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DATA COMMUNICATION AND DATA FUSION ARCHITECTURE FOR RAPID RESPONSE 96-98

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Data Communication and Data Fusion Architecture for Rapid Response 96-98

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Jan L. Spoelstra
Director

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Data communication and data fusion architecture for Rapid Response 96-98

Trangeled, A., Franchi, P., Berni, A.

Executive Summary: The concept of Rapid Environmental Assessment (REA) has emerged in recent years as one of the most interesting research topics in Military Oceanography (MILOC): REA in a military environment is defined as "the acquisition, compilation and release of tactically relevant environmental information in a tactically relevant time frame".

In this context, REA implies the integration of traditional methods of information gathering in MILOC with modern communications and data processing techniques, to ensure the timely delivery of environmental data to naval forces and commands in the course of a crisis situation.

A fundamental aspect of Rapid Environmental Assessment deals with the quantity and quality of data that need to be gathered, processed and delivered to the final users. This document concentrates on the technological aspects of data processing, fusion and transmission, illustrating the evolution of the techniques adopted and their innovative impact on the overall capacity of the system.

The Rapid Response series of operations demonstrated how Commercial-Off-The-shelf (COTS) Internet technologies could be successfully integrated to build *ad-hoc* networks in support of REA surveys. This paper analyzes the technologies and the methodologies that were used for the generation and the distribution of REA products. Recommendations aimed at the definition of operational systems are included.

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Introduction

1.1 Rapid Environmental Assessment: supporting NATO's Crisis Response Doctrine

The concept of Rapid Environmental Assessment (REA) has emerged in recent years as one of the most interesting research topics in Military Oceanography (MILOC): REA in a military environment is defined as "the acquisition, compilation and release of tactically relevant environmental information in a tactically relevant time frame".

In this context, REA implies the integration of traditional methods of information gathering in MILOC with modern communications and data processing techniques, to ensure the timely delivery of environmental data to naval forces and commands in the course of a crisis situation.

A fundamental aspect of Rapid Environmental Assessment deals with the quantity and quality of data that need to be gathered, processed and delivered to the final users. This document will concentrate on the technological aspects of data processing, fusion and transmission, illustrating the evolution of the techniques adopted and their innovative impact on the overall capacity of the system.

1.2 MILOC: analysis time

In the past, MILOC efforts concentrated on gathering information from a strategically important area. Data were collected over a long period, and several months would pass before reporting of the results, which would eventually find their way into operational databases, Tactical Decision Aid (TDA) and Environmental Briefing Dockets (EBD). The end product was neither timely nor current [1].

The principal aim of REA is to provide a framework for the prediction of sonar parameters and to supply ASW, MW and AW CTJFs (Combined Joint Tactical Forces) commanders with environmental parameters within a time scale compatible with tactical operations.

The NATO security policy is designed to enable the NRV *Alliance* to ensure security in an area (Euro-Atlantic) for which the availability of *a priori* knowledge is minimal.

Rapid Response operations were conceived to develop effective REA techniques in such areas, validating an experimental configuration precursor to operational crisis management techniques and methodologies.

1.3 Communications in support of at-sea experiments

If was clear at the outset that communications would play a vital role in supporting REA activities. SACLANTCEN began exploiting Internet technologies in support of field experiments in 1994. Yellow Shark 95 and Winter Sun 95 contributed valuable experience [2]. **Rapid Response** experiments involved the evaluation of a wide range of commercial-off-the-shelf (COTS) communication technologies to provide the necessary support. The resulting infrastructure was used to transfer raw and processed data from at-sea platforms to ashore centres and *vice versa*.

The **Rapid Response** series was the first implementation of a distributed REA data fusion server using Internet technology.

2 Communications infrastructure

In this section we will illustrate the components used to provide the communication infrastructure in support of the **Rapid Response** exercises.

Wireless communication technologies, either using commercial services (such as cellular telephones or satellite) or radio frequency (RF) links, have played a fundamental role in the provision of the basic network layer. On top of these links we demonstrated how standard Internet technologies can be used for the integration of at-sea platforms with a network infrastructure ashore, making the timely accomplishment of fundamental REA methodologies, such as data dissemination and evaluation, a feasible task.

Internet protocols and services play a fundamental role in modern computer networking, and the military world makes no exception: our choice of adopting COTS products to satisfy our requirements was forced by the fast pace of technological innovation. This has brought us to devising a modular project structure, where each component of the system, being based on published and open standards, can be selectively upgraded or substituted without reengineering the whole system.

On the other hand, this approach still leaves a number of open issues, such as the applicability of COTS network technologies to treatment of classified information. We consider our work as *proof of concept*, while the appropriate NATO authorities are studying the security implications of Internet technologies in greater depth.

2.1 Wireless communications

Wireless communications are the indispensable media to relay data from ship to ship and from ship to shore. The choice of a particular technology varies according to what is commercially available in a particular location and the associated cost.

2.1.1 Cellular phones

Our activities involved the evaluation of analog and digital cellular telephone technologies, ETACS and GSM, to measure the capability of transferring data from ships participating in a survey to a data fusion facility. The biggest limitation for both standards is the narrow bandwidth, 9.6 Kbit/s at best, which makes them suitable only for applications such as e-mail or transfer of files of moderate size.

We were able to demonstrate that cellular phones offer cheap connectivity for ships operating near the shore (up to 100 km for ETACS, up to 32 km for GSM). The main scientific laboratory onboard NRV *Alliance* has been equipped with vehicular cellular phones compliant to both standards.

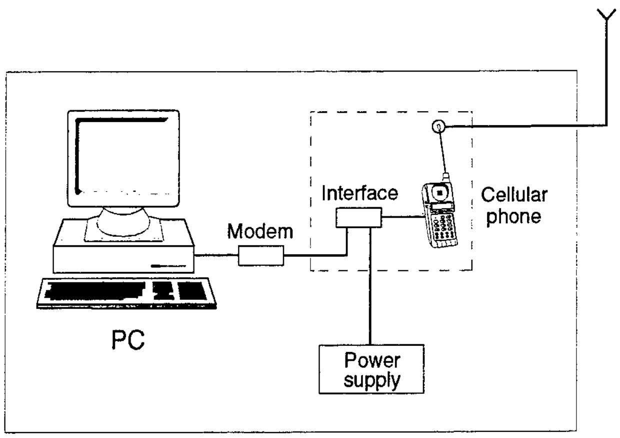

Figure 1 *Cellular phone installation*

The cellular phones, encapsulated in a watertight box, are installed on top of the mast, together with their respective omni-directional antennas. The telephone systems are equipped with computer interfaces (RS-232 Cellular modem and GSM PC Card) that can be connected to data processing equipment .

2.1.2 SATCOM

SATCOM offers worldwide higher bandwidth coverage with a higher cost.

NRV *Alliance* has been equipped with a NERA Saturn B marine high-speed data (HSD) system, offering a 64Kbit/s full duplex link with the worldwide public ISDN network, using the Inmarsat network.

The Inmarsat satellite service has been for years the *de facto* commercial standard for ship to shore communications. Satellite capacity for the Inmarsat system consists of four satellites placed in geosynchronous orbits over the Atlantic (east and west), Pacific and Indian oceans. Calls from a terminal are relayed to a Land Earth Station (LES), where they are routed through the international switched telecommunication networks.

Inmarsat-B gives the possibility of using ISDN data transfers for connections between data networks using bridges or routers.

The system has an efficient error correction system providing a very low Bit Error Rate and is very cost-efficient compared to lower speed analog systems (such as Inmarsat-A without the high-speed data option), which can transfer data with speeds in the order of 9.6 Kbit/s, under optimal conditions.

Even if the cost for the Inmarsat-B HSD connection is about three times higher, the data transfer is six times faster, and the call set-up time is only 3-4 seconds, compared to a minimum of 30 seconds with Inmarsat-A.

Alternative providers and satellite communication technologies are now emerging that will soon provide even more cost-effective solutions. While in the past a great deal of experimental work was conducted in deep waters, in support of ASW studies, a major focus of SACLANTCEN activities is now on the exploration of shallow waters, in areas that are reasonably near to the shore. This means that SATCOM could be integrated by alternative communication technologies such as Line-Of-Sight (LOS) links between a ship and an ashore site [3]. In certain situations it was more convenient to adopt cellular phones, at the price of a lower performance.

2.2 Routers

An entire local area network onboard a ship participating in a REA survey can be connected to other ships and land based sites using IP routers that can be configured as needed to use the appropriate communication channels (cellular, SATCOM, radio). The routers take care of all the connection set-up phases (automatic or semi-automatic, as required) and offer basic functionality such as accounting and access control.

2.3 Application servers

Computers onboard and ashore must be integrated with various network technologies in order to permit the flow of information required by REA survey participants.

During the three **Rapid Response** experiments, two Unix servers were used to support data processing and transmission activities. This allowed us to rely on a well-known operating system and vendor independent programming environment, so that applications could be ported with minimal effort.

Software packages publicly available through the Internet enabled us to access up-to-date programs in source code, which were modified as needed to fit our requirements.

The Internet protocol suite assured interoperability for data communications and retrieval between computers with different architectures and operating systems.

Whenever it was necessary to replicate a service in different locations (typically, at-sea and ashore), the same file system conventions were followed on all participating computer systems, to provide a consistent framework for configuration and management.

2.3.1 Data presentation

All the unclassified data collected and processed during the **Rapid Response** experiments, together with background information documents have been published in the course of the experiments using the HyperText Transfer Protocol (HTTP) [4].

2.3.2 Data transfer

Given the importance that REA has in the preparation of a naval operation, it is fundamental that, in all locations, data are stored and updated in a coherent manner. This requirement is difficult to accomplish when no permanent data link is available between the parties involved. Our solution to the problem has been to devise a mirroring strategy based on incremental updates that were made available to clients at regular intervals. A batch procedure was initiated synchronously by participants: if, for any reason, a participant was unable to establish a successful connection in due time, recovery was always possible at a later stage.

The file transfer protocol (FTP) has been widely used as the underlying mechanism for the respective updating of the Web servers, and for the transfer of bundled e-mail messages between systems.

On the two sides of the connection, archives containing new or updated World Wide Web (WWW) pages and mail messages were prepared by batch procedures. All files were compressed in order to optimize the use of communication channels.

3
Rapid Response 96-98

3.1 Rapid Response 96

Operation **Rapid Response 96 (RR96)** was the first of a series of exercises designed to validate the experimental concept of rapid environmental assessment in an operational context. Operation **Rapid Response 96** was held in support of the CINCSOUTH annual maritime LIVEX, **Dynamic Mix 96**, and the associated MCM exercise **Damsel Fair**. The operational orders for **RR96** identified the exercise area as a portion of sea between Sicily, Tunisia and Sardinia.

Participants in **RR96**, in addition to the SACLANTCEN vessels *Alliance* and *Manning*, included USNS *Pathfinder*, HMS *Herald* and the Italian research vessel *Magnaghi*. Aircraft based at NAS Sigonella conducted maritime reconnaissance for ambient noise evaluation and performed AXBT measurements. Aircraft data were brought to NAS Sigonella for electronic transfer to SACLANTCEN.

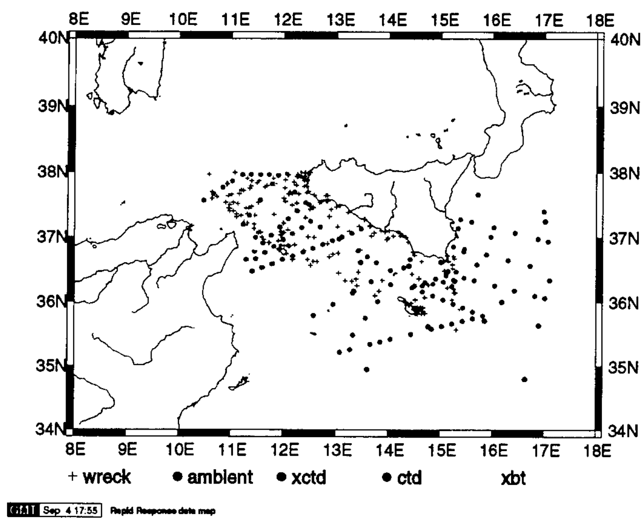

Figure 2 *Operational Areas for Rapid Response 96*

All participants in the survey relayed data directly to SACLANTCEN using ETACS telephones and FTP. A WWW server at SACLANTCEN was used to present data in an organized structure to external customers.

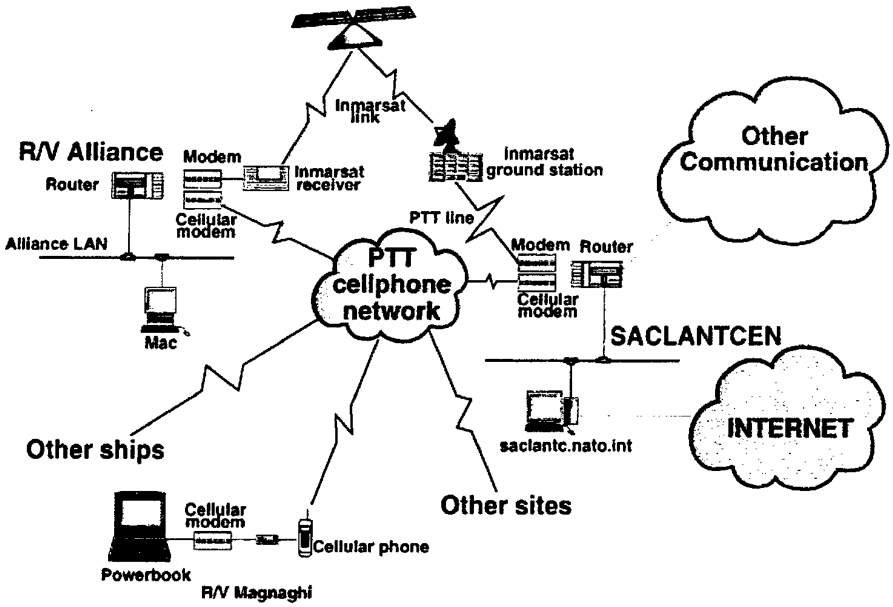

Figure 3 *Network Architecture for Rapid Response 96*

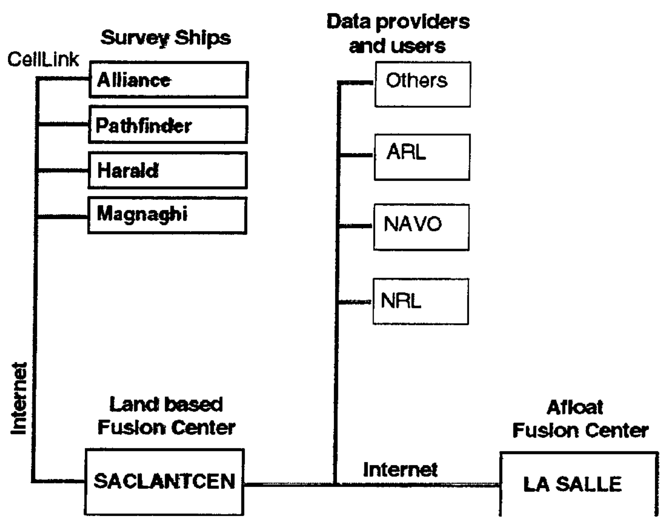

Figure 4 *Data fusion flowchart for Rapid Response 96*

A copy of all data was transferred using SATCOM to USS *La Salle* for use during **Dynamic Mix 96**.

3.2 Rapid Response 97

Rapid Response 97 (**RR97**) has been the second exercise of the series, in support of **Dynamic Mix 97** and **Damsel Fair**, and was a significantly larger exercise then its predecessor.

NRV *Alliance* was the leading ship of a fleet of 8 survey vessels operating in the Strait of Messina, the Ionian, Adriatic and Aegean Sea. The other vessels were FS *D'Entrecasteaux*, WFS *Planet*, HNLMS *Tydeman*, HMS *Roebuck*, USNS *Pathfinder*, HENA *Pytheas* and ITS *Crotone*.

Besides her role as main platform for oceanographic and acoustic measurements, NRV *Alliance* acted as communication centre for the survey. The survey ships had access to the SACLANTCEN Fusion Centre via ETACS dial-up connections and Inmarsat, enabling them to exchange data with the server mirror at SACLANTCEN.

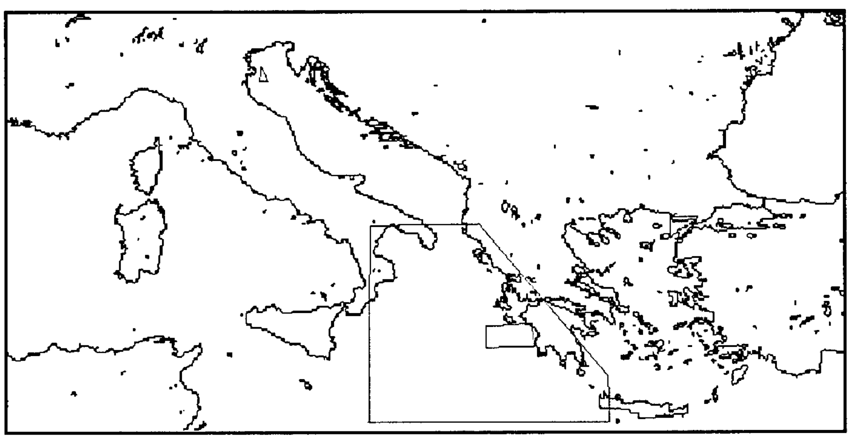

Figure 5 *Operational areas for Rapid Response 97*

With few exceptions, all data were processed on board NRV *Alliance* during the cruise and made available to the MILOC community with a delay ranging from a few hours to a few days, depending on the type of data. A two-way Web server-mirroring scheme was implemented between the Data Fusion Centre at SACLANTCEN and NRV *Alliance*. Measurement results were directly included on Web pages that were mirrored back to the Fusion Centre ashore, twice a day, using Inmarsat-B.

3.3 Rapid Response 98

Rapid Response 98 (**RR98**) was the third and final exercise in a series of three, this time offering coordinated environmental reconnaissance in support of exercise **Strong Resolve 98**, taking place in an Atlantic area south of the Iberian peninsula. The REA activities integrated air, sea and satellite remote sensing operations with archive data searches to acquire essential oceanographic and atmospheric data for mine warfare (MW), amphibious warfare (AW) and anti submarine warfare (ASW).

Participants to the exercise included NRV *Alliance*, HMS *Roebuck*, USNS *Pathfinder*, WFS *Planet*, SPS *Tofino* and FS *D'Entrecasteaux.*

NRV *Alliance* was tasked for oceanographic and acoustic measurements and hosted the data fusion centre for the survey. Internet technology was used for all data transmission between survey participants and to deliver processed data to the customers.

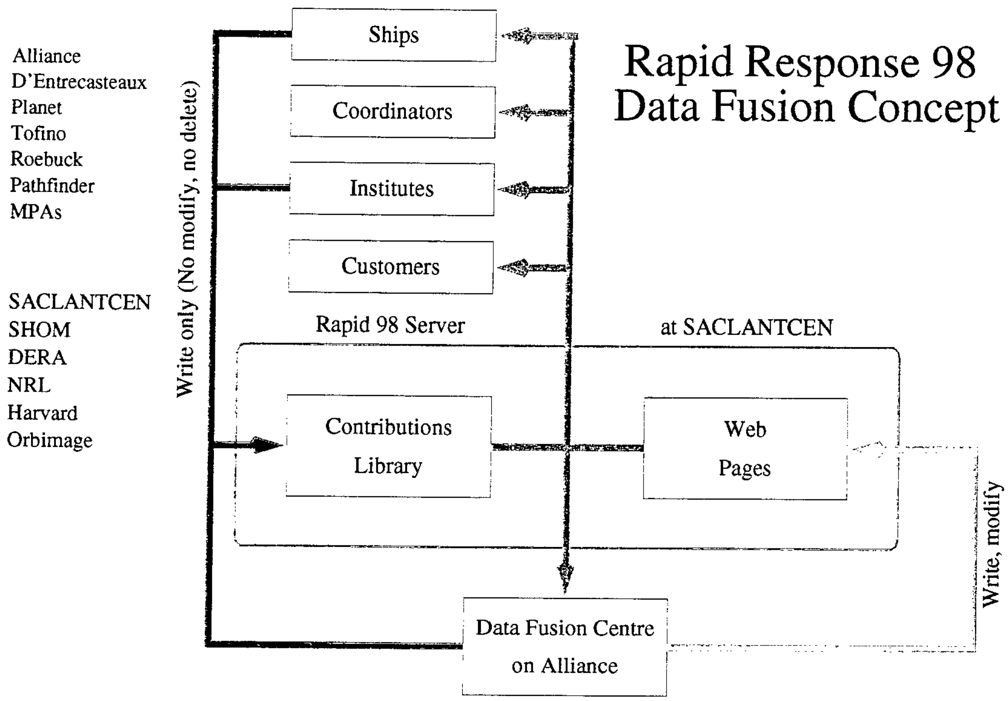

Figure 6 *Data fusion for Rapid Response 98*

The data fusion for **RR98** took place onboard NRV *Alliance*, with external access *via* a mirror Web site at SACLANTCEN.

At the end of **RR98**, while **Strong Resolve 98** was still proceeding, the data fusion operations control was switched to SACLANTCEN.

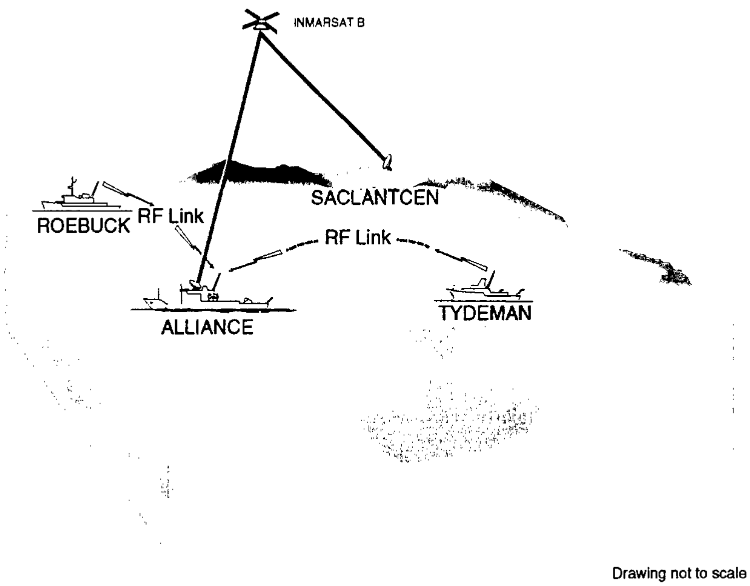

Figure 7 *Summary of Ship-Shore Network Architecture for RR97 and RR98*

4
Data conventions

A variety of data types were distributed through the **Rapid Response** home page, ranging from simple ASCII files containing XBT data to large image files containing high resolution satellite remote sensing data.

In consideration of the high volume of data that was generated by **Rapid Response** survey participants, standardization in file formats was found to be essential, to ensure the rapid fusion of data. File format standardization was not limited to naming issues, but was extended to the data set structure and to the attachment to the file of geographic/time information, in order to ease subsequent retrieval. The header files were subject to minor changes between **RR96** and **RR98**.

4.1 Data types

During a REA survey a large number of data needs to be gathered, transmitted, fused and presented to customers. The following sections, extracted from [5], provide a comprehensive listing.

4.1.1 Atmosphere

- Meteorological ship observations
- Upper air observations by weather balloons
- Drifting meteorology buoys, deployed from aircraft

4.1.2 Beach and hinterland

- Landsat satellite images
- SPOT satellite images
- Aerial photographs
- Photogrammetry
- Beach photographs
- Trafficability measures by hand-held bottom penetrometer
- Trafficability assessed by conventional methods
- Maps
- Reports
- Beach profiles

- Surf measurements
- Numerical surf predictions

4.1.3 Ocean surface

- Tidal water level
- Sea surface height from satellite altimeter
- Wave height from satellite altimeter
- Wave height and spectrum from wave rider buoys
- Ocean features by radar images from satellites
- Surface roughness and microwave emission indicating surface wind
- Radiation temperature images of the sea surface
- Ocean color
- Lagrangian current measurements by surface drifters

4.1.4 Water column

- Deep currents by drifters drogued to several hundred meters depth
- Eulerian current measurements by moored current meters
- Current profiles by acoustic current profilers (ADCP) on the ocean bottom
- Current profiles underway by ship borne ADCPs
- Temperature profiles by ship deployed expendable probes (XBT)
- Temperature profiles by air dropped probes (AXBT)
- Temperature, salinity and derived parameters by CTD probes
- High resolution parameter fields by towed CTD chains
- Water samples for laboratory analysis
- Transparency by Secchi discs
- Transparency from multi-color satellite imagery
- Chlorophyll from multi-color satellite imagery
- Shipping density (for noise assessment) by naval patrol aircraft
- Spectral ambient noise by sonobuoys
- Directional noise by towed hydrophone arrays
- Reverberation levels by towed hydrophone arrays
- Transmission loss

4.1.5 Ocean bottom

- SPOT satellite images for depth and bottom type in shallow waters
- Airborne laser system for depth in shallow waters
- Single beam echo sounding
- Multibeam area mapping
- Side scan sonar imaging
- Assessment by video cameras

- Bottom grabs
- Cores
- Mechanical bottom parameters by Expendable Bottom Penetrometers
- Seismic reflection profiles
- Sound velocity in the bottom layers
- High frequency bottom reverberation
- Inverse modeling of bottom parameters

4.2 Data archival structure

Before any data fusion can take place, raw data have to be uploaded to a data fusion server. The server can be either centralized or distributed. In case a distributed architecture is adopted, mirroring and cross-hyperlink strategies have to be implemented to ensure that all data are made available to participants and other users.

During the first two experiments, survey participants used FTP clients to upload data files into a predefined directory structure: data files were processed automatically at regular intervals and moved to the appropriate directory for presentation. In **RR98**, this procedure was totally changed, so that uploaded data files were immediately accessible through a separate *Contributions Library.*

To ease the fusion process and to build a database of geographical and temporal information used by the data search engines, supplementary information on the data files (latitude, longitude, date, time, data type, file name) had to be provided.

This information could either be written in a separate file or in first lines of the data file, provided the ASCII character coding was respected: this means that for binary files such as graphic data, the use of an external header file was mandatory.

4.3 Data presentation

At the end of the fusion process all data were made available in hypertext form, for the Web home page of the data fusion centre.

The initial presentation layout, adopted during **RR96**, was designed to comply with the structure for data presentation. Environmental information was grouped by potential customers (ASW, AW, MW). The **RR96** REA data presentation homepage is given in Annex A. This approach revealed soon its shortcomings. If a customer was trying to extract a certain type of data (e.g. a temperature profile) it was necessary to visit several branches of the data directory structure to retrieve all data of interest (e.g. XBT, AXBT, CTD).

In order to offer an efficient framework for data management, presentation and retrieval, during **RR97** and **RR98**, a different approach was followed, discriminating between storage locations and data access hierarchy.

The arrival gates for data upload were located in a contribution directory and named after the data contributor. It was the task of the Fusion Centre to create a coherent framework for data presentation, grouping data in the most appropriate fashion.

Using the technique of hyperlinks, a logical structure for data presentation has been defined, which is totally decoupled from the archival structure. Data was presented to REA customers using the following structure:

Area	*Ionian Sea, Saros Gulf, etc.* (this level omitted in **Rapid Response 98**)
Story	*atmosphere, beach, sea surface, water column, bottom*
Type	*temperature, current, noise, sediment thickness*
Status	*historical, actual measurement, analysis, prediction*
Source	*satellite, aircraft, ship, buoy, laboratory*

During **RR98** an additional hyperlink to the contribution library has been added to allow access to raw data as they arrived.

4.4 Data fusion facility

To illustrate the methodologies adopted for data fusion we will concentrate on the solution provided for **RR98**.

All incoming files were placed in a dedicated area of the data fusion server, called the *Contributions Library*. The general policy was that files in this area should remain essentially untouched, making them immediately available to interested parties. Periodically, all new files in the Contributions Library were transmitted to the data fusion centre onboard NRV *Alliance*.

The incoming files would then be validated and integrated into the Web hierarchy (*fused*), and subsequently added to the data search engines index files.

Incoming data files were scanned for errors in file name, format and content. Errors were manually corrected whenever necessary. The corrected versions were subsequently advanced to library of changes.

New Web hyperlinks were established, so that both original data files and the corrected versions were accessible from the **RR98** server's Environment pages.

The new data files and replacements for web pages containing the hyperlinks were subsequently transmitted to SACLANTCEN for inclusion on the data fusion server ashore.

4.4.1 Database maintenance

An automatic syntax analysis program was initiated periodically to scan the contributor directories, searching for newly uploaded files. The analyzer started parsing all header files: the header contents were lexically analyzed and the variable values were checked for consistency. If no discrepancies were detected, the information gathered from the header was added to the data search engine. In case an error was correctable, data or header files were copied into a *changes* directory and the corrected information added to the search engine, otherwise an error notification was sent to the data fusion manager using electronic mail.

Whenever the syntax analysis was successful, data found in the header file were converted into a common format:

- decimal representation for geographic coordinates (latitude and longitude)
- number of seconds elapsed from 1 Jan 1970 (the Unix *epoch*) for data timestamps
- pre-defined identification codes for specific data types

This information was added to a *header database*, an ASCII file delimited by conventional characters.

Programs coded using the Perl high-level programming language were later used to select data and to extract statistics on the uploaded files, eliminating the need of a specialized database engine.

We have observed that, in the course of a typical REA survey, files that need to be indexed are typically less than ten thousand. A task of this magnitude can be easily treated following our approach, without introducing any serious performance downgrade. Should the data volume increase (e.g. during the survey of an extremely wide geographic area using a large number of vessels) the need for a specialized database engine and a fully featured distributed file system will have to be considered.

At the end of the data fusion process, customers could select and retrieve data of interest by querying the data search engine, reachable through hyperlinks in the data fusion centre homepage.

The customer could choose to display the data on screen or to have it downloaded to his computer. To minimize download times, all files were offered in compressed form.

A sample data search page is given in Annex B.

4.4.2 2-way mirroring

During **RR96**, all data were transferred, processed and published on the data fusion server at SACLANTCEN.

During **RR97** and **RR98** the great majority of data fusion activities took place onboard NRV *Alliance*. External customers could access the data fusion results through a server mirror installed at SACLANTCEN.

On both servers, newly arrived data files were archived and automatically transferred to the other server as soon as possible. The mirror server took care of discriminating between files of local and remote origin, to avoid duplications and minimize the usage of the SATCOM channel.

4.5 Authentication

To prevent access from unauthorized sites and individuals, we exploited the authentication mechanisms available in the HTTP server.

A first level of authentication was offered by verification of the IP address of the calling host against a list of authorized IP addresses. A second level was given by a username-password authentication scheme. These mechanisms can be configured on a *per-user* and *per-directory* basis, allowing a great flexibility and granularity in defining which areas of the server can be accessed by whom. In addition, firewall configuration schemes and *TCP-wrappers* were used to control FTP and interactive access to the data fusion server.

A drawback of our approach towards authentication is that all customers had to communicate in advance to the data fusion managers the IP address of the computer they intended to use to access the **Rapid Response** Web site. In many cases, Internet providers do not offer a fixed IP address.

Another possible problem that we felt could arise from our approach, was unauthorized access to the Web server as a consequence of a mix of address spoofing and sniffing attacks. In fact an attacker could, at least in theory, record username and password information, while it was transmitted by a legitimate user, and *play it back*, hiding his computer behind a forged IP address.

During **RR98** we experimented with the use of Secure Socket Layer (SSL) encryption to provide a secure environment for authentication and data transmission. The SSL version used public key encryption algorithms with 40 bit keys. In order to be able to offer a fully functional setup, we had to configure a Certification Authority (CA) on the data fusion server. Customers obtained the SACLANTCEN public key from the CA and were able to access the **RR98** server by means of an encrypted session: this architecture is sufficient to avoid the *playback* attacks mentioned previously. In order to reach a higher degree of security, longer keys should however be used.

4.6 Auditing, logging and statistics

All authentication and connection information was stored in the HTTP server log files. Real time analysis of the logs enabled the detection of unauthorized connection attempts and of connection problems by legitimate customers. Subsequent analysis of the log files enabled the generation of useful statistics on server usage (per site, per time of day, per data type, per geographical location).

4.7 Data portability issues

During the final stages of **Rapid Response 96**, the interest in obtaining the data had grown so high that a number of commands requested a copy of the data fusion Web site on CD-ROM.

This turned out to be a cumbersome task, as most of the Web pages were generated dynamically "on-the-fly", and relied on the HTTP server to perform so-called Server-Side-Includes (SSI). Rather than repeating the same coding of background, logos etc. in each and every Web page, the server would perform this task. In addition to that, the pages included a mix of absolute and relative hyperlinks, that is, links referenced only by the local directory name, with no explicit reference to the server hostname.

We found that the naming conventions we had initially adopted (mixed-case long filenames) caused problems to some operating systems based on MS-DOS, such as Windows 3.1.

While this technique accelerated the Web page production phase, it turned out to be impossible to transfer the Web site as it was to a CD-ROM readable on multiple platforms. A direct copy yielded a CD-ROM of which only the top-level directory was visible, so that browsing was impossible.

To produce a CD-ROM, that is truly compatible with all the common operating systems, including the older ones (i.e. MS-DOS and MS-Windows 3.1), all file names have to follow the ISO 9660 naming convention, with 8-character file names and 3-character file suffixes.

In order to produce a usable **RR96** CD-ROM, most of the files on the server had to renamed, all links had to be modified to point to the renamed files, "dynamic" pages had to be converted to "static" and all hyperlinks had to be made relative.

For **RR97**, all data providers were required to conform to the ISO 9660 standard. Unfortunately, this requirement was largely ignored, so we were faced the task of renaming the incoming data files, to overcome the problems that emerged during **RR96**.

This activity proved to be a time consuming task: this is the main reason that brought us to devise a mixed Web structure, comprising both raw and fused data, which has been adopted during **RR98**.

5
Future methodology – REA In A Box

A major disadvantage of present REA systems is the complexity in configuring and operating both data processing and communication systems. For this reason, the **Rapid Response** operations have had to rely on experienced technical and scientific personnel with in-depth knowledge of computing and communications systems.

On the other hand, in the course of our activities, we had the possibility of testing different technologies and configuration policies. It is our opinion that the lessons learned can be transferred with profit to devise a *REA In A Box* (RIAB) system, that is, a system that can be easily deployed on site, using a variety of platforms, offering a turnkey solution to REA survey participants.

A fully functional RIAB system should incorporate the following components:

- Internet Server System (Intel-type platform running a Unix-based operating system, such as Linux or Solaris), pre-installed with appropriate software and pre-configured, with standard layout for data upload and retrieval
- Mobile high data rate SATCOM system, functional to the appropriate geographical area (this is true mostly for geosynchronous satellites; low Earth orbit (LEO) satellites should provide more flexibility)
- Access to a SATCOM ground station acting as relay to wide area networks with the appropriate classification level
- High-data-rate line-of-sight ship-to-ship communication system.

Requirements for operational REA systems should also include:

- Strong encryption and authentication to ensure data integrity and confidentiality
- Multilevel security structure
- Provision to connect to classified networks such as CRONOS and NIDTS

It is our intention to continue our activities to come to a complete definition of a RIAB prototype based on COTS technology.

6
Conclusions

The **Rapid Response** operations demonstrated how COTS Internet technologies could be successfully integrated to build *ad hoc* networks in support of REA surveys. All three operations, conducted between 1996 and 1998, relied on experienced technical and scientific personnel with an in depth knowledge of computing and communications systems. The precious experience SACLANTCEN obtained in this field can now be used to define a fully functional *REA In A Box* system, that is, a data processing and communication system that can be deployed on site with little advance notice, requiring minimal support by specialized personnel.

It is our opinion that significant improvements can be obtained in the field of automatic data fusion, provided adequate interfaces for data generation and upload are developed and distributed among REA survey participants.

The following components could also be upgraded with limited investment or with the cooperation of the appropriate authorities:

- Wide area communications infrastructure: **Rapid Response** relied on commercial infrastructure (cellular phones) that may be unavailable in case of a crisis situation. Another limitation of cellular phones is the small transmission bandwidth they offer. Access to adequate SATCOM resources will offer high-bandwidth links to ashore commands with a high degree of reliability.

- Ship-to-ship communications: impressive improvements could be obtained by employing state of the art RF network equipment, employing techniques to improve jam resistance and to lower the probability of detection. Bandwidths between 1 and 10 Mbit/s could be obtained at a range of several nautical miles.

- Encryption: the adoption of strong encryption is a fundamental requirement to transform REA into an operational tool with the adequate degree of classification.

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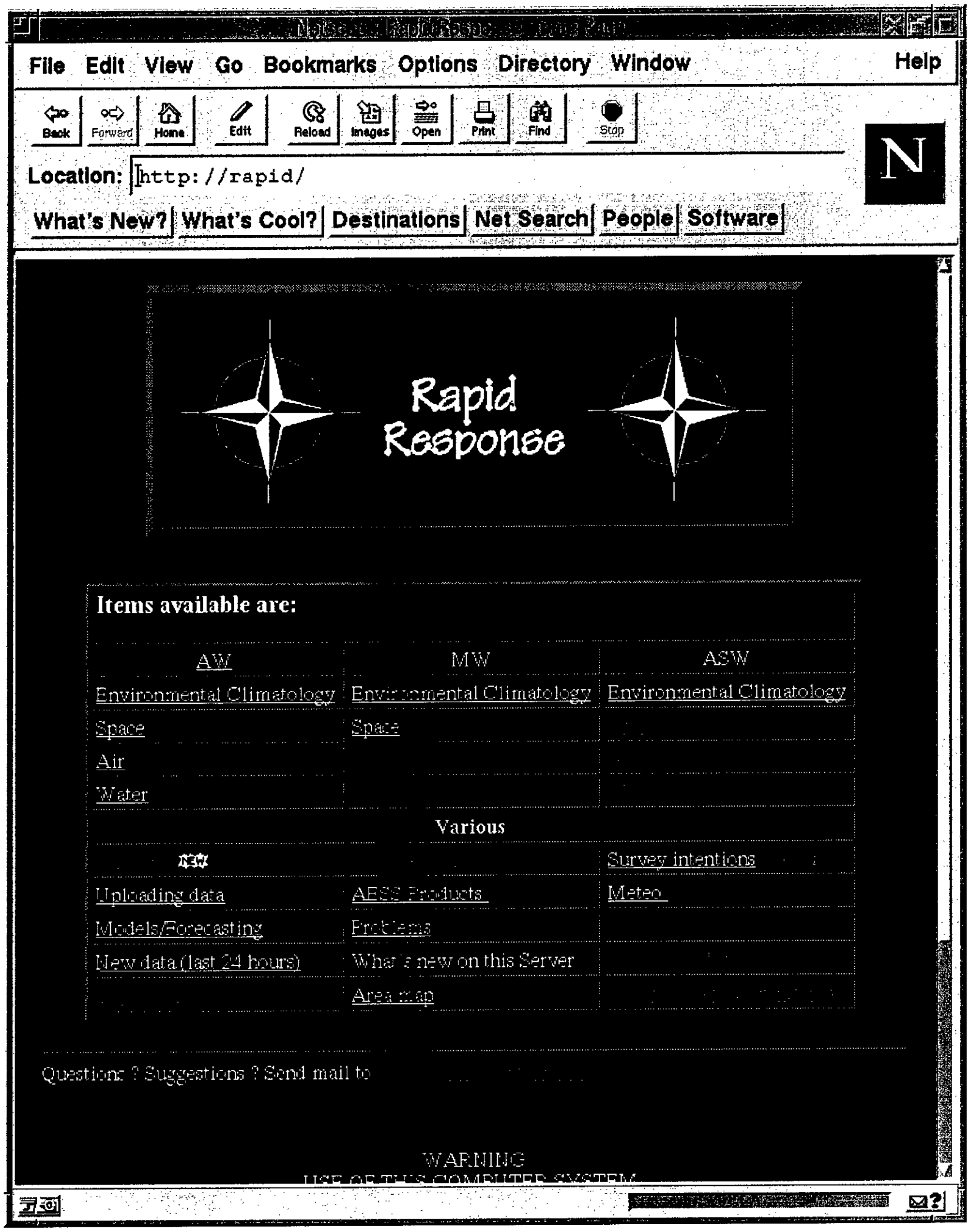
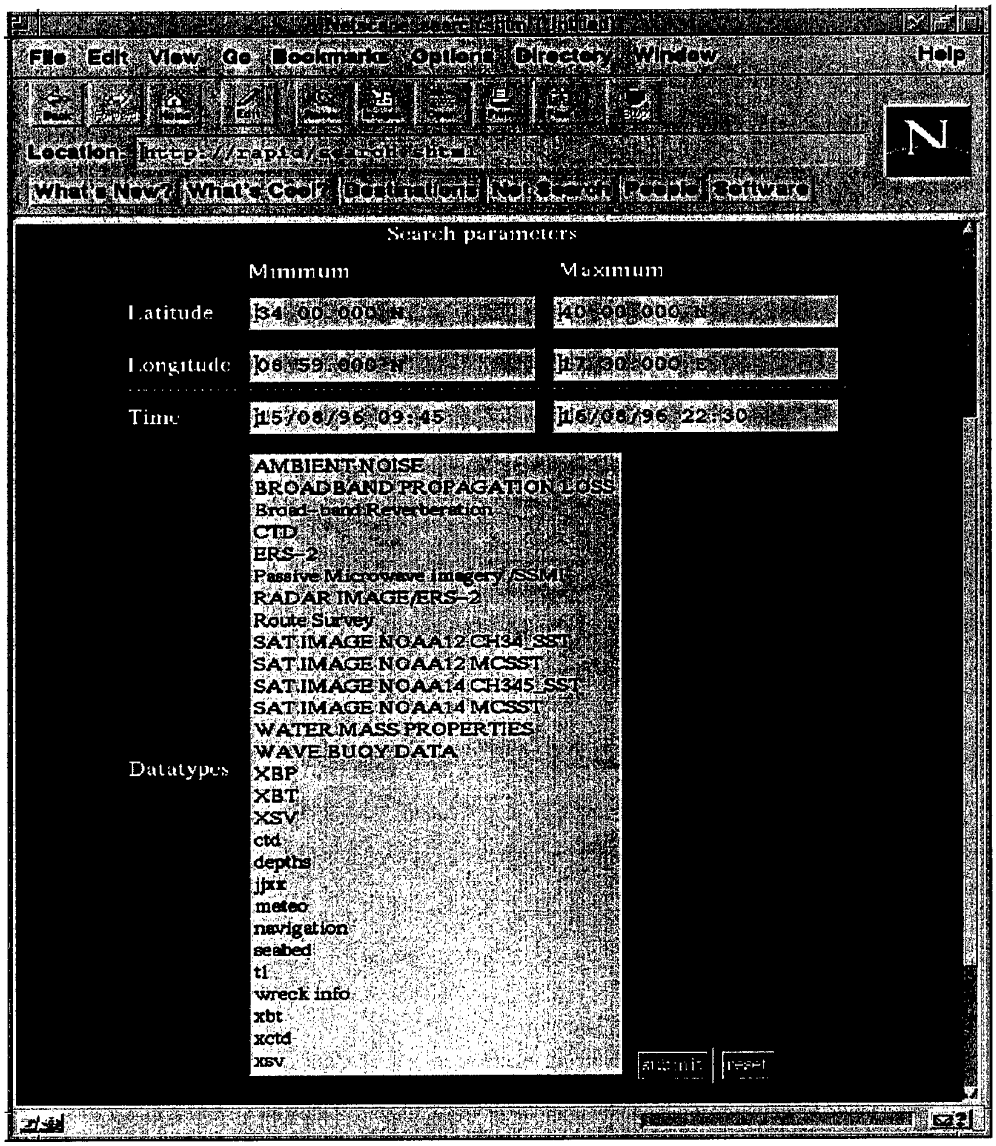
Annex A – RR96 data fusion home page



Annex B – RR97/98 data search and retrieval Web page



Annex C – Glossary

ASCII	American Standard Code for Information Interchange
ASW	Anti-submarine Warfare
AW	Amphibious Warfare
COTS	Commercial off the shelf
CTJF	Combined Joint Tactical Force
ETACS	Extended Total Access Communications System
FTP	File Transfer Protocol
GSM	Global System for Mobile communications
HTTP	Hypertext Transfer Protocol
ISDN	Integrated Services Data Network
LOS	Line of sight
MCM	Mine countermeasures
MILOC	Military Oceanography
MW	Mine Warfare
REA	Rapid Environmental Assessment
RF	Radio Frequency
RIAB	REA in a box
SATCOM	Satellite communications
TDA	Tactical Decision Aid
XBT	Expendable Bathythermograph

Document Data Sheet

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Title

Data communication and data fusion architecture for Rapid Response 96-98

Abstract

The concept of Rapid Environmental Assessment (REA) has emerged in recent years as one of the most interesting research topics in Military Oceanography (MILOC): REA in a military environment is defined as "the acquisition, compilation and release of tactically relevant environmental information in a tactically relevant time frame".

In this context, REA implies the integration of traditional methods of information gathering in MILOC with modern communications and data processing techniques, to ensure the timely delivery of environmental data to naval forces and commands in the course of a crisis situation.

A fundamental aspect of Rapid Environmental Assessment deals with the quantity and quality of data that need to be gathered, processed and delivered to the final users. This document concentrates on the technological aspects of data processing, fusion and transmission, illustrating the evolution of the techniques adopted and their innovative impact on the overall capacity of the system.

The Rapid Response series of operations demonstrated how Commercial-Off-The-shelf (COTS) Internet technologies could be successfully integrated to build *ad-hoc* networks in support of REA surveys. This paper analyzes the technologies and the methodologies that were used for the generation and the distribution of REA products. Recommendations aimed at the definition of operational systems are included.

Keywords

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