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ON THE MEASUREMENT OF CURRENTS FOR  
REAL-TIME APPLICATIONS: AN OVERVIEW

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ABSTRACT

The greatest benefit of some of the new current measurement techniques being developed may not be in the areas of improved accuracy or handling the dynamics better; it may simply be in their ability to avoid many of the problems that cause so much inconvenience and expense when using conventional methods. Some of these new techniques are either land-based or installed in the water at the edge of a waterway, and thus are no more difficult to maintain than a tide gage. Such techniques are, therefore, appropriate for permanent real-time systems in harbors and estuaries. In this paper various current measurement techniques are looked at from the point of view of their usefulness in real-time harbor applications. Various techniques for real-time applications over the continental shelf are also discussed.

INTRODUCTION

The various motivations for developing new current measurement technology can probably be grouped into three categories. First, the primary motivation has been to improve the accuracy of current measurements, especially in noisy environments, such as near the surface. The hydrodynamic response of a current measuring device to its surroundings, and the importance of signal-to-noise in this response, dominate most discussions on current measurement techniques.

Second, new techniques are developed in order to obtain simultaneous spatial coverage of the current field, for example, in order to obtain a vertical current profile, without having to pull a sensor up and down through the water column, which would not provide truly simultaneous data (and thus might make a difference in studying high frequency phenomena); or, in order to obtain a horizontal (synoptic) representation of the circulation in a bay, without having

to travel back and forth across the bay in a boat, which could take hours and not only would not provide simultaneous data, but the data might cover different tidal phases. Examples of new techniques for such purposes include remote acoustic Doppler systems, which measure simultaneous vertical current profiles, and high frequency radar systems (such as CODAR), which provide synoptic representations of near-surface circulation.

Third, new current measurement systems are developed that promise to be easier and more economical to operate and maintain. Most oceanographers are well aware of the effort required to deploy and recover current meter moorings and platforms, to retrieve or turn around in situ data storage tapes, and to repair or replace malfunctioning current meters -- the effort and the expense. They are well aware of the harsh environment in which current meters must operate, the problems with fouling and biofouling, the chances of a mooring breaking loose, and the chances of losing an instrument. In harbors and estuaries especially, there is also the good chance that a mooring will be hit by a ship.

The greatest benefit of some of the new current measurement techniques being developed may not be in their improved accuracy or their better handling of the dynamics; it may simply be in their ability to avoid many of these problems that cause so much inconvenience and expense. Some of the new techniques are either land-based or installed in the water at the edge of a waterway, and thus are no more difficult to maintain than a tide gage.

To some oceanographers these new techniques may have drawbacks because the measured values are averages over a pathlength or area that is too large for their particular research. (Of course, there are other researchers, i.e., numerical modelers, who know they cannot afford to take their models to the kind of high resolution that would require approximately point measurements, and who, in fact,

might prefer a measurement technique that can provide data averaged over volumes that more nearby match those represented by their numerical model grids.) There are, however, other applications for these new current measurement techniques -- applications that take advantage of their easy installation and maintenance and their ability to survive. These are not research applications, but applications involving practical use by members of the commercial or operational marine community. These are applications where extreme accuracy is less important than knowing that the system will be operating, and that it will not be knocked out by a ship or a storm, or that it will not become fouled. These are the considerations that are critical when current data are required in real time for a particular application.

In this paper various current measurement techniques will be looked at from the point of view of their usefulness to various real-time applications.

#### REAL-TIME CURRENT MEASUREMENT APPLICATIONS

What are the applications for which real-time current data are a requirement? This was a strongly debated question at a symposium in May 1985 at the Johns Hopkins University Applied Physics Laboratory (1). There was a good deal of disagreement on exactly what were legitimate applications of the technology that can provide current data in real time. Some of the real-time systems that were developed or proposed for various applications were quite elaborate, involving, for example, numerical hydrodynamic models (driven by real-time data from the field, and even run into the future using statistical forecasting techniques), multiple telecommunication techniques, and sophisticated data assimilation and database management schemes. Other systems were more modest, and perhaps more economically feasible for many applications. The most likely uses for real-time current data are listed in Table 1 and discussed below.

The National Ocean Service (NOS) became involved in real-time systems primarily because of the benefits in the area of safe navigation. There are certain ports (e.g., Miami) where the currents (or the cross-channel current shears) are strong enough that the chances of bringing a large vessel into port safely are improved by having an accurate knowledge of the currents. Such accuracy requires actual data in real time, rather than just tidal current predictions, because such data include important meteorologically-generated flows. Several pilots' associations have requested such real-time data. Because of the heavy ship

Table 1. Real-Time Current Measurement Applications

- Safe Navigation
- Economical Navigation
- Search and Rescue
- Hazardous Spill Cleanup
- Controlled Release of Pollutants
- Experiment Modification and Performance Assessment
- Data Backup
- Data Retrieval (From Difficult Locations, or If Quantities Are Too Large To Store In Situ)

traffic the most important requirement is for a system that can measure currents in the ship channels without being hit by the ships. It would have to be a permanent system, operating around the clock, and as such must be easily maintainable.

Another possible application is in the area of economical navigation. Can knowledge of the currents save a commercial shipper money? From the days of Ben Franklin, ships have tried to take either advantage of or avoid the Gulf Stream, depending on travel direction. Modern ship routing considers currents to some extent, as best it can, although winds and waves may presently be more important (or at least easier to ascertain). But could knowledge of the currents along the intercoastal waterway save fuel? Or would knowledge of the beginning of the tidal phase most conducive to maneuvering a large vessel provide any advantage?

Real-time current information is a requirement in search and rescue operations. The chances of selecting the correct area in which to carry out a search are greatly increased if one knows what the circulation was at the time, and since, the ship or person was lost. A real-time system for this purpose would have to cover a large area, be able to be made operational at a moment's notice, and be able to provide data on which reasonable hindcasts, nowcasts, and forecasts could be based. This is, of course, an area of concern to both the Coast Guard and the Navy.

Circulation information is needed when there is a spill of hazardous materials (e.g., an oil spill), in order to predict where the spill will go. As in the search and rescue case, a real-time system, would not need to operate all the time, but it must have the capability to

be made operational at a moment's notice.

A real-time current measurement system would be a requirement when there is controlled release of pollutants in a harbor or estuary. Model studies would initially be done to determine the optimum period of release for maximum flushing of the pollutants; this would usually be during the ebb phase, but perhaps only near the beginning, or only when speeds are above some critical value. A real-time system for this application would have to be permanent, operating around the clock, and easily maintainable.

While these first five applications generally apply to users in the marine community who are not necessarily oceanographers, the last three applications in Table 1 apply to oceanographic research and could have been grouped under the heading of data quality. The emphasis in this paper will not be on these last three applications, primarily because, with these, the real-time requirement does not provide the justification for a particular current measurement technique. In this case the current measurement technique is chosen first, based on the needs of the research, and the telemetry system is added in order to increase the chances of obtaining good quality data.

Being able to obtain the data in real time allows experiment modification and performance assessment, that is, it allows one, first, to see if the current meter is even operating, and second, to decide if it was placed in the best location or set at the best sampling rate, etc., and whether the experiment should be changed in any way.

A real-time system provides data backup. Given the hazardous conditions in which current meters must operate, obtaining the data in real time assures us that we have the data even if the instrument and its internal data storage tapes are lost. In fact, there may be cases where real-time data retrieval is the only feasible way to obtain the data. The current measuring device may be at a location that would make it difficult to retrieve internal data storage tapes, or it may put out so much data that its interval storage capabilities are not sufficient. This might be the case with an acoustic Doppler system that outputs data and various quality assurance parameters for many depth bins.

#### SAFE NAVIGATION

Safe navigation is the reason that NOS became involved in real-time systems. NOS publishes tide tables, tidal current

tables, and tidal current charts, and has been doing so since 1853, when it was known as the Coast Survey. These products, of course, provide only astronomical tidal predictions, that is, predictions of water level changes and currents that will result from the gravitational effects of the moon and sun. They do not include the effects of wind, atmospheric pressure, or river discharge, which can also significantly affect water level and circulation. The pilots and shippers have relied on these tables over the years, and they have worked reasonably well in the harbors and estuaries of the East and West coasts, primarily because the tidal signal generally dominates the meteorological signal, except during storms. (Along the Gulf coast this has not been the case, and tidal predictions alone have been less useful there.)

But now, tankers and cargo vessels have grown so large that navigational channels in most ports are not deep enough to handle their drafts, except near high water or when the wind is blowing in the right direction to raise the water level. These vessels have grown so large that maneuvering in certain turning basins and harbor entrances depends on more accurate knowledge of the currents (especially the times of slack, which are easily changed by the nontidal flow). Meteorological effects can no longer be ignored or simply guessed at.

When one is dealing only with tidal prediction, one has the luxury of dealing with a periodic geophysical phenomenon. The astronomical periods of the relative movements of the earth, moon, and sun, found in the tide-producing forces, are well known. No matter what the hydrodynamic effects of the ocean basin, the continental shelf, or the estuary, these same periods are found in all water level and current records (along with easily determined new periods generated by the nonlinear effects of shallow water). Consequently, with a time series long enough to harmonically separate the most important tidal frequencies, one can calculate pairs of amplitudes and phases from which tide and tidal current predictions can be made for the location where the observations were made.

Tide predictions can be made very accurately years into the future (assuming there are no major bathymetric changes). Tidal current predictions have generally been somewhat less accurate for several reasons. First, until recently, current records have usually been much shorter than water level records, and thus fewer tidal constituents could be determined. Second, local bathymetric changes (after

the data were obtained) can change the tidal current significantly while hardly affecting the tide. Third, the harmonic constants obtained from a particular current record could have been affected by baroclinic effects or by the nonlinear interaction effect of storm surge or river discharge. There is also the problem of determining how much of the mean flow, calculated from that current record, is the result of the wind (and thus is temporary) and how much is tidally-induced (and thus is permanent).

In contrast to tidal prediction, forecasting nontidal water level changes or currents due to changes in wind or pressure or river discharge is a much more difficult problem, depending as it does on forecasting random meteorological phenomena. If the differences that nontidal effects can make are important to a pilot or shipper, then the only alternative is to supply real-time data instead of tidal predictions. If short-term forecasts are also required, they can only be expected to be reliable if they are extrapolated forward in time from the real-time data (using an appropriate statistical technique).

#### POTENTIAL CURRENT MEASUREMENT TECHNIQUES FOR REAL-TIME HARBOR APPLICATIONS

Let us suppose there is a harbor entrance in which the local pilots association and/or port authority have asked us to install a system that will provide them with current speeds and directions in real time. Their highest priority is the accuracy of the times of slack water and the direction of flow. They would like fairly accurate current speeds (perhaps to a quarter or half a knot [13 to 25 cm/sec]), and short-term forecasts would also be useful. (The largest ships make critical course corrections before they reach the entrance itself; they need to keep a steady speed for maximum control.)

The pilots most need this information for large vessels with deep drafts. The entrance sees very heavy commercial ship traffic, as well as recreational boaters. There may be a fouling problem, either a lot of floating debris (e.g., as in New York Harbor) or, if the harbor is not too polluted, biofouling.

What system could be used to provide the real-time current data that are needed? In the case of Miami Harbor, NOS used a remote acoustic Doppler system (RADS). There are, however, certainly other possible techniques, some of which have been described at this conference. Some of these techniques are still experimental, but offer potential because of the ease of maintenance they would have.

One thing that is clear, a conventional current meter on a mooring will not provide an easy solution to the problem. Even if we could use a meter that is not susceptible to fouling by floating debris or to biofouling, it would certainly not survive long in or near the shipping channel, or even at the edge. Maintenance and repair would require at least divers, and perhaps even redeployment of the mooring. A conventional current meter attached to an easily accessible fixed structure might be workable, if the meter was placed far enough away from eddies created by the structure, and if a circulation study of the entire harbor entrance was carried out in order to see how the currents near the structure correlate to the currents where the ships travel, so that the data could be adjusted to represent the shipping channel.

Since the current flow in the entrance is likely to be bidirectional, we might use a system for determining currents from electric field measurements (2). If there was a cable across or under the channel, we could take advantage of that. Otherwise, we could use probes at the edges. We would also have to monitor conductivity in real time. Since this system measures relative currents, not absolute currents, we would have to calibrate the whole system using another current measurement technique. In addition, we must take out the ionospheric effects, and determine any possible effect of the nearby ocean on the electric currents. The result would be cross-sectionally averaged current speeds, which would have to be adjusted to represent the ship channels using the data from a small current survey. All this effort could probably be justified by the ease of maintenance and repair that goes with it being a land-based system.

If the harbor entrance was near enough the ocean or a large bay to be assured of approximately 6m waves, and if the entrance was wide enough (at least 1-2 kilometers), we might consider using a high frequency radar system, such as CODAR (described by Porter, et al, in this volume). If a site could be found to look straight down the channel, the radial values from a single transmitter/receiver could be used; otherwise two transmitter/receivers would have to be used simultaneously (using two different frequencies). The current speeds would represent an average for the width of the entrance, over approximately a wavelength (approx. 6m) of depth. A current survey would be required, so that the values from the CODAR could be adjusted to represent the flow over full depth in the shipping channels. The current data obtained to determine the proper correlations would

have to cover various meteorological situations, because the wind-driven currents will be much stronger near the surface, where CODAR uses the waves to make its measurements.

If the harbor entrance is too narrow to use CODAR, a dual frequency microwave technique might work (3). That measurement would also represent the near-surface layer, and the same care would have to be taken in determining how to adjust the measurement so it could represent the depth covered by the draft of a large vessel.

There are several acoustic methods that might be applied to this requirement for real-time current information in a harbor entrance (although they should still be considered experimental). A basic reciprocal acoustic transmission system could be set up using a transmitter on one side of the entrance, and one or more receivers on the opposite side; other transmitters and receivers could be put on any available structures. The current velocities obtained are path-averaged; use of two receivers can give cross-sectionally averaged values. Such systems only measure relative currents because of the inability to determine exact path lengths. The system must therefore be calibrated using simultaneous current measurements from another measurement system.

The acoustic scintillation technique described by Clifford (in this volume) provides absolute current velocities that are path averaged. If one were to use the system tested in Cordova Channel, some adjustment (based on a small current survey with conventional meters) might be necessary so that the values could be used to represent the flow where the ships travel. Again, one transmitter can be put on one side of the entrance, and two receivers on the opposite side (the distance between the receivers being chosen to make a weighting function approximately uniform).

The system now being developed by Clifford using path weighting with spatial filters, would be even more useful, since one could choose to weight the measurement for the center of the ship channel. Such a system has great potential for real-time current monitoring in ship channels.

The remote acoustic Doppler system is the one NOS actually used in Government Cut, Miami. It sat on the bottom, looking upward, and provided real-time current data in 6 bins of approximately 1.1 m in height. This system has the advantage of being below the ships' keels yet being able to measure currents along almost the entire water column, and thus cover the

entire draft of large vessels.

The Doppler session of this conference provided a great deal of information and experimental results for this technique. What is especially relevant to its usefulness in a real-time application is that it does require installation by ship, so it is important that the system work without problems for long periods and that the configuration remain stable for long periods, i.e., that a shifting bottom does not change the alignment significantly away from vertical. Depending on the nature of the bottom this might be a problem. Willow mats under the platform, and perhaps improved platform design might reduce such problems. There is still the question, however, of maintenance and repair, this not being a land-based system.

The remote acoustic Doppler sensor could be used in a sideward-looking configuration, and thus could be land-based. If problems can be overcome relating to side lobes due to backscatter from the surface and bottom (one method involves a coherent system placed at mid-depth), this technique could be quite useful. Although it only has a limited range (less than a 100m), again, some correction factor might be calculated based on simultaneous data from current meters temporarily deployed near the areas where the ships travel.

One point should be remembered about the use of these systems, especially those where some type of an engineering correction factor might have to be used in order to make the current velocities represent the area of the channel where the ships travel. Although small errors may result from such a correction scheme, the real-time data provided is still a big improvement over tidal current predictions alone. This is especially true for slack times, which any nontidal flow will change, but which should not be as adversely affected by a correction scheme as current speeds. The current techniques discussed in this section are summarized in Table 2.

#### THE MIAMI AND DELAWARE BAY REAL-TIME SYSTEMS

The Miami experience appears at this point to have been a positive one. The users of the system, the pilots, are using the real-time current information on a daily basis. The Port of Miami has expressed its intention to buy its own system. NOS, with contract help, has shown that a remote acoustic Doppler system (RADS) system combined with a PC and appropriate software, can provide the necessary real-time information, in a

Table 2. Applicability of Various Current Measurement Techniques To Real-Time Monitoring In a Harbor

Technique	Installation	Measurement Coverage	Infield <sup>1</sup> Calibration or Adjustment Required	Fouling Problems	Other Problems
Conventional Current Meter	Mooring	Essentially Point Measurement	No	Yes	Surviving in ship channels. Requires divers and/or ship to repair.
	On a Structure	Essentially Point Measurement	Adjustment	Yes	Eddies from structure
Electric Field Measurement	Cable on or under bottom, or probes at edge	Cross-sectionally Averaged Measurement	Calibration	No	Must also monitor conductivity. Must take out ionospheric effects and effects of ocean on electrical currents. Still experimental.
HF Radar (e.g., CODAR)	On Land	Averaged over $\geq$ 1 km horizontally, from surface to $\sim$ 6m depth	Adjustment	No	Can only be used for wide harbor entrances.
Dual Frequency Microwave	On Land	Averaged over (on the order of) 10m horizontally, from surface to $\sim$ 6m depth	Adjustment	No	Technology still developing
Reciprocal Acoustic Transmission	At edges or on structures	Path-averaged (can be cross-sectionally averaged) measurement	Calibration	No	Still experimental.
Acoustic Scintillation (unweighted Method)	At edges	Path Averaged Measurement	Adjustment	No	Still experimental.
Acoustic Scintillation (Path Weighting with Spatial Filters)	At edges	Weighted Path Average (e.g., for Center of Channel)	No	No	In development
Remote Acoustic Doppler	On bottom, looking upward	Almost entire water column in Bins $\geq$ 1.2m (incoherent system)	No	No	Requires divers and/or ship to repair. Maintaining stable (vertical) configuration if bottom moves.
	On structure, mounted transversely	Horizontal bins at one depth	Adjustment	No	In development; requires narrow beam/coherent system; limited range.

<sup>1</sup> "Calibration" indicates that the technique cannot provide absolute current measurements, and so must be calibrated in the field using another current measurement technique. "Adjustment" indicates that the technique can provide absolute current measurements, but not in the shipping channel; a data series is required in the shipping channel in order to determine how to adjust the real-time data so that it can represent the shipping channel.

convenient form, to a critical user (Figure 1).

As mentioned in the last section, the main concern with using a RADS in a real-time system is how much effort and expense will be required to keep it operating indefinitely. The two especially relevant considerations are the reliability of the instrument itself, and the importance of maintaining a stable configuration.

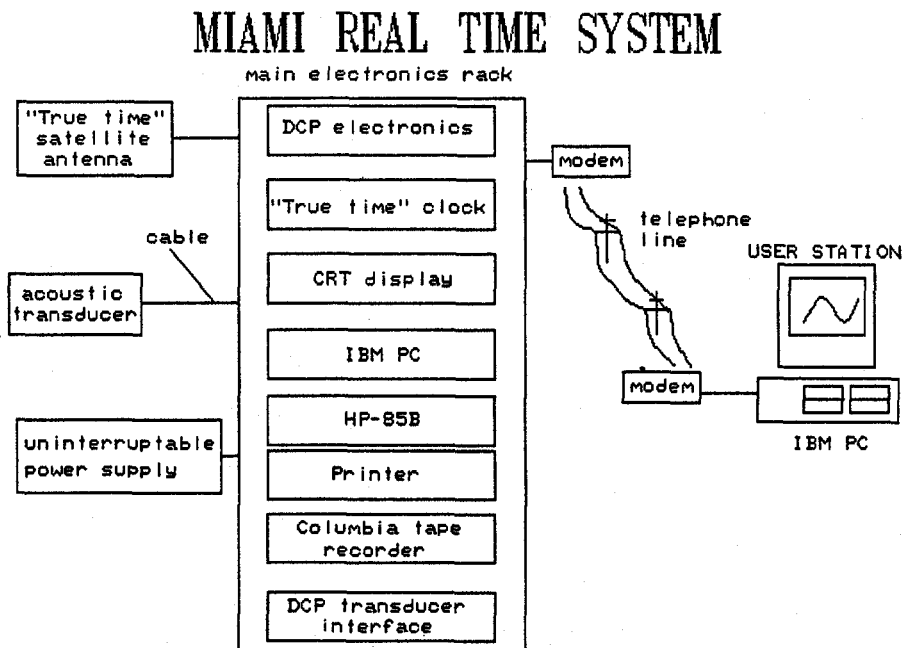
The system in Miami has been operating since December 1984. The AMETEK unit has gone down only twice, both times because of a clock (replacing the board finally solved that problem). There were power outage problems that were reduced by the addition of an uninterrupted power supply. There were also sequential turn on problems, that were solved by delaying the start up of the HP-85 computer. There were also differences in the values calculated in the four individual beams of the RADS as well as differences between current meters in a intercomparison that was carried out (4), indicating significant motion on small spatial scales. NOS also financed a contract circulation survey, which covered both Government Cut and the inner harbor, to see how the current information at the RADS location compared with that from other locations. Current speeds and calculated mean flows varied considerably over the length and width of

Government Cut, but times were fairly close.

NOS also installed a real-time RADS system in the Delaware Bay, which was part the intercomparison study described by Magnell (in this volume). It was primarily part of a real-time numerical model system implemented by NOS in Delaware River and Bay. The RADS provided real-time performance assessment of the currents predicted at that location by the model, and its data were also used by the Delaware Bay pilots. The RD Instruments unit used has been operating for about 1½ years without a malfunction. In the beginning, there were power problems from the nearby lighthouse. After eight months, comparison to a VMCM showed no performance degradation. There has been some tilting of the instrument ( $\sim 10^\circ$ ) over the 1½-year period of operation, which has resulted in some data degradation from one beam, but the remaining three beams still supplied consistent data. The RADS also worked well even when covered with a few inches of sand. On those occasions the signal strength dropped, but the signal-to-noise remained high enough for the RADS to provide good current data.

As regards the short-term forecasting of currents, only a very limited univariate forecasting technique has been tried in order to extrapolate the currents in

Figure 1. Schematic of Miami Harbor Real-Time System Using a Remote Acoustic Doppler Sensor



Government Cut, Miami, a few hours into the future. This technique did not work well, which was probably to be expected, since the lower frequency/longer time lag meteorologically-induced effects are much less important with currents than with water levels. A multivariate technique relying on real-time wind data will be required, and even then the forecasts may only be accurate for very short time periods. In Delaware Bay, forecasts of currents (and water levels) have been attempted, but in this case current data were not used as input; the forecasts resulted from running a numerical hydrodynamic model into the future using forecast winds from the LFM weather model of the National Weather Service.

#### REAL-TIME CURRENT MEASUREMENT TECHNIQUES FOR OTHER APPLICATIONS

The emphasis of this paper has been on harbor and estuary real-time systems used for safe navigation, because of NOS' experience in these areas. Of the other potential applications listed in Table 1, the controlled release of pollutants has similar requirements -- a permanent, reliable real-time current measurement system. Much of what was said in the last two sections about the usefulness of various techniques applies to this application, (except there will not be the requirement for data in the middle of the shipping channel). If search and rescue or hazardous spill cleanup happened to be required in a large estuary where any of the above real-time currents systems were in operation, they would also provide useful information for those applications.

The more difficult problem is providing real-time current information for search and rescue or hazardous spill cleanup over the continental shelf. Such real-time information would not be required all the time, but whatever technique was used would have to be capable of being made operational on a moment's notice, and would have to be able to cover a fairly large area. A brief mention will be made of some techniques that might be used over the continental shelf for particular applications.

Within approximately 60km of the coast a high frequency radar system (such as CODAR) could be used. Further away from the coast over-the-horizon radar could be used, although the area over which the current is representative would be much larger than with CODAR. Using CODAR on a ship is another possibility.

Tests have been done on using synthetic aperture radar (SAR) on aircraft. Measured bandwidth correction techniques

apparently have increased the accuracy of this microwave Doppler technique (5). Such a technique would seem to have search and rescue applications. Microwave radars on satellites have been used to supply altimetric profiles of the sea surface, from which geostrophic currents were calculated. Results have been good where satellite coverage was dense enough to have collinear tracks (6).

Real-time current data can also be obtained using Lagrangian techniques and aircraft deployment. The Coast Guard has developed a microwave tracking system that can track up to 56 surface transponders simultaneously in a 25-by 40-mile range at shore's edge. All Coast Guard aircraft and vessels are certified to carry these transponders (as well as life-raft-mounted weather stations). They have also tested VHF and HF communication with LORAN-C tracked drifting buoys and the use of satellite observed features (7).

Floats can be tracked, of course, with LORAN-C, the Global Positioning System (GPS), ARGOS, and other positioning techniques. As has been described in several papers in this volume, a positioning system can also be combined with a shipboard acoustic Doppler system to provide current data. While such a shipboard-based system might not be put into operation as quickly as one would like for a search and rescue application, there is another interesting possibility. Ships of opportunity have been used before, but a well thought out real-time connected network of properly selected ships might be of advantage to a variety of users. Circulation models and careful study of ship routes could be used to select a critical number of ships on which to install acoustic Doppler systems. The data system on each ship would automatically send the data in real time to a central location via INMARSAT (if available). Other telecommunication methods that could be used include: satellite systems such as GOES (for modest data quantities) and ARGOS (for very small data quantities), a meteorburst system (data rates on the same order as GOES), and HF radio systems linked over moderate distances. (These methods were described in some detail by Briscoe during the telemetry meeting at this conference). These data (perhaps synthesized using a model) would be useful for ship routing, Naval purposes, and, if the need arose, for search and rescue and hazardous spill cleanup. It would also be useful for research purposes, because the increasing accuracy of positioning systems (e.g., GPS) and acoustic Doppler systems has made the data more reliable. One problem might be getting data close enough to the



surface, where it would be most useful for search and rescue and oil spill applications. Whether it be this application, or another, real-time data acquisition and dissemination does provide the means for a variety of users to combine forces (and share expenses) in order to obtain data useful to all of them.

#### SUMMARY

The greatest benefit of some of the new current measurement techniques being developed may not be in the area of improved accuracy or of handing the dynamics better; it may simply be in their ability to remain in operation for long periods of time with minimal maintenance, because they avoid many of the problems associated with conventional moored current meters. Such methods may therefore be the most likely choice for real-time applications, especially in harbors with heavy ship traffic. (The synoptic area coverage provided by some of these new techniques is, of course, another important benefit.)

Other new methods provide a means of obtaining real-time circulation data over the continental shelf, on an on-demand basis, for such applications as search and rescue and hazardous spill cleanup. Real-time data acquisition and dissemination systems provide the means for a variety of users to combine forces (and share expenses) in order to obtain data useful for a variety of purposes.

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