AN AIR DEPLOYABLE BUOY FOR SEARCH AND RESCUE OPERATIONS

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Abstract - **Maritime rescue operations often involve extensive searches for drifting objects, typically life rafts or persons in the water, and search operations are directed based on computer predictions of drift trajectories. These predictions are based on estimates of local wind and wave conditions and, since there are uncertainties associated with these estimates the search area grows rapidly with time, and often within a few hours the area may be far larger than can be effectively searched by available aircraft and ships. This paper will describe the development of a new tool for maritime Search and Rescue (SAR) activities, called a self locating Datum Marker Buoy (DMB). It comprises an air deployable buoy that drifts with the same trajectory as a life raft (primarily driven by the wind) or as a person in the water (primarily driven by the surface current) depending on the configuration chosen prior to deployment. The buoy contains a GPS receiver and an ARGOS satellite transmitter so that it is able to relay near real-time position data to a Rescue Coordination Center, and thus allows the search activities to be directed in a more focused, and successful manner. The development of the buoy will be discussed in the paper, results of drift validation trials in conditions of high winds and currents will be presented, and the impact of DMB data on search area predictions will be shown.**

I. INTRODUCTION

A fundamental problem in maritime search and rescue is the rapid growth of the search area, that region which comprises the best estimate of where drift objects, either life rafts or persons in the water, may be found. In fact, these search areas tend to expand in size quadratically with time. From the moment when the last known position of drift objects can be ascertained the search area changes in both size and position in a manner dependent on environmental conditions, and the accuracy with which these conditions can be estimated. Often, uncertainties regarding local winds and currents cause the search area to grow to a size which makes it impossible for available resources to carry out a search without leaving gaps in coverage [1].

A recent example of how quickly the search area can expand is given by the SAR operation which responded to the sinking of the *Salvidor Allende* 900 kilometers south of St. John's, Newfoundland, in December 1994. In this case the search area expanded from a few square miles to the size of Prince Edward Island over a two day period. Only two of the thirty-one crew members were rescued in the SAR operation, and one of these survivors was found in the water 112 kilometers from the location predicted by the rescue team [2].

The Canadian and US Coast Guards have conducted experiments which have shown that the use of free floating Datum Marker Buoys (DMB's) can significantly reduce the errors associated with the estimation of sea surface currents [3]. When deployed in the vicinity of a marine disaster they can have a significant effect on limiting the size of the search area, thus allowing the search assets to focus their efforts. The Rescue Coordination Center (RCC) at Halifax, Nova Scotia, has recommended the use of aircraft launched self locating DMB's for marine SAR operations [4]. Such buoys would be able to determine their geographic position and report it to the RCC, rather than act only as a beacon to guide search assets to the search area.

With funding support from the New SAR Initiatives budget the Defence Research Establishment Atlantic (DREA) acted as Program Manager for the development of an air deployable DMB concept proposed by Seimac, Limited, of Dartmouth, Nova Scotia. Since 1989 Seimac has carried out studies for both the Canadian Coast Guard (CCG) and the US Coast Guard to investigate air deployable and self locating DMB's [5], and Seimac proposed to further this work by developing an air deployable, self locating DMB whose in-water configuration could be chosen prior to launch to have the drift trajectory of either a person in the water (PIW), or a four person life raft. The PIW configuration constrains the buoy to drift primarily with the surface current, while in the life raft configuration the buoy is driven primarily by the prevailing wind. The program commenced in July 1996, progressed through drift validation and air drop trials, and provided 39 advanced prototype DMB's in May 1997 for evaluation by the Canadian SAR community. This paper will discuss the features of the Seimac self locating DMB's, and provide results of the experimental program associated with their development.

II. TECHNICAL FEATURES

In its packaged form the Seimac self locating DMB closely resembles a standard size - A sonobuoy, a device well known to the Maritime Air community, and much of the technology incorporated in the DMB has its origin in contemporary sonobuoy hardware. Fig. 1 shows the configuration of the DMB in its packaged form, as well as the component parts prior to deployment. The DMB can either be gravity launched from an aircraft, or thrown over the side of a ship; in the former case a parachute deploys after the unit exits the aircraft, and acts as a descent retarder/stabilizer as the DMB drops to the surface. The ballistic characteristics of the DMB - i.e. configuration, size, weight, and location of the center of gravity - were purposely made identical to one of the standard production sonobuoys manufactured for the Canadian Forces, in order that the technical risk for this part of the DMB development would be minimized.

After water entry the water serves to connect two electrical terminals which results in a small gas cylinder releasing its contents to inflate the float of the DMB surface unit. This in turn allows the DMB components to escape from the outer tube, and remain suspended as the tube drops away and sinks. The configuration that the DMB will assume after water entry is made prior to launching the DMB from the aircraft or ship; in the life raft configuration only the surface unit emerges from the packaging tube, while in the PIW configuration the surface unit is tethered to a drogue, and both components are deployed from the tube.

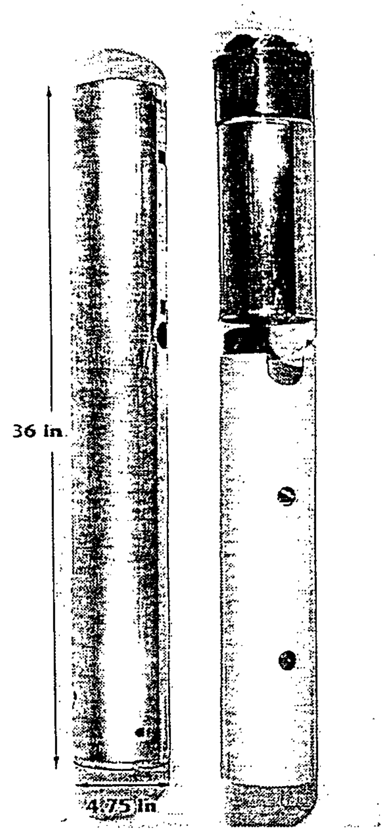

Fig. 1 The DMB packaging tube (left) and contents.

The surface unit of the DMB is equipped with a miniature satellite navigator (GPS), a small satellite data transmitter designed to be used with the ARGOS satellite system, and a sea-surface temperature sensor. Specifically, a Seimac "Smart CAT" Certified ARGOS Transmitter is integrated with a GPS receiver to encode drift data in the Service ARGOS specified GPS position message. This small and inexpensive device reports hourly GPS position measurements via the ARGOS satellite system by storing acquired positions in internal memory and continuously broadcasting a message containing the six most recent hourly positions. This reporting scheme overcomes gaps in the satellite orbits and provides a complete data set. Interleaved with this message is a sensor message reporting sea surface temperature as well as a number of buoy status measurements such as battery voltage. On board batteries are sufficient for about 120 hours of operation. Fig. 2 shows the electronics assembly, gas cylinder, and battery packaging arrangement contained by the DMB surface unit.

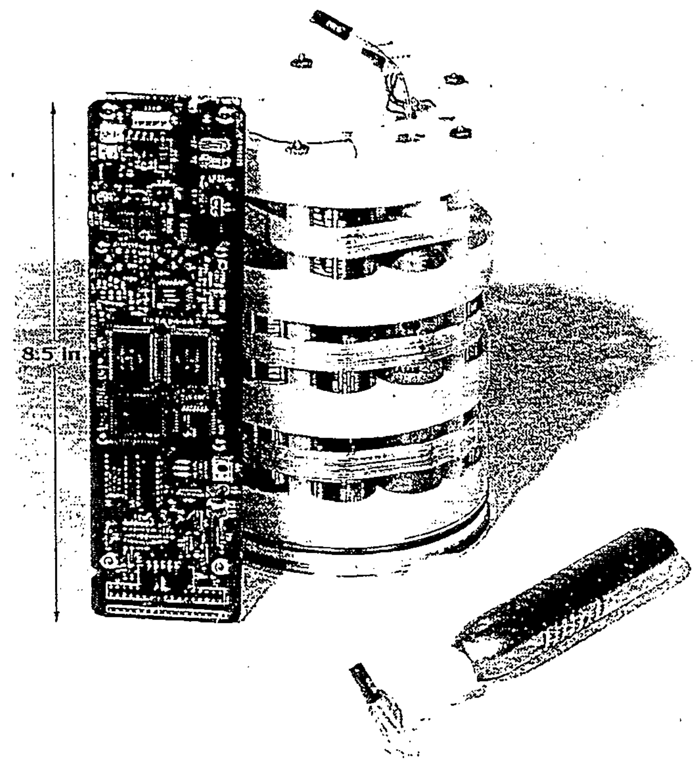

Fig. 2 Internal components of a DMB surface unit: GPS/ARGOS electronics, battery pack, and gas cartridge.

III. DRIFT TRAJECTORY VALIDATION TRIALS

Prototypes of the Seimac self locating DMB's were tested at sea in November 1996 at two locations in the western North Atlantic Ocean. Trials were conducted from the Canadian Forces Auxiliary Vessel (CFAV) QUEST by DREA and Seimac staff to observe the drift characteristics of the DMB's in comparison with that of reference drift objects under open ocean conditions. The drift objects used were Beaufort 4-person life rafts and Seimac Accurate Surface Trackers (AST's), which are drifting buoys that are commonly used by the Canadian Coast Guard College and the Bedford Institute of Oceanography for tracking surface currents, and have been used in numerous experiments as reference surface drifters.

Four experiments using these reference drift objects were carried out. The first two were south-east of Bermuda under relatively low surface current conditions and in winds below 25 knots. The two subsequent experiments were carried

out in the *Gulf* Stream, and here the drifter objects were subjected
to both high surface currents and wind and sea conditions up to Beaufort force 9 [6].

In the first experiment, a total of nine PIW objects were deployed, comprised of three AST's and six self locating DMB's. The array of drifters stayed closely together and were all within visual range of the bridge of QUEST on recovery 17 hours later. Total drift track length was just four nautical miles. Winds ranged between 5 and 15 knots.

In the second experiment, nine maximum leeway drift objects were deployed, three reference drift objects - in this case Beaufort four person life rafts - and six DMBs configured to drift as life rafts. The 15 n.mi. drift tracks of the life rafts and DMB's were highly correlated, although one of the three life rafts drifted slightly away from the rest of the field. Winds ranged from 25 knots (NW) at the beginning of the deployment, diminishing to 15 knots (NE) by the end of the experiment 21 hours later.

The third and fourth experiments were performed in the Gulf Stream in moderate to strong wind conditions, and in strong currents. In the third experiment, nine drift objects were deployed, comprising three AST's as reference objects and six DMB's configured as PIW's. These drifters remained closely clustered together throughout a 40 hour deployment and over a drift track of approximately 120 nautical miles in length. In fact, the drift objects remained grouped closely enough to be able to see all objects from the bridge level of the research vessel for most of the experiment.

Nineteen hours after commencing the third experiment a field of three life rafts and six DMB's in the life raft configuration were added to the drifter field. This brought the total number of drift objects in the water to eighteen for the fourth experiment. Winds increased steadily to 30 knots by the evening of that day, and continued to increase overnight to 40 knots with gusts to 50. It was observed immediately that the PIW drift objects and the life raft drift objects began to separate into two distinct groups, and continued to diverge over the next twenty-one hours, at which time the experiment was terminated. All three Beaufort life rafts sustained some damage during this experiment; these rafts are designed to be connected to a small drogue which acts as a sea anchor in the presence of high winds and, as the experiment progressed one raft after another broke free of its drogue. Its trajectory then became much more aligned with the wind direction, and divergent to that of the DMB's. A simple examination of the drift tracks showed qualitatively that the DMB's tracked the reference drift objects very closely in extreme environmental conditions, and a later regression analysis confirmed this observation.

IV. DRIFT CHARACTERISTICS : LINEAR REGRESSION ANALYSIS

The regression analysis gives a quantitative measure of how closely the DMB's were able to track the reference drift objects over the course of the four experiments. In the analysis, the hourly position of each DMB and reference drift object was used to determine its drift speed and direction, and then the DMB data were plotted on a scatter diagram against the corresponding data for the reference drift objects. Finally, a straight line was fitted to the data based on a least squares linear regression.

The drift data from the PIW experiments - deployments 1 and 3/4 - were plotted together in Fig. 3 as were those obtained during the life raft experiments - deployments 2 and 4. This produced a data set comprising measurements taken in light, moderate and strong winds and currents. Drift speeds ranged up to 4 knots, and drift directions included all four quadrants. All of the data from the PIW deployments 1 and 3/4 were included in the analysis. In the life raft data set only the data from drogued life rafts was used.

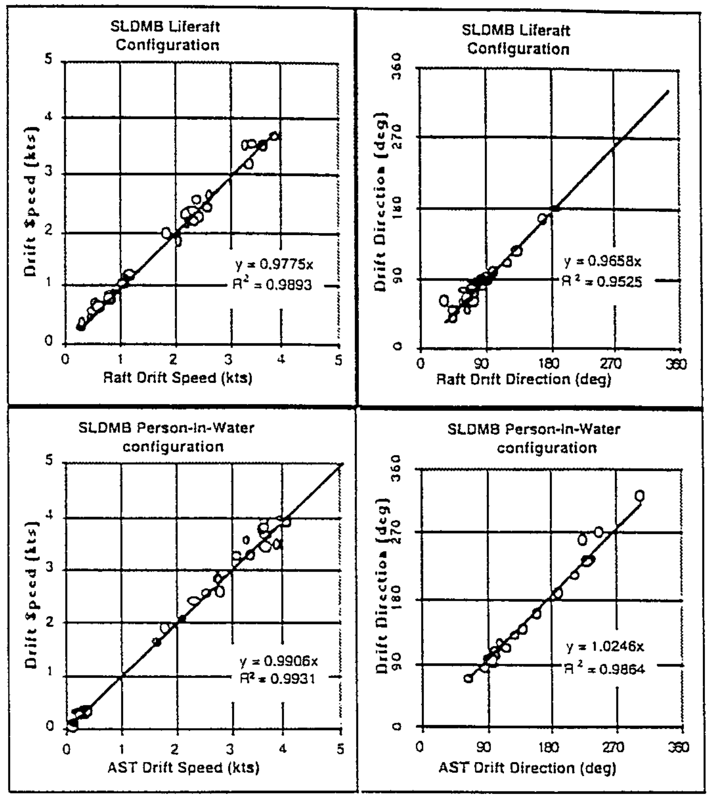

Fig. 3 Regression analysis of Q235 drift validation trials. The DMB's and the reference drift objects have virtually identical drift trajectories.

V. AIR DEPLOYMENT TRIALS

In March 1997 DREA organized air deployment trials for the prototype DMB's using a CP140 AURORA aircraft stationed at Canadian Forces Base Greenwood. The trial took place near the approaches to Halifax Harbour, and a diving team was stationed at the drop site to recover buoy hardware from the bottom, particularly DMB hardware which failed to deploy or which sank after deployment. The purpose of the experiment was to observe the aircraft separation and descent behavior of the hardware, the deployment of the buoys after water entry, and the capability of the buoy electronics to survive the shock loading of water entry. Five DMB's were launched sequentially from the aircraft at an altitude of 500 feet and at a speed of 180 knots. All buoys cleared the aircraft's slipstream safely, descended stably, and deployed properly. The PIW configuration was chosen for the DMB's in this trial, as this configuration entails a more extensive deployment of components from the packaging tube than the life raft configuration. The electronic systems of all five DMB's survived water impact, and gave good data over their ARGOS system transmitters. After the completion of this trial the design of the DMB's was considered to be satisfactory, and Seimac commenced the final build of the 39 DMB's for delivery at the completion of the contract.

VI. DMB SEARCH PREDICTIONS

A "quick-look" analysis of the data received from the DMB's during the four experiments was carried out by the Canadian Coast Guard College (CCG) [7]. For each experiment the track of the reference drift objects was predicted using the best available wind and current data - as would be available for a real Search and Rescue operation - and compared to the predicted track and final location of these objects using the periodic data available from the field of DMB's. The CANSARP computer simulation currently in use by the Rescue Coordination Centers for search area predictions was used in the analysis. The results were compelling as an argument for the use of DMB's in SAR operations: when the data from the DMB's was employed in the computer simulation to determine the most probable search area, the drift objects were in all cases located near the center of the area, while in only one of the four deployments was the drift object located within the predicted search area without the DMB data. Predictions without DMB data were poorest in the Gulf Stream deployments, and large errors between predicted and actual drift object location resulted - 67 nautical miles for the PIW deployments in experiments 3 and 4, and 27 nautical miles for the life raft deployments in experiment 4.

VII. END-TO-END SYSTEM TRIAL

In an end-to-end system trial, two of the DMB's delivered by Seimac were deployed from an Aurora aircraft in the North Atlantic 300 n.mi. south of Newfoundland on 9 June 1997. The Aurora crew configured one of the drifters as a PIW and the other as a life raft prior to launching the buoys from the aircraft. Drift data were collected by the ARGOS ground station in Maryland, forwarded to Seimac and then redistributed to the RCC in Halifax, the RCC in Trenton, Ontario and the Canadian Coast Guard College in Sydney for their analysis. The trial continued until the programmed shut-down time for the DMB's 120 hours later on June 14th.

The drift paths are shown plotted in Fig. 4 on a background of the sea surface temperature. The PIW drifter followed a south-east course along a thermal gradient near a cold core eddy (K) which was developing north of the Gulf Stream, and its trajectory terminated in a tight spiral path. The life raft DMB moved across the thermal gradient apparently pushed by a 20-25 knot south-west wind which began to blow on June 12th. The sea surface temperature analysis shown was issued by the DND METOC centre for June 13.

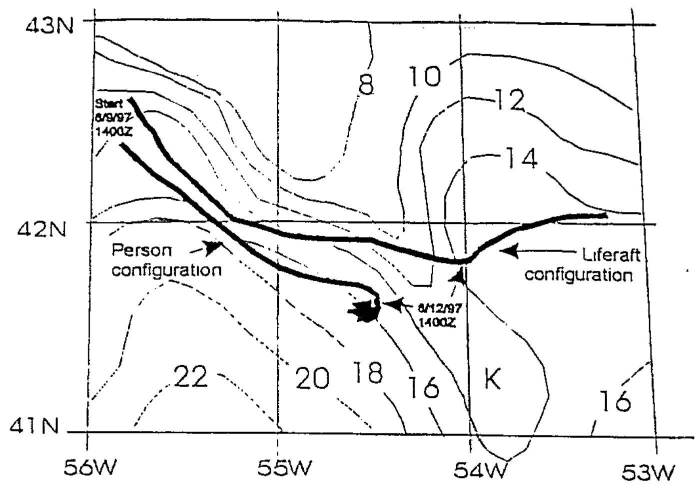

Fig. 4 Drift tracks of two DMB's air deployed in the North Atlantic. The buoy configured as a PIW closely followed a sea surface temperature contour. The buoy configured as a liferaft was blown across the temperature gradient.

VIII. CONCLUSION

A new SAR tool has been developed to an advanced prototype stage in a remarkably short time. The self locating Datum Marker Buoys developed by Seimac Limited and the Defence Research Establishment Atlantic have been shown to closely track two common drift objects associated with marine disasters - either a four person life raft or a person in the water - and their use in SAR tactics has been shown to provide a very marked improvement in the accuracy of search area predictions. The employment of these self locating DMB's in future SAR scenarios will save lives and reduce the cost of search and rescue operations.

ACKNOWLEDGMENTS

Many persons contributed to the success of this project. The staff of the Rescue Coordination Center in Halifax provided the enthusiasm and support necessary to obtain project funding, and Major Chuck Grenkow of Air Command HQ/SAR in Winnipeg, Manitoba contributed critical organizational effort in his role as Project Director. The design team at Seimac, particularly Ron Burke, Ken Mah, and Allan MacDonald produced a Datum Marker Buoy whose performance greatly exceeded the expectations that would be normal for the budget they were given, and Don Mosher at DREA was highly effective in organizing the air deployment trials needed to evaluate the buoys.

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