INTEGRATION OF COMMERCIAL GPS INTO MILITARY SYSTEMS

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BIOGRAPHY

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Richard Mang has been an Electronic Engineering Technician at the Naval Research Laboratory for 17 years. Prior to working for NRL, Richard spent eight years as a Navigational Electronics Technician in the U.S. Air Force.

ABSTRACT

Amphibious Assault Vehicle (AAV) drivers have only a small portal through which to navigate a lane. Therefore, their ability to attend to outside visual cues, such as marker buoys, may be seriously diminished by physical barriers such as sea spray, darkness, fog, and other factors. Landing craft crew workload can be intense: the driver has numerous electronic devices to monitor, up to 18 infantry Marines to transport, and a relatively narrow lane in which to safely navigate. Thus, any new systems to be introduced must be very easy to interpret and understand. A new navigational system for these platforms should "be capable of conveying critical information concerning navigation … in a manner that is easily interpretable under often stressful conditions" (Lohrenz, et. al.). There is minimal space inside AAVs, with just enough room for a predetermined number of Marines and their equipment. The device should be small and unobtrusive to minimally hinder normal operations. Assault and landing craft can be very difficult to control. Waves, currents, wind, and the speed of the vehicle all factor into this challenge. A digital navigation tool, such as a moving-map, could aid a driver in controlling the vehicle by displaying the vehicle's current location and track, along with upcoming waypoints and lane boundaries (e.g., if the craft tends to drift left, then try to stay to the right side of the lane). To meet the demands and concerns of mine countermeasures and amphibious communities, NRL is investigating various mapping systems and developing software to compress different map types and imagery into a displayable format.

INTRODUCTION

The U.S. Marine Corps' AAV currently has no integrated navigational device and must rely on a small portal with a dangerous blind spot to navigate. Although equipped with radio capabilities, weather conditions do not always allow a crewmember to give direction to the driver because of limited or no line of sight. In the near future, the Marine Corps plans to implement the Data Automated Communications System (DACT) in the AAV platform (figure 1), which would provide some electronic charting capability, but not all vehicles are scheduled to receive this system.

The Office of Naval Research (ONR) funded the NRL Moving-Map Capabilities (MMC) team (Code 7440.1) to equip AAVs with Differential GPS (DGPS) Moving Map systems to test for improvements in lane navigation. NRL planned to accomplish the following tasks:

- Determine what navigation information should be displayed;
- Combine this information with precise lane coordinates;
- Display the lane as an overlay on an electronic chart;
- Evaluate how AAV drivers respond to these displays.

To develop the most reliable and accurate demonstration product possible with the funding available, NRL decided to use commercial off-the shelf (COTS) GPS products. In addition, NRL has developed software to compress different map types and imagery into the Raster Product Format (RPF, MIL-STD-2411) to allow bathymetry data, nautical charts, and satellite and acoustic imagery to be loaded on devices that display standard National Imagery and Mapping Agency (NIMA) RPF data. Mission specific overlays, such as threat rings, lane markings, possible mine-like objects, and waypoints, can be displayed over the RPF map for enhanced situational awareness.

Figure 1. Amphibious Assault Vehicles (AAVs)

BACKGROUND

A case study performed by the Office of the Defense Standardization Program in 1996 identified the AN/PSN-8 Manpack (an Army-developed 17-pound GPS receiver) as costing over $40,000. A smaller, more recent version is the Small Lightweight GPS Receiver (SLGR). During the Manpack's development, commercial GPS receivers became available. The commercial version of SLGR most attractive to the military weighed about four pounds and cost only about $4,000 each. "Until recently, both military and commercial GPS receivers were power hungry, bulky and very expensive" (Vansuch, 2002). This is no longer the case. Reasonably priced commercial GPS systems can now be found virtually anywhere in the United States.

With the March 1996 dissolution of the Federal Government's policy of Selective Availability, commercial GPS users now have access to a highly accurate, stable system of satellites, with no limitation or degradation from the government. This ensures reliability that, until recently, was available only for military use. In turn, the Federal Government now can leverage the advancements made by commercial producers. According to NIMA (2001), "A military user of GPS in a differential mode may reach an accuracy of 2 to 7 meters. … With an established maintenance system, electronic charts used with a valid display system will be the navigation method of choice for most mariners."

With GPS systems evolving quickly, and many different commercial vendors striving to improve their individual products, it would greatly benefit the military to take advantage of the commercial development in GPS devices. The Lockheed Martin website (2002) states, "Over the past 10 years, GPS has evolved beyond its military origins. Not only does GPS provide such service as situational awareness and precision weapon guidance for the military. It is now an information resource supporting a wide range of civil, scientific, and commercial functions -- from air traffic control to the Internet -- with precision location and timing information."

The military is no longer the sole technological development force in our country. Rather than civilian companies relying on military development, there has been a turning point, where "there's a lot more we can gain today by looking at commercial technology and figuring out how we can use it for national security needs" (Lyles, 2002). In the Gulf War, many pilots relied on commercial GPS to guide them through areas where visibility was extremely low, or nonexistent. "Without a reliable navigation system, U.S. forces could not have performed the maneuvers of Operation Desert Storm. With GPS, the soldiers were able to go places and maneuver in sandstorms or at night when even the troops who lived there couldn't. Initially, more than 1,000 portable commercial receivers were purchased for their use. The demand was so great that, before the end of the conflict, more than 9,000 commercial receivers were in use in the Gulf region. They were carried by foot soldiers and attached to vehicles, helicopters, and aircraft instrument panels. GPS receivers were used in several aircraft, including F-16 fighters, KC-135 aerial refuelers, and B-2 bombers; Navy ships used them for rendezvous, minesweeping, and aircraft operations" (The Aerospace Corporation, 1999).

Many of the nation's military platforms, including fighter jets, tanks and AAVs, were not designed to support a GPS system. Integration of a commercial GPS product on these platforms may be more appropriate than a military GPS. For example, in 1999, a squadron of A-10 ground support aircraft were outfitted with commercial, handheld GPS receivers from Garmin Corp, which provided the aircraft with "GPS capabilities faster and at a lower cost than plans to retrofit the A-10 with military GPS receivers" (Brewin, 1999).

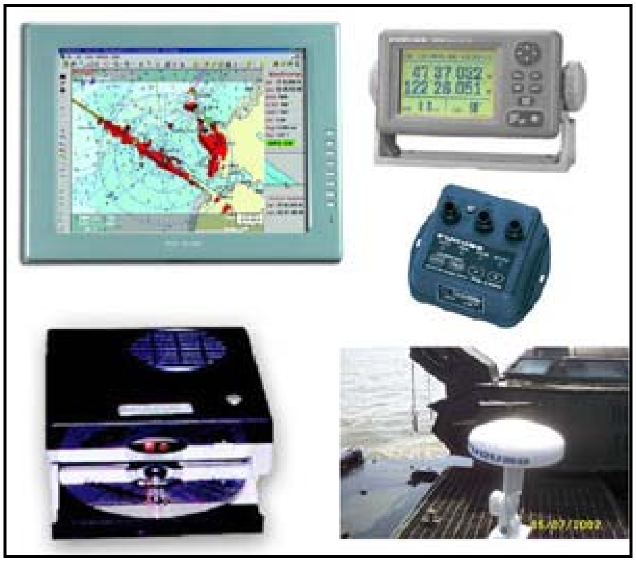

Figure 2. System Components.
Clockwise from top-left: Nauticomp display, Furuno GP-36 DGPS receiver, Furuno PG-1000 heading sensor, Furuno DGPS antenna, and Argonaut computer.

NRL MOVING MAP SYSTEM COMPONENTS

NRL configured several AAVs with a moving map display connected to an Argonaut computer temporarily installed in the rear of the vehicle. Table 1 lists the moving map system hardware and software components.

Hardware Components	Software Components
Argonaut computer	Windows 2000 Operating System
Furuno DGPS receiver (GP-36)	FalconView (PFPS)
Furuno DGPS antenna	Heading Sensor Integration Software (NRL)
1 Nauticomp display - 10.4"	
Furuno Magnetic Heading Sensor (PG-1000)	

Table 1. Components of NRL Moving Map System

The Argonaut (a standard 1.3 GHz PC running Windows 2000) is a relatively small computer, which better accommodates the AAV's space restrictions. NRL configured the computer to run FalconView, which is the moving map component of the government-owned Portable Flight Planning Software (PFPS). FalconView accepts location input from any National Marine Electronics Association (NMEA) compliant GPS system, Precision Lightweight GPS Receiver (PLGR) data, and Predator data. FalconView can display several different map data types, including RPF, standard NIMA charts, and standard National Oceanic and Atmospheric Administration (NOAA) charts.

Figure 3. Vehicle Driver's Display

The display screen was a water-resistant 10.4-inch Nauticomp PC color monitor, which was attached to the vehicle driver's hatch (figure 3) to be out of the way when the vehicle was not in operation.

A Furuno DGPS antenna was placed on the outside of the vehicle, slightly aft of the crew chief hatch. The antenna was connected to a Furuno GP-36 DGPS receiver using a pre-existing thru-hull cavity. A Furuno PG-1000 heading sensor was used to stabilize the view on the moving map display while the vehicle was stationary. NRL wrote software to integrate the heading sensor data with the DGPS data for input into FalconView. The heading sensor was positioned in the rear of the vehicle with the PC and receiver.

TESTING

NRL's Moving Map has been tested on the AAV platform three times in the past 18 months. It has been tested on both the Navy's Landing Craft Utility (LCU) and Landing Craft Air Cushion (LCAC) in addition to the AAV; however, discussion in this paper is limited to AAV testing and results.

AAV testing took place at the Amphibious Vehicle Test Branch (AVTB) at Camp Pendleton, CA, and at the 3rd Platoon, Company A, 4th Assault Amphibian Battalion Reserve Unit at the CB Base in Gulfport, MS.

After arriving on site, the NRL team spent one day installing the moving map equipment on the test vehicles and a short training session for the crew. The following day(s) were spent testing the system and evaluating crew performance navigating with the moving map versus using their baseline means of navigation. The baseline – and only – means of navigation available to the AAV crew at this time is a military PLGR. The PLGR displays the vehicle position in latitude and longitude on a small hand held device (figure 4). It provides current location information and navigation guidance by indicating whether to turn left or right – based on the preset course – to reach the next waypoint. Standard procedure calls for the crew chief to operate the PLGR while relaying directional information and instructions to the driver. All communication is achieved through an internal radio link, as the crew chief is located on the opposite side of the vehicle (figure 5).

Figure 5. PLGR

Although the PLGR was used as the baseline for testing, it is not always available to every AAV crew in either training or wartime environments. In addition, the crewmembers exhibited unfamiliarity with its function, and time was required to train crewmembers in PLGR operation. After the initial PLGR training, the NRL team spent about ten minutes explaining the moving map concept and training drivers on its operation.

During each test/demonstration, a course was determined ahead of time based on the area in which the vehicles were cleared to operate. Specific waypoints were entered into both the moving map system and the PLGR. The PLGR showed position numerically, while the moving map system showed position graphically.

When navigating with the moving-map display, AAV drivers were instructed to follow the lane markings on the display and to stay as close to the centerline as possible. When navigating with the PLGR, AAV drivers were told to aim for the next waypoint as precisely as possible. The moving-map display was turned off during PLGR tests, and the PLGR was not issued to drivers during moving map tests. Both test conditions (moving map and PLGR) were repeated with the same drivers on the same course, in both clockwise and counterclockwise directions to reduce familiarity. These runs were repeated over several days, and the vehicle's position was recorded once per second during each test run by the NRL moving map system's computer for later analysis.

Figure 6. Driver and Crew Chief Positions

RESULTS

After each test, results were determined by calculating how well the drivers could stay in their lane with the moving map versus the PLGR. This was accomplished by comparing each individual run to the actual course. Results were measured using cross track error (CTE), which is the positive perpendicular distance between the planned route and the actual track (recorded as a series of latitude and longitude points from the DGPS receiver), and is similar in magnitude to root mean square error:

$$\mathbf{CTE_P} = \frac{\left| C_X C_Y * [(Y_E-Y_S)(X_P-X_S) - (X_E-X_S)(Y_P-Y_S)] \right|}{\text{SQRT}\left[(C_X (X_E-X_S))^2 + (C_Y (Y_E-Y_S))^2 \right]}$$

Where:

$\mathbf{C_X}$ = constant to convert longitude into meters (for the average latitude of the course),

$\mathbf{C_Y}$ = constant to convert latitude into meters (which is independent of longitude),

$\mathbf{(X_P,Y_P)}$ = longitude (X) and latitude (Y) of the DGPS point along the actual track,

$\mathbf{(X_S,Y_S)}$ = longitude and latitude of the starting point of the planned route segment, and

(X_E,Y_E) = longitude and latitude of the ending point of the planned route segment.

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.

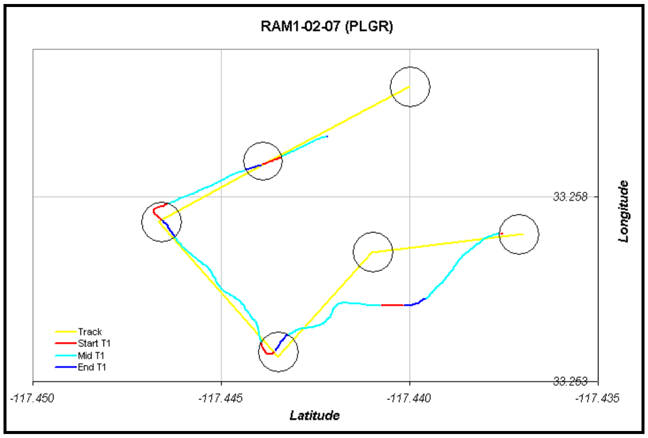

Figure 7. Example Run Using PLGR

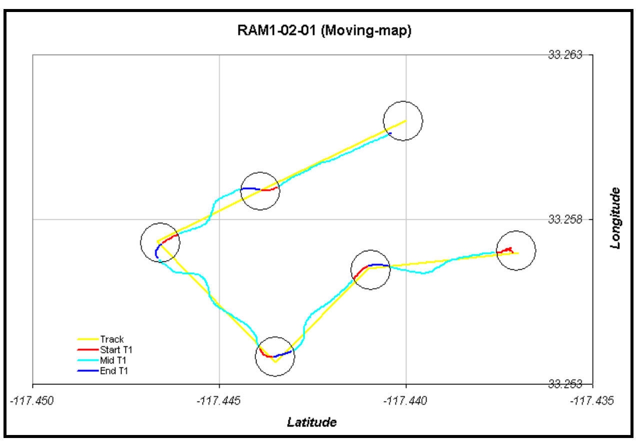

Figure 8. Example Run Using Moving Map

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 6 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 figures 6 and 7 show smaller 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.

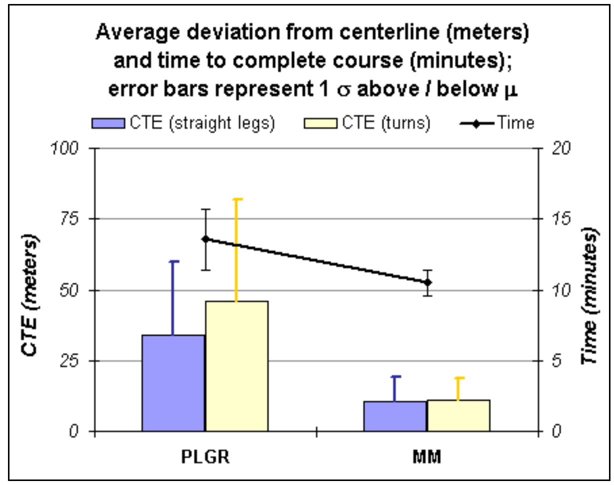

Figure 8. Summary of AAV Test Runs during TH03

The plots in figure 8 reveal significant reductions in CTE (and, thus, a significant reduction in lane width requirements) when driving with the moving-map display vs. PLGR. Such a reduction in lane width equates to a corresponding reduction in labor, time, and threat to safety required to clear the lane prior to an assault. Figure 8 also shows that drivers were able to complete the course in significantly less time with the moving-map (~11 min) vs. PLGR (~14 min), which would further reduce potential risks to the crew during an assault.

SUMMARY

The Naval Research Laboratory investigated, developed, and demonstrated GOTS moving map software on COTS hardware (including commercial GPS) to electronically display precise lane navigation. The demonstrated system provides an improved means of guiding AAV drivers through a cleared lane to the beach during an amphibious assault in the presence of mines. During these tests and military demonstrations, we concluded that the use of commercial GPS equipment is a very cost-effective and reliable option for military amphibious assault missions.

AAV crewmembers reported that the moving-map system demonstrated to them 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!”

The moving map system demonstrated by NRL significantly improved the navigation performance of AAV platform by enhancing crew situational awareness, improving crew communications, and decreasing crew reaction times, compared with existing systems.

Based on these results, the Mine Warfare Readiness and Effectiveness Measuring (MIREM, 2003) team recently recommended in a fleet-wide Navy message that "some type of graphic navigation system / display should be expedited to the fleet. The system should provide … clear navigational and situational awareness (craft displayed relative to intended track), direct interface with the craft driver (reduced maneuvering reaction time), and a means to ingest and display EDSS data (minimized error in entry and transfer of information)."

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