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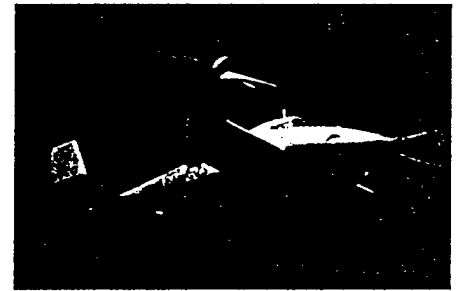
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Cover: For the Marine recruit, not much has changed over the years. For the Corps itself, a great deal is changing. (Photo: Infantry Assault Course, Camp Pendleton, Sergeant Jason C. Huffine, USMC)

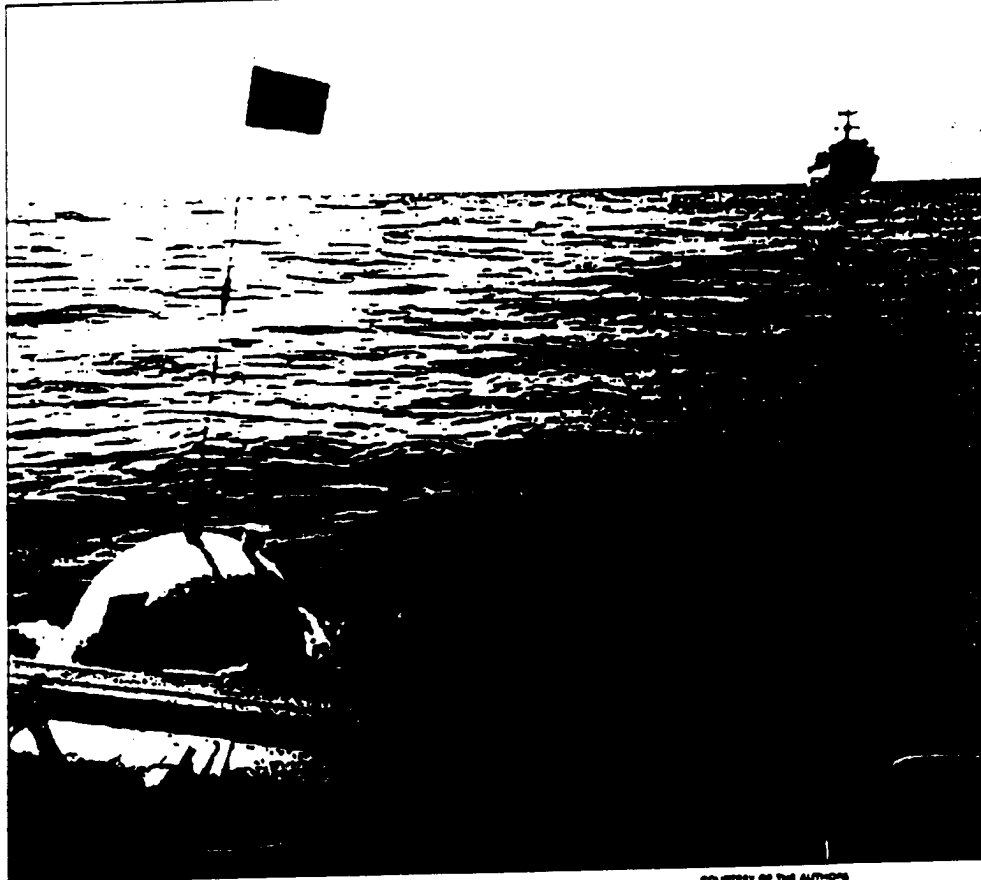
Buoys Provide Real-Time Surf Data

By Major C. Reid Nichols, U.S. Marine Corps Reserve,
Commander David W. Tungett, U.S. Navy and Richard A. Allard

U.S. Navy beachmasters are using small, lightweight recording buoys to provide timely and accurate information for controlling boat lanes and tracking real-time changes in surf conditions. The buoys, which log pitch, roll, and yaw to determine a wide variety of wave parameters, employ recently developed miniaturized accelerometers and magnetometers to measure wave characteristics that are entered into the Navy Standard Surf Model to calculate automatically surf information and the Modified Surf Index (MSI).

Tests conducted along U.S. East Coast amphibious warfare training areas clearly demonstrate the wave buoys' capabilities. During Joint Task Force Exercise 97-3, for example, wave buoys supported mine clearing operations by landing craft air cushion (LCACs) by providing the data necessary to determine surf conditions. After the breaching operation, the buoys were easily extracted with the beachmaster's lighter, amphibious resupply cargo (LARC-V) craft. To keep pace with this state-of-the-art technology and to ensure the Beachmaster's continued relevance to naval expeditionary warfare, Beachmaster Unit Two has included the present version of the littoral warfare wave buoys in training exercises and soon will deploy routinely with them.

During NATO's Exercise Strong Resolve '98, mine and amphibious warfare missions were conducted across a one-kilometer stretch of shoreline in the Spanish training area of Sierra De Retin, which is located between Capes Trafalgar and Plata. Two littoral warfare wave buoys were deployed to provide real-time measurement of surf conditions on the assault beach. For this peacekeeping exercise, the wave buoys were deployed and extracted with assistance from HMS *Roebuck*. The two 18-inch diameter littoral warfare wave buoys were moored quickly in 20 feet of water on the right and left flanks of the landing beach; deploying and retrieving the 63-pound buoys by hand posed no difficulty for the sailors. An operations specialist from Beachmaster Unit Two and a team of research and development scientists from the Naval Research Laboratory (NRL) operated the coupled wave buoy and surf model system for several weeks in Andalusia, Spain. A computer on board the buoy automatically processed raw data taken hourly to determine wave height, wave period, and wave direction infor-



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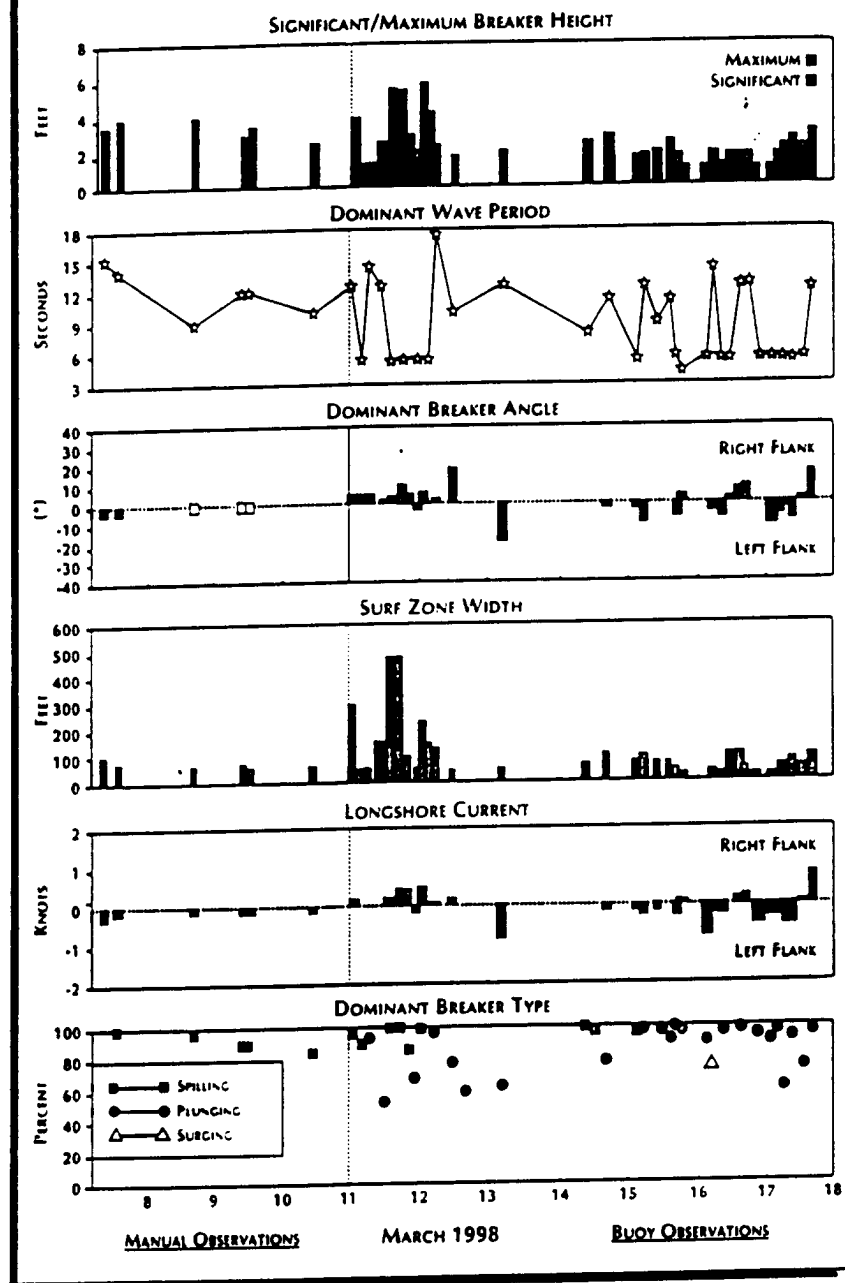
mation. An ultrahigh frequency radio link established between a ground station and the buoy transmitted commands to the buoy and downloaded processed buoy information. The command center was located in a vehicle-mounted mobile station parked along the coastal road. It included a small weather-observation station, a radio and omnidirectional antenna, and a laptop computer with modem. Using buoy information along with hydrographic depth profiles, tides, and local wind measurements as inputs, operators ran the Navy standard surf model on the computer to calculate important surf zone parameters. For this particular exercise, the MSI was computed but not used for tactical decisions. Wave buoy data was provided to the ground station only during three to four interrogations per day and therefore was less susceptible to spoofing or jamming. Figure 1 depicts examples of the resulting near real-time meteorological and oceanographic (METOC) buoy and model information.

To demonstrate the ability of maritime forces to collect environmental intelligence and disseminate it rapidly to

Teams deployed the littoral warfare wave buoys from inflatable boats launched from HMS *Roebuck* (background). Two buoys were moored in 20 feet of water off the right and left flanks of the landing beach.

other forces worldwide, surf observations, wave buoy and model output, and model forecasts were provided to NATO and partner countries via the Worldwide Web from 4 to 18 March 1998. To exploit the buoy's capabilities operationally, METOC personnel working at the Naval European Meteorological and Oceanographic Command in Rota, Spain, and on board the USS *Mount Whitney* (LCC-20) contacted the wave buoy ground station at Zahara de Los Atunes several times each day for immediate coastal zone data. Following the amphibious exercise, the buoys were extracted and returned to the Naval Research Laboratory at Stennis Space Center, Mississippi, having collected and stored approximately 340 wave-data files over the two-week period.

Figure 1: Left Flank 36° 9.7' N, 5° 53.24' W



During Strong Resolve '98, the beachmaster participating in the littoral warfare wave buoy demonstration conducted three to four surf observations per day from right and left flanks of the assault beach using the traditional manual method of physically observing 100 wave repetitions. Longshore current speed and direction were estimated from the 60-second drift distance of wood floats thrown into the surf zone. Wind speed and direction on the beach were measured with a hand-held anemometer. Additional observations important for LCAC operations included deviations from astronomical tide predictions, shoreline location, as well as beach and backshore dimensions. Comparative analyses were then con-

ducted among surf observations, littoral warfare wave buoy and Navy standard surf model output, and NRL surf zone forecasts. Key parameters for intercomparison were surf height (distance from trough to crest); period (time between breakers); breaker type (plunging, spilling, or surging); wave direction, longshore current, surf zone width, wind speed, and wind direction. Figure 1 compares beachmaster surf observations, littoral warfare wave buoy information, and larger scale-model forecasts from the Naval Research Laboratory over a period of ten days.

Quantitative differences between manual and automated reports on the surf zone were caused by subjective decisions,

model sensitivity, and varying input parameters. The beachmaster's surf observations were labor intensive and depended on his interpretation of wave heights, breaker angle, and width of surf. As gross differences between model output and visual surf observations were identified, manual calculation errors were identified and corrected. Wave height, wave period, surf type, breaker angle, and current direction varied the least. Surf-zone width was the parameter having the largest difference. At the ground station, depth profile inputs were adjusted scientifically based on sediment grain size to obtain Navy standard surf model calculations which closely agreed to observations. Ground station inputs included actual beach winds, adjusted water levels, and smoothed depth profiles. Other input to the Navy standard surf model from large scale models did not use real incident wave conditions, actual winds, or "tuned" depth profiles. Consequently, these forecast results deviated the most from beachmaster surf observations and output from the coupled wave buoy and surf model.

A coupled littoral warfare wave buoy and Navy standard surf model provides a simple and easily deployed system for beachmasters to employ. Objective results are derived rapidly from actual wave buoy information measured just outside of the surf zone. Information can be tuned to match actual conditions by slightly adjusting beachface depth profiles, water level, and inputting actual local winds. While beachmaster observations routinely require 30 minutes (including computations), buoy results are available in minutes from remote locations. Other modeling systems are time consuming and dependent on large-scale wave and wind models, complex wave refraction and diffraction models, and gross beach profiles. This family of modeling systems is run from powerful computers on distant platforms and away from calibration data. Surf information derived from wave buoys increases chances for mission success and safety by providing the beachmasters with valid knowledge on parameters associated with landing craft casualties. This technology provides the commander with information that can be used to overcome dynamic shallow-water challenges to maritime and naval expeditionary force power projection.

Major Nichols works on applied meteorological and oceanographic projects with Neptune Sciences, Inc.; he is a reservist with the Fourth Marine Aircraft Wing. Commander Tungett, a Surface Warfare Officer, commands Beachmaster Unit Two. Mr. Allard is an oceanographer in the Naval Research Laboratory's Ocean Dynamics and Predictions Branch.