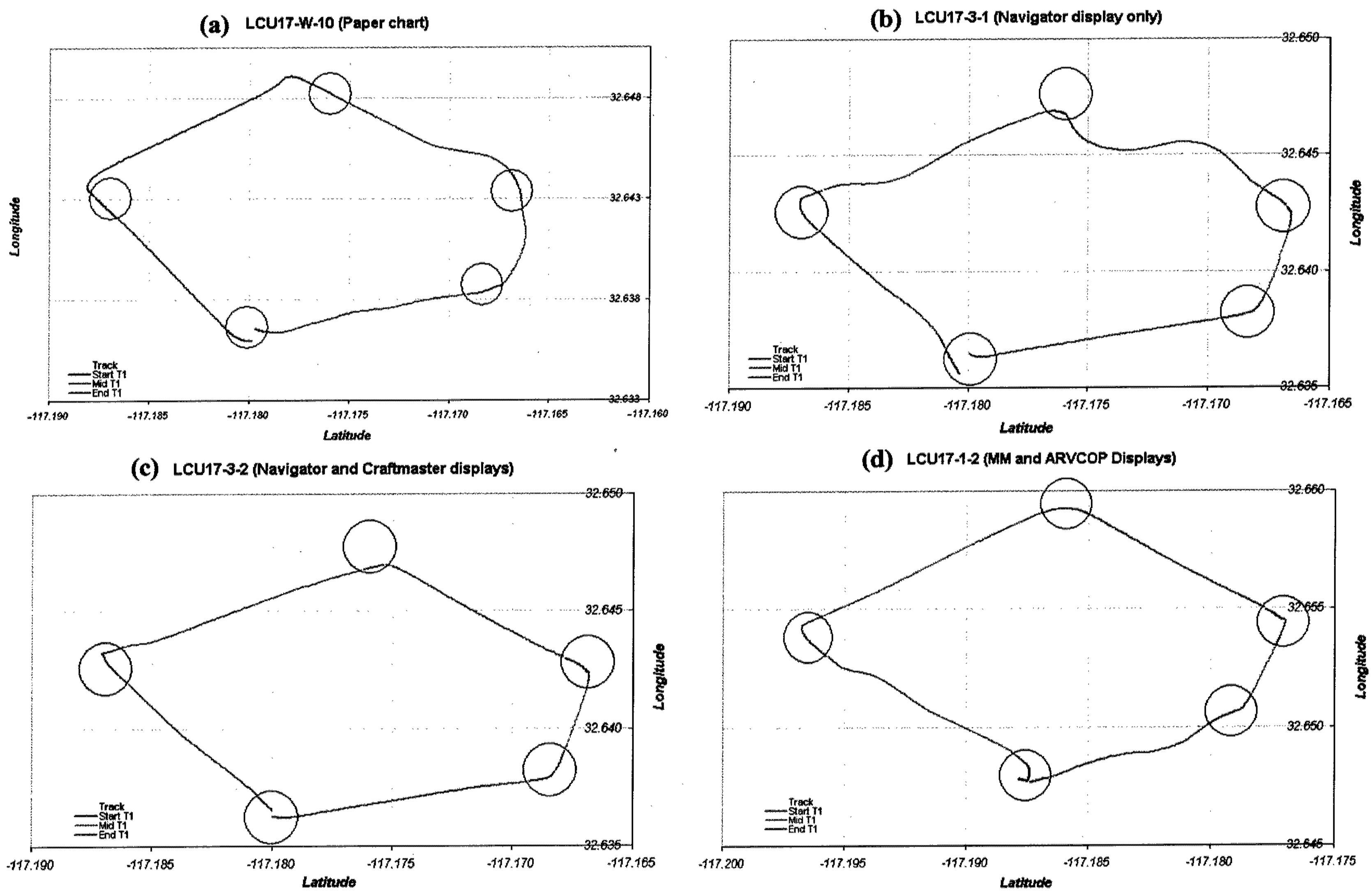

Figure 7. Plots of sample LCU runs, each using one of the test configurations: a) paper chart for navigator; b) moving-map for navigator; b) moving-map for navigator and craftmaster; c) moving-map for both and ARVCOP for craftmaster.

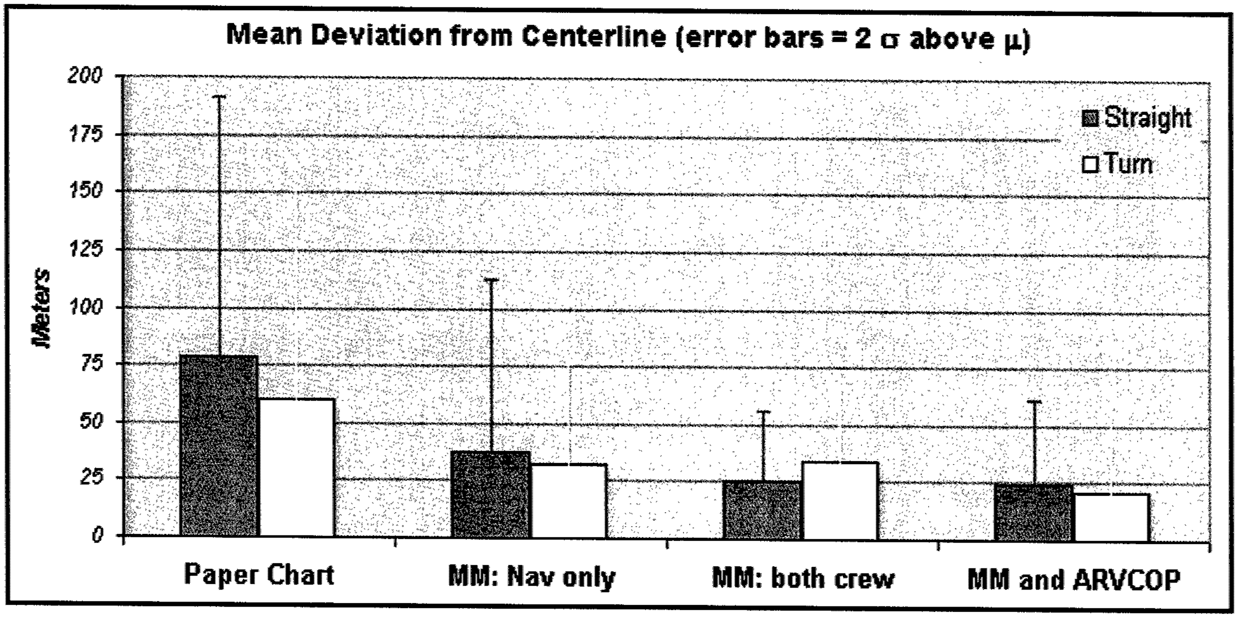

Figure 8. Cross-track error of sample LCU runs.

<u>AAV test runs</u>

Figure 9 presents recorded DGPS tracks of a sample AAV run for each test condition:

a. Driver using a hand-held PLGR;
b. Driver using NRL moving-map display.

Both runs were conducted with the same vehicle, driver, and crew chief. Both runs occurred on the same day, under similar environmental conditions.

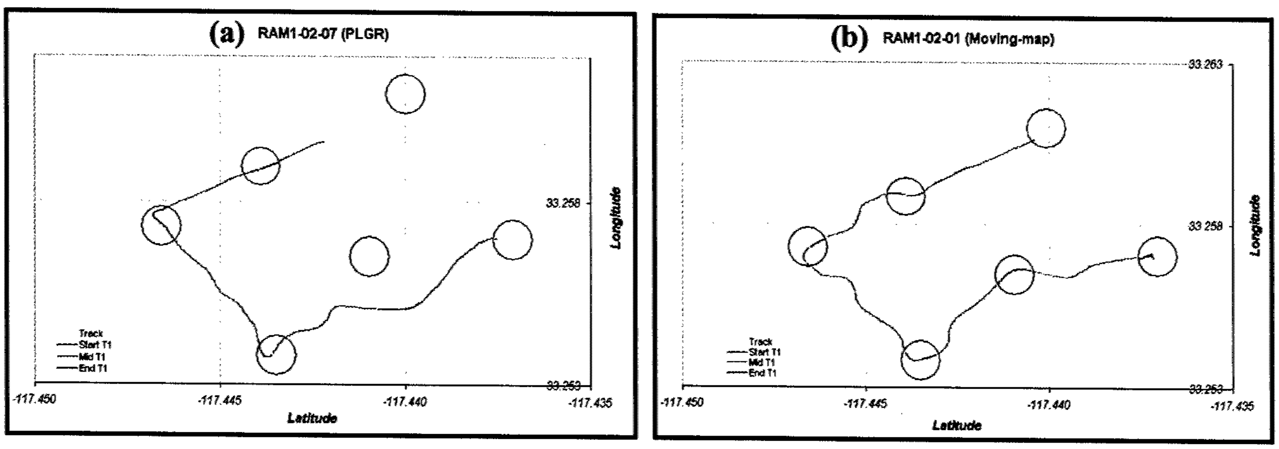

Figure 9. Sample AAV runs, each using one of the test configurations: a) PLGR, b) NRL-MM.

Figure 10 shows that the average cross-track error of a AAV using the PLGR (along a straight course) was nearly 3x that of the same AAV using the moving-map display. While turning, the cross-track error of the AAV using a PLGR was almost 5x that of the AAV using a moving-map.

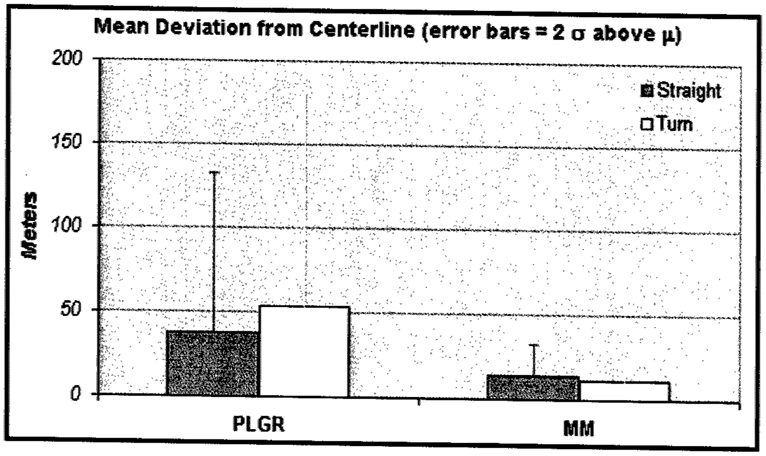

Figure 10. Cross-track error of a sample AAV run using the PLGR and a sample run using the NRL-MM display.

Conclusions

The minimum lane width required by a vehicle can be approximated in terms of the CTE: ($\mu_{CTE} + 2\sigma_{CTE}$) accounts for 95% of the variability of the track. Therefore, the top of the error bars in figures 8 and 10 provide a reasonable estimate of the minimum required lane width for the LCU and AAV platforms used in this study.

LCU

The navigator reported that using a paper chart as the sole method of navigating was cumbersome and difficult. The plot of the track (figure 7a) suggests that one of the most difficult tasks under this condition was anticipating turns. In addition, it appears as though the navigator miscalculated the northernmost waypoint (and possibly the next waypoint to the left), since that entire route segment was significantly offset from the planned route. The CTE in figure 8 confirms that this method of navigating was the least accurate of the four tests.

Providing the navigator (but not the craftmaster) with a map display improved the situation by reducing the chance of human error when calculating and navigating to waypoints: all five turns are relatively close to the intended waypoints. The waviness of the northeastern segment (northeastern route segment, shown in figure 7b) suggests that the helmsman may have had some problems with over-steering, which might have been caused by the delay between the time when the navigator provided course corrections to the craftmaster and the craftmaster relayed his instructions back to the helmsman. Time lags tend to degrade operator performance on tracking tasks (Sanders and McCormick, 1993), possibly causing the over-steering problem shown here.

The plots and CTE results both suggest that providing both the navigator and craftmaster with a common moving-map display results in the most precise navigation along a predefined course. While there is not enough data provided in this paper to draw statistical conclusions, this apparent trend will be investigated in the final report for this project.

AAV

The drivers who had experience using a PLGR were reluctant to accept that the moving-map display might improve their lane navigation performance! However, even the experienced driver of the track shown in figure 9a experienced a common PLGR problem: missing a waypoint. When a waypoint is accidentally missed while using a PLGR, the driver can only aim for the next waypoint (i.e., there is no way to regain the track until the next waypoint is reached). This is a potentially dangerous situation, since the AAV runs the risk of hitting a mine whenever it is outside the predetermined lane. The longer it remains outside the lane, the more risk it assumes.

Both tracks in figure 9 show back-and-forth movements around the centerline. Discussions with the crew revealed that this is a necessary maneuver to cut through waves. If the AAV moves straight forward, its hull would be buried beneath the surface and slow down considerably. Instead, the driver tends to weave back and forth across the surface.

The plot in figure 10 reveals a significant improvement in CTE (thus, a significant reduction in lane width requirements) when driving with the moving-map display vs. the PLGR. Such a reduction in lane width results in a reduction in labor and time required to clear the lane prior to an assault.

Acknowledgements

The Office of Naval Research (ONR) sponsored this project under program element number 0603782N. We thank Doug Todoroff (program manager at ONR) and Dick Root (program manager at NRL) for their support. We also thank Richard Mang of NRL for his valuable assistance procuring, testing, installing, and troubleshooting every piece of hardware during this project!

References

Gendron, M.L., S.A. Myrick, S.S. Edwards, R.A. Mang (2002). *Demonstrating a moving-map system with electronic charts for improved lane navigation: testing on AAVs in Gulfport MS.* NRL/MR/7440—02-8280. Naval Research Laboratory, Stennis Space Center, MS. Sept. 30.

Sanders, M.S. and E.J. McCormick (1993). *Human Factors in Engineering and Design.* McGraw-Hill, Inc. New York, NY. pp. 322-323.