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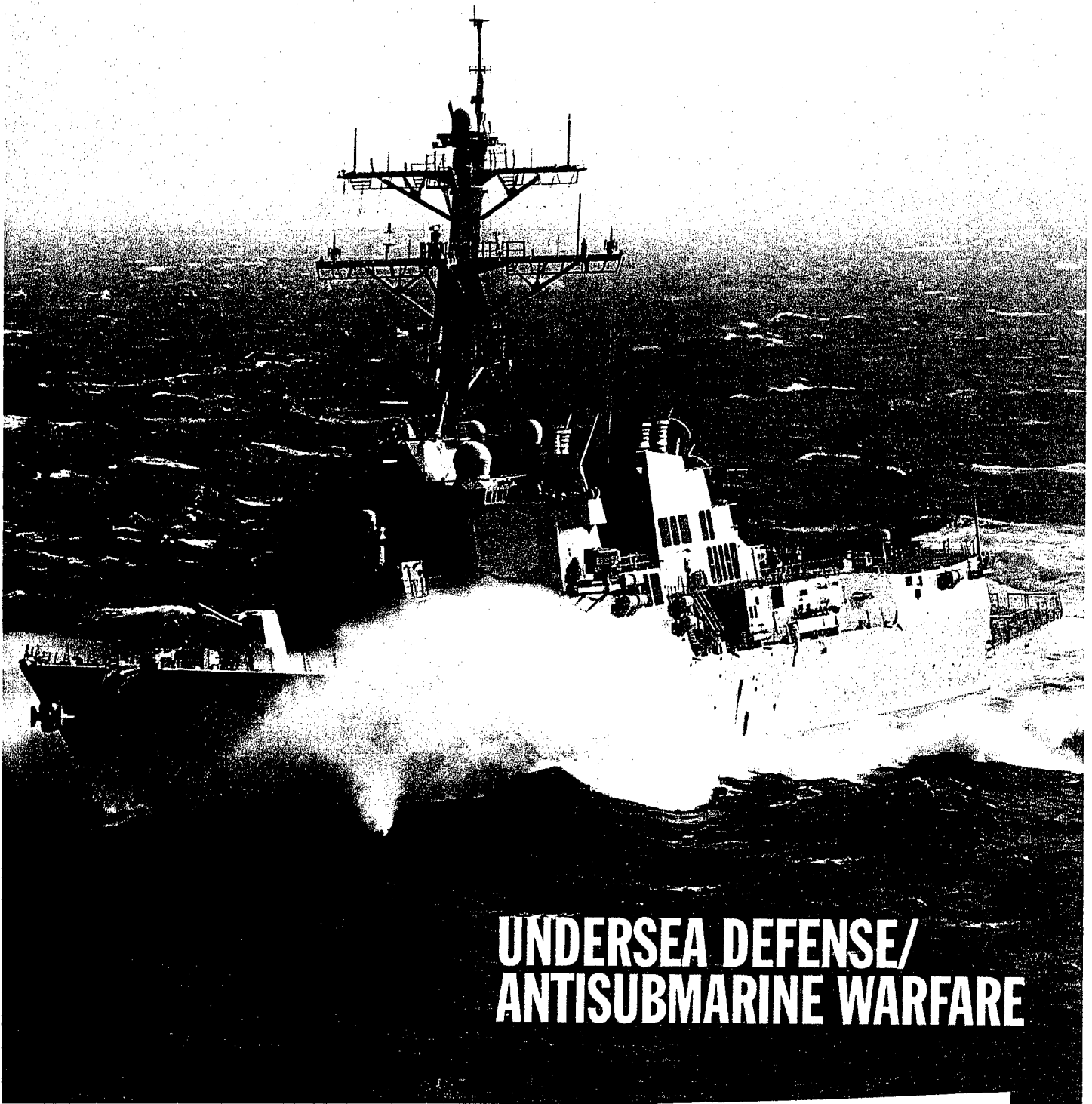
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14. ABSTRACT This paper examines rapid environmental assessment (REA) in the context of naval requirements and characteristics for the North Atlantic Treaty Organization (NATO). The time and space scales of REA are very application dependent, and "rapid" refers to the speed of responding to a request for information rather than an indication of time scales of variability within the survey domain. The paper examines civilian technologies such as internet, geographic information systems (GIS) and other communication capabilities that are used to facilitate REA. An example REA scenario is presented for the Gulf of Mexico in the Shelf Energy and Exchange Dynamics (SEED) domain using nested Navy Coastal Ocean Model (NCOM) domains. Recent advances in sensors and platforms provide new opportunities for multiple views of the battlespace with more information to improve future REAs.					
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Rapid Environmental Assessment Within NATO

Underwater Warfare Programs Fuse Civilian Technologies with Military Architectures to Deliver Oceanographic Products

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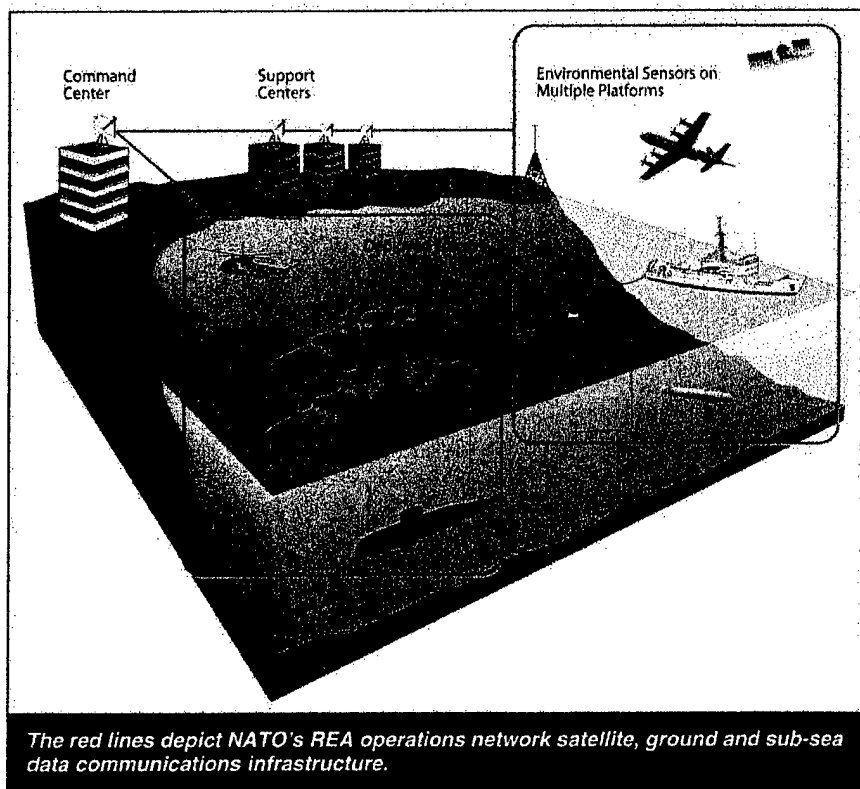
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A rapid environmental assessment (REA) provides deployed forces with environmental information in littoral waters in tactical time frames. Literature in the United States uses the term “warfighters” instead of “deployed forces,” otherwise, the navies of the North Atlantic Treaty Organization (NATO) have developed a common view of REA.

From a NATO perspective, REA was born in 1995 when the Supreme Allied Commander, Atlantic (SACLANT), identified it as a new requirement. REA emerged as a result of NATO's post-Cold War shift in operations toward crisis response and littoral waters. Since then, REA has evolved from a concept to a network of operations engaged in antisubmarine warfare, mine warfare, amphibious warfare and other military activities. In antisubmarine warfare, for example, REA products require data pertaining to sound speed through the water column, ambient noise, bathymetry, seabed composition, fronts, eddies, magnetic anomalies, sea-ice,



The red lines depict NATO's REA operations network satellite, ground and sub-sea data communications infrastructure.

state, salinity and temperature, underwater visibility, etc. NATO's product specifications for REA were published in 2001.

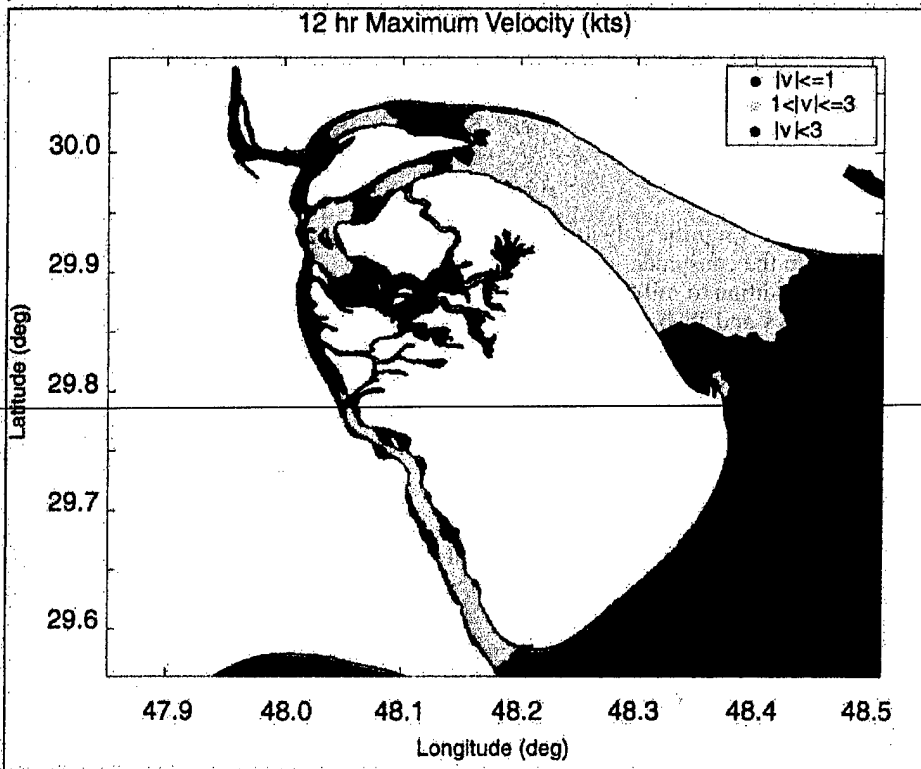
NATO's shift toward littoral waters and crisis response redefined the temporal and spatial scales of interest, the relevant environmental boundaries, the speed and format in which deployed forces require environmental information and the technologies that allow NATO to fulfill such requirements. Implied in this statement is the fact that the information is, to an increasing extent, requested and retrieved by the deployed warfighter, not the shore-based specialist.

Focusing on this latter development takes one to the state-of-the-art in REA.

A diver engaged in a covert amphibious operation, for example, wants to know when and where currents and water visibility will be suitable for operations. In this case, time-series maps of current vectors and satellite-derived ocean color images are not the required information products. The required products are much simpler in content and appearance, but require substantive processing to produce.

Similarly, an antisubmarine warfare sonar operator does not want the mul-

Graphic courtesy of Dr. Cheryl Ann Blain, NRL-SSC.



intertidal zone, it refers to coastal or shallow waters. Unfortunately, from an ocean-observing perspective, there is no precise definition of such waters. Herein, we choose to adopt the definition of Michel Even of the Etablissement Principal du Service Hydrographique et Océanographique de la Marine in France, "There is no precise definition of shallow waters: from the shoreline to the continental slope (when it exists) could be one. They are, in fact, generally characterized by the influence of the bottom: through its acoustical properties, its topography, its nature, its density..."

Enabling Technologies

A range of technologies are enabling REA operations, with civilian technologies playing a key role. We group them as follows:

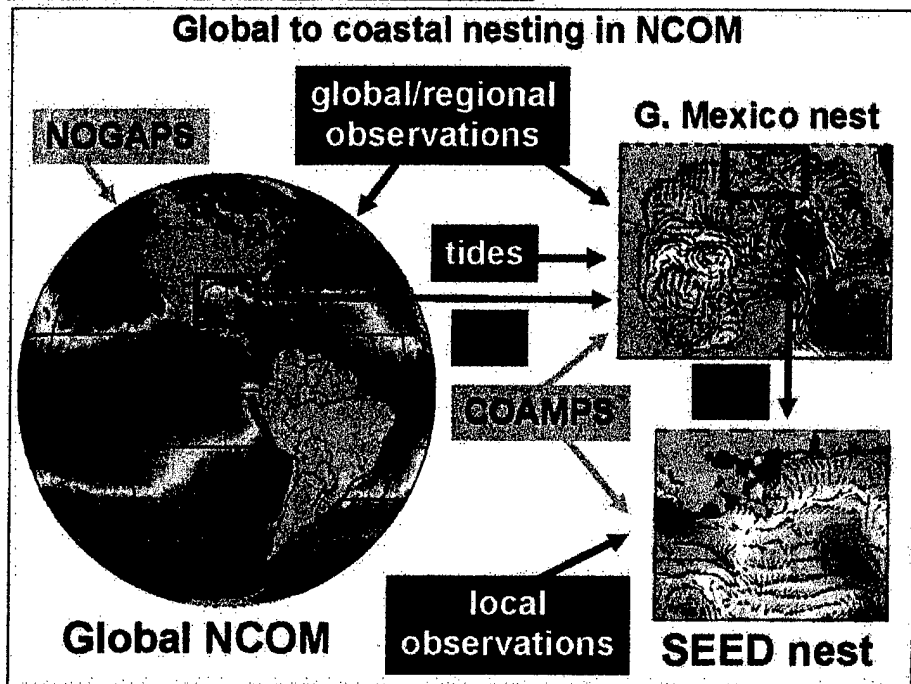
(Above) Generated by the coastal circulation model ADCIRC, this 12-hour maximum current threshold product is an example of a wartime REA product produced in support of Operation Iraqi Freedom in 2003.

(Right) An example of models configured for use in REA.

itude of environmental parameters listed above—the operator simply wants to know what impact environmental conditions will have on sonar performance, the so-called "range of the day."

Time and Space

The temporal variability of littoral oceanographic features falls within the range of hours to days to weeks. However, sea-bottom and beach features, which may influence water column properties, usually vary on longer time scales—perhaps weeks to months, or on geological time scales. NATO recognizes this by defining two main areas for REA data: static and dynamic. Static data change on time scales of weeks, months or years, whereas dynamic data change within hours or days and are, therefore, perishable. Static data are categorized into what NATO refers to as additional military layers (AMLs). The initial AML vector product specifications were published in November 2001.



Graphic courtesy of Dr. Cheryl Ann Blain, NRL-SSC.

Regardless, the "rapid" in REA does not refer to the time scales of environmental variability or the duration of a tactical military operation; it refers to the time available to respond to a request for environmental information. Indeed, the definitive aspect of the term REA is the word "rapid." After all, we have been conducting environmental assessments for as long as war has been waged at sea.

Spatial scales of relevance to REA are ill-defined. In this context, littoral does not refer to the classic oceanographic definition of waters within the

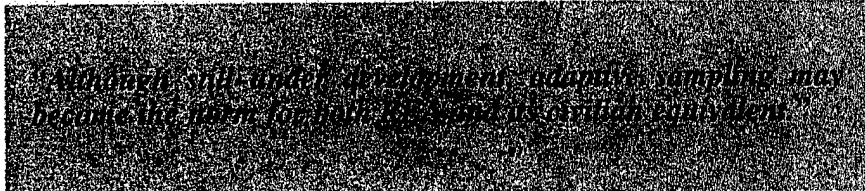
World Wide Web, geographic information systems (GIS) and data communications; environmental modeling and adaptive sampling techniques; and sensors and platforms.

Web, GIS and Data Communications. These technologies are largely being driven by commerce and the civilian consumer. They are widely available and relatively inexpensive. They are also components of NATO's REA infrastructure, and have been instrumental in putting information into the hands of deployed forces in the required format and time frame.

Web browsing, in combination with NATO data-communication architectures, are two of the main enablers of REA. Such architectures are platform independent, use commercial-off-the-shelf hardware and software, and permit user-defined searches of distributed databases in real time—regardless of whether the database is civilian or military, classified or unclassified, at sea or onshore, within national boundaries or housed on a foreign server.

Client-server Web architectures also allow computations to be done on the server side, thereby transferring only the processed information to sea. This addresses the goal of providing deployed forces with what they need, rather than all available environmental data. It also minimizes bandwidth requirements.

Military research and development (R&D) centers have developed GIS and Web software, but it is questionable as to whether they can do so at the same pace as the private sector, the reason being that the private sector is developing these technologies for a broad market and is able to justify a much larger level of R&D expenditure. The broader market focus also



Although sub-model development, adaptive sampling may become the norm for both military and civilian applications.

results in a significantly lower per-unit cost to the consumer.

In addition to military and commercial GIS and Web technologies, there are also non-proprietary, open-source systems designed by, or for, public consortia.

Environmental Monitoring and Adaptive Sampling. In addition to the Web and real-time database architectures, REA relies on direct observation. Unfortunately, the temporal and spatial variability of littoral processes are such that most sampling techniques are prone to aliasing. It is not practical to solve this problem with direct observation alone. Instead, ocean models are used to estimate environmental conditions in real time—this is referred to as nowcasting. When the models are used to project future conditions, the procedure is termed forecasting.

REA typically relies on a suite of ocean and atmospheric models to pro-

vide optimum assessment of the localized environment. This example focuses on the Slope to Shelf Energy and Exchange Dynamics (SEED) project being conducted by the Naval Research Laboratory on the Mississippi River shelf and slope; but a similar configuration could be employed in any REA domain. At its core is a dynamic ocean model that covers the region of interest with sufficient spatial and temporal resolution, in this case a high-resolution implementation of the U.S. Navy Coastal Ocean Model (NCOM). This local model assimilates available local observations, is forced by high-resolution winds from a local atmospheric model and uses lateral boundary conditions from a regional ocean model. For this SEED scenario, winds are from the Coupled Ocean-Atmosphere Model Prediction System (COAMPS) and boundary conditions are taken from a larger-scale NCOM. The regional ocean model, in turn, uses regional winds, here also from COAMPS, and boundary conditions from a global ocean model.

Global NCOM assimilates global *in-situ* observations and dynamic profiles derived from satellite altimeter and temperature observations through the Modular Ocean Data Assimilation System, and it employs atmospheric fields from the Navy Operational Global Atmospheric Prediction System. More intermediate nests may be added as necessary. Even finer-scale models, such as the Advanced Circulation Model for Shelves, Coasts and Estuaries, may be interfaced with the inner nest.

These global and nested capabilities place the U.S. Navy on the vanguard of ocean and coastal modeling for military REA nowcasting and forecasting purposes.

Navies that engage in adaptive sampling use nowcasting to maximize the efficiency of their sampling programs by focusing limited *in-situ* sampling capabilities on critical locations and periods. Ocean models are used to target influential features, such as fronts and eddies, or to study regions identified by the assimilation fields as being of high uncertainty.

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More sophisticated methods using adjoint models and representer functions may indicate preferred observation points in locations of relatively high-error growth rates or large influence. Models also indicate which locations are expected to have an impact in areas where access is denied.

Although still under development, adaptive sampling may become the norm for both REA and its civilian equivalent. As a cautionary note, the final products from environmental models are as reliable as the assumptions, climatologies and direct observations upon which they are based.

Sensors and Platforms. While developments in sensor design do not appear to be a driving force behind REA, recent advancements in platforms that house such sensors have opened new opportunities in this field, particularly in relation to covert platforms. This partially reflects the fact that, unlike open-ocean waters, littoral waters are sovereign and may pose additional difficulties for traditional observation methods.

"Satellites, aircraft and shore-based installations are capable of providing synoptic views of the maritime battlespace."

Data collection for environmental assessment involves sensors mounted on five types of platforms: satellites, aircraft, vessels, shore-based installations and *in-situ* platforms. Satellites and various subsea platforms can be deployed and operated covertly and, therefore, are of ever-increasing significance to REA operations.

Buoy and shipborne sensors are the most prevalent. However, they are not covert and only provide point-source data. This can be problematic for applications such as antisubmarine warfare where such platforms may be the primary means to obtain crucial seabed data. This is but one example of the view that marine environmental monitoring is platform-limited.

Satellites, aircraft and shore-based installations are capable of providing synoptic views of the maritime battlespace. All three types of platforms target surface waters. To an increasing extent, however, various subsurface

features such as bathymetry and seabed topography are being investigated with the aid of airborne and spaceborne sensors.

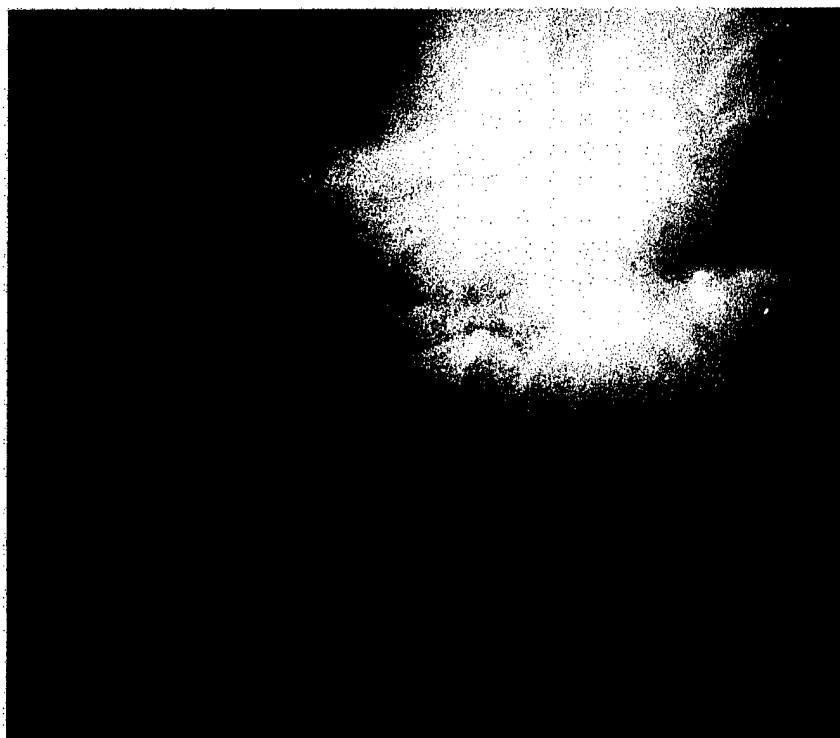
Unfortunately, most civilian satellite programs have poor revisit times for tactical military purposes, which again exemplifies the fact that REA is platform-limited.

Conclusions


In a period of fewer than 10 years, REA progressed from a concept to a network of operations that are expand-

ing NATO's tactical capabilities in littoral waters. To a significant extent, this involves applying civilian technologies to military operations. However, REA is less a matter of building new pieces of a kit and more a matter of data management, fusion and display, systems engineering and listening to the client-deployed forces.

REA is also a matter of being able to operate covertly. This requirement is having fundamental influence on the choice of platform for environmental sensing, and it is enhancing the value



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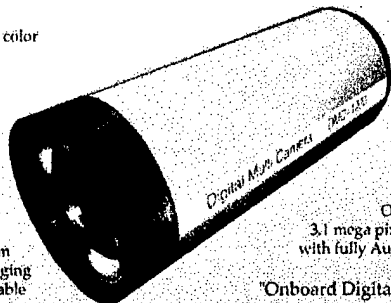
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"In a period of fewer than 10 years, REA progressed from a concept to a network of operations that are expanding NATO's tactical capabilities in littoral waters."

of environmental modeling techniques. This process will continue into the foreseeable future, with REA becoming less of an entity onto itself and more a component of the maritime recognized environmental picture, of which oceanographic features are but one aspect. /st/

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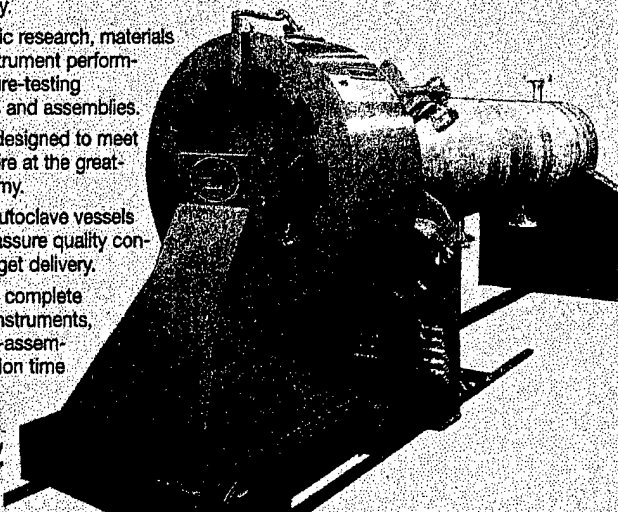
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