NURC - a NATO Research Centre

Taking the Future to Sea

50th Anniversary
1959-2009

Foreword

This year we celebrate the 50th anniversary of the NATO Research Centre in La Spezia, Liguria (Italy). I congratulate the NURC staff and alumni on fifty magnificent years, and my hope for them is fifty more years of success that will help uphold NATO as the kind of institution that the Trans-Atlantic Alliance and the world need and deserve.

The motto of this celebration is "taking the future to sea", a nice, punchy statement, as it puts together the notions of action and subsequent prospects of success while referring to a sea-environment that we all, sailors and those in related professions, cherish. There is unfortunately no mention of "technology", yet the word has self-referred roots –"τέχνη" (craft) and "λογία" (saying): it is commonplace to state that usage and knowledge of tools and crafts is at the core of development of the human species, and the human ability to adapt to and to change its natural and social environment.

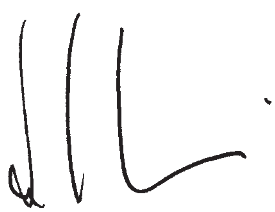
From its birth on, the Centre has been at the cutting edge of the Atlantic Alliance's innovation strategy. Technical and operational innovation is the core of the NURC identity. The Centre's function is still "about taking inventions, assessing their value and promoting their transformation into equipment, systems and capabilities by NATO Commands and by the NATO members states' armed forces". While we are no longer a single military thrust area research lab, i.e. anti-submarine warfare, innovation remains our only engine. As a reminder, SACLANTCEN as NURC was formerly known, made a more formal commitment to NATO naval/maritime research and technology (R&T) after the fall of the Berlin Wall, by expanding its programme of work to all undersea warfare technologies and by preparing itself for the next security crisis such as the Gulf Wars. This has led to successes in the new world of unmanned systems, robotics, artificial intelligence and automatic decision making, as well as synthetic aperture sensors. The beginning of this century saw the Centre venture into new fields of maritime security & safety such as anti-terrorism, anti-piracy, maritime situational awareness or protection of the natural environment, activities which became major foci for growth after the huge slumps of the 90's and the first five years of the next century that left the Centre under critical mass. The losers and winners have not emerged as yet, but these challenges teased out a new life for the Centre based upon its traditional culture of science, invention and technology for the navies and, more broadly, the maritime community.

I am grateful to the former managers of NURC who have accomplished what executives at other research labs have not been able to do as successfully, to transform an institution that could have been a lagging legacy of the Cold War into one of the bright stars of the digital age.

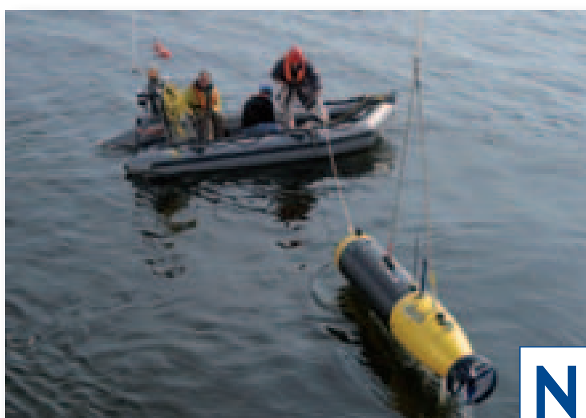
To close this introductory remark, I would like to stress that it is a privilege for me to be the Director of this Centre at the time of its 50th anniversary, sharing the experience with people who have committed their life to the "service" of the Atlantic Alliance. I am proud to be part of this great adventure that brought together the best technical skills and the best scientific talents of the NATO member states, and built an exceptional organisation.

Let's remember the forefathers of NURC, those great men who believed that the NATO Research Centre in La Spezia was the kind of talented organisation that needed to exist to foster multinational cooperation, to grow and develop bright naval/maritime researchers as the most difficult team leading task is multicultural integration.

Let's honour the crews of the Centre and all the people outside who have initiated, steered and supported NURC in the last 50 years.



François-Régis MARTIN-LAUZER, PhD, RADM (FRA Eng. Corps, res.)
Director
La Spezia, April 2009



Despite the evolution in technology, the uniqueness of the Centre remains in its ability to test concepts and technologies at sea.

Establishment of the Centre

In the mid 1950s, a series of events challenged the balance of power between the United States and the Soviet Union. In 1955 the Soviet Union, for the first time, launched a ballistic missile from a submarine. Two years later, on 4 October 1957, the world's first artificial satellite, Sputnik I, was launched into orbit by the USSR. Those two achievements were more than enough to worry the U.S. The U.S. started its own Submarine Launched Ballistic Missile (SLBM) programme under then Chief of Naval Operations, Admiral Arleigh Burke, with the mission to launch a 1,500-nautical-mile Polaris missile from a submarine. The initial goal was to have this operational by 1965, but Soviet activities resulted in an accelerated schedule to deliver the first submarine by December 1959 and the second vessel by March 1960.

In order to restrict movement to the USSR submarine fleet, and to guarantee safe movement to their own, the United States and NATO understood the need for better scientific knowledge of the undersea environment. Many nations had active research laboratories in this field, but there was a feeling that something had to be done to improve the synergies among the nations, in order to ensure the ability of NATO to counter any Warsaw Pact move in the underwater domain. Members of the U.S. Naval Research Advisory Committee paid a visit to numerous nations – Canada, Denmark, France, Germany, Italy, the Netherlands, Norway and the United Kingdom – and reached an agreement to work together by pooling scientific information and expertise in anti-submarine warfare (ASW) research.

Inauguration ceremony of the SACLANT ASW Research Centre by SACLANT Admiral Jerauld Wright USN, 2 May 1959

Location of the Centre in La Spezia, 1960s photo

A suitable location and funding had to be found. The first problem was quickly solved, as Italy offered to provide a facility within its naval base in La Spezia. Climatic considerations, which allowed experiments to be carried out for most of the year, and the location, which provided easy access both to deep and shallow waters, led to the acceptance of this solution. The Supreme Allied Commander Atlantic was the NATO commander responsible for ASW and it was the

The Maria Paolina G.

The S.S. Aragonese was the first ship chartered by the Centre, replaced by the Maria Paolina G. in 1964

Norfolk-based command which in June 1958 endorsed the creation of a NATO international scientific organisation devoted to undersea research. Pending final approval of financial support from NATO members, the U.S. Secretary of Defence agreed to provide the necessary funding to allow for the immediate establishment of this organisation. Although multinational, the new organisation thus started with U.S. funds and on 2 May 1959 the "SACLANT ASW Research Centre" or SACLANTCEN was officially commissioned. The flags of the nine NATO nations that provided personnel to the Centre were raised for the first time with that of the Atlantic Alliance in the Italian naval compound east of La Spezia which still hosts the Centre today. The Centre was managed by an Italian non-profit company, Società Internazionale Ricerche Marine or SIRIMAR, initially a subsidiary of Raytheon, but later owned and managed by Pennsylvania State University. This interim period lasted about four years with the SIRIMAR contract set to expire on 30 June 1963.

The SACLANTCEN Scientific Advisory Committee at a meeting during the early years

In mid 1962 discussions in Paris resulted in a charter that was officially adopted by the North Atlantic Council on 20 October. This charter recognised the Centre as a NATO organisation under the direction of the Supreme Allied Commander Atlantic (SACLANT). The Scientific Advisory Council which provided advice to SACLANT in the early years, evolved into the Scientific Committee of National Representatives (SCNR) which to this day provides advice related to the Centre's Program Of Work (POW).

The early years

SACLANTCEN's mission was to conduct research and provide scientific and technical advice in the field of anti-submarine warfare to SACLANT. It could also be called upon to assist NATO nations in this domain. In order to carry out its mission, the Centre chartered an old freighter, the Aragonese, which was quickly transformed into a research vessel, giving the organisation a sea-going capability. In 1964 the 2,800t Maria Paolina G. was chartered, replacing the ageing Aragonese.

> **SACLANTCEN's mission was to conduct research and provide scientific and technical advice in the field of anti-submarine warfare**

In the early years the scientific programme was mostly centred on underwater acoustics, oceanography, systems concepts evaluation and antisubmarine warfare. The understanding of the complexity of sound propagation under water was the basis for detecting and classifying submarines. Research groups were organised according to the areas of study. The Underwater Acoustics Research group carried out theoretical analysis, computer modelling and experiments at sea to better correlate sound reflection and scattering with temperature, salinity and depth. The Oceanographic Research group built on this work, studying the behaviour of the sea as well

Much of the instrumentation in the early days had to be designed, built and tested by the Centre's engineers

as the interaction between the air and the sea. The evaluation of future ASW systems was a major component of the SACLANTCEN research programme. The ASW Studies group assessed the feasibility of future ASW systems and verified if further research was needed, working in coordination with other branches of the Centre. Another group, the System Concepts Evaluation group, was responsible for the experimental evaluation of concepts, carrying out tests at sea as well as follow-up analyses. Each group had its own staff to provide digital computing and engineering support. Later on, the support elements were consolidated and centralised to form the Technical Support Department. Digital computing, electronic and acoustic engineering, ocean engineering, scientific and technical information, and ship operations remained the key elements supporting the Centre's activities.

Until the mid '70s, the Centre's research focus was mainly on blue waters, where Soviet nuclear submarines prowled for possible attacks on the continental U.S. or to disrupt lines of communications between North America and Europe, where reinforcements and supplies would have travelled in case of an increase in tension between NATO and the Warsaw Pact. In particular the Mediterranean and the Strait of Gibraltar which connected the two main operational areas, were of major interest. Studies in these two areas, carried out in the mid '60s, resulted in significant developments in oceanographic buoy technology. In particular, the Strait of Gibraltar is a body of water with high currents and internal waves, challenging oceanographers to develop instruments that can withstand the harsh conditions and produce valid data. SACLANTCEN engineers had to design and build the robust instruments needed to measure CTD (conductivity, temperature, depths) since they were available on the market at that time. During this period, the Centre also built a laboratory to test and measure instruments being built, marking the start of calibration activities that are still being conducted today. The Gibraltar sea cruises produced a number of innovations in ocean engineering, many of which are still in use today, and the studies published were widely referenced by other researchers.

A typical mission at mid-range distance could bring the Maria Paolina G. and the scientists in the southern Mediterranean or in the Black Sea, often shadowed by Soviet "fishing boats"

A number of programmes in the research and classification of underwater targets were established at SACLANTCEN from the beginning. A few programmes were non-acoustic, such as extremely low frequencies electromagnetic and surface effects, but most were sonar-related. Space-

frequency interference patterns of continuous waves, frequency modulation (FM) sonar techniques and reliable acoustic paths were some of the fields investigated in the early years. The most successful was FM sonar, and the digital FM technique is still part of current active sonar. While space-frequency classification was mostly effective at close ranges, it did not suit the operational requirements at the time. The Reliable Acoustic Path project which exploited deep sound propagation paths, resulted in the construction of the "Deep Panoramic Sonar" based on a multiple array system known as MEDUSA (Mediterranean Experimental Deep Underwater Sonar Apparatus). This was the first active sonar developed at SACLANTCEN and was used in experiments until 1973.

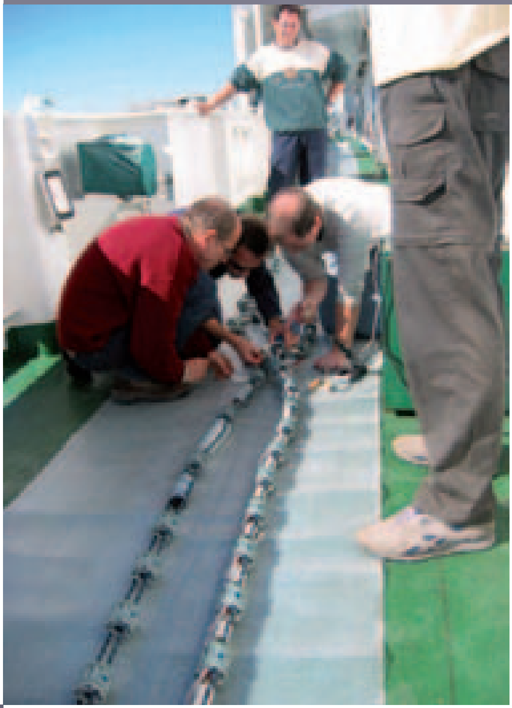
Experiments at sea, for example in the Strait of Gibraltar and the Greenland-Iceland-U.K. Gap, posed many technical challenges due to the difficult oceanographic conditions

In the very early years of the Centre a geophysical campaign was carried out in the Red Sea, with 90 percent of the missions related to acoustics. A typical mission could bring the Maria Paolina G. and the scientists in the southern Mediterranean or in the Black Sea together, often shadowed by Soviet "fishing boats". In the mid-60s two longer cruises were carried out in the Greenland-Iceland-U.K. Gap, normally known as the GIUK Gap, the only available outlet into the ocean for Soviet submarines operating from the Northern Fleet bases on the Kola Peninsula. These Military Oceanographic (MILOC) campaigns were executed in cooperation with the U.S. and Canada. These cruises frequently lasted for months, obliging the Centre to carefully plan these missions as the Maria Paolina G. had a three-week endurance at sea.

In the late '60s, the need to increase the efficiency of buoy operations at sea resulted in a new activity, scientific diving. Training some scientists to operate underwater solved the problem of frequently retrieving deployed buoys in order to extract data, not an easy feat in choppy waters. A number of scientists became certified divers, making it possible for them to work in the calmer underwater environment. The adoption of mateable connectors for underwater work also made it easier for scientists to connect and disconnect various modules to the instruments. All of these resulted in more effective operations, enabling scientists to verify in real-time how a prototype is functioning. Scientific diving as a professional activity, first practised by SACLANTCEN scientists in 1969, became recognised by NATO in 1974.

Scientific diving which started in late 60's has resulted in more efficient underwater research at SACLANTCEN

In the late '70s, towed arrays made their presence at SACLANTCEN. The Centre started testing the first experimental hydrophone linear array built by Hughes Aircraft Corporation, and went on to design and test others including towed arrays



The T-Boat Manning joined SACLANTCEN's research fleet in 1974

The Centre in the 70's

SACLANTCEN was a pioneer in the of use underwater buoy connectors which led to a significant increase in the efficiency of data recording operations. At the same time, progress in electronics and the close links to the U.S. resulted in the updating of digital computing equipment. A new facility was built to host the centralised computer centre, enhancing the support provided by the Computer Department. Activity at sea remained quite intensive, and in 1974 the Manning, a T-Boat built for the U.S. Army and previously used by Columbia University for oceanographic work, joined the SACLANTCEN fleet on loan from the U.S. Government.

After more than a decade mostly dedicated to deep waters, shallow waters became a new priority as submarine activity in those areas was increasing

Half-way through the Centre existence during the Cold War period, in 1975, the scientific side of SACLANTCEN was reorganised into two main divisions, the Environmental and Systems Research Division, and the Operational and Analytical Research Division. The former was made of four working groups, deep water research, shallow water research, applied oceanography and signal processing, while the latter was subdivided into three groups, force effectiveness studies, tactical studies and theoretical studies. After more than a decade mostly dedicated to deep waters, shallow waters became a new priority as submarine activity in those areas was increasing and submarines were becoming quieter and available to more nations. To address shallow water problems, new factors had to be taken into consideration such as the type of ocean floor, sound reflection, reverberation and clutter.

This led to further research on oceanography and acoustics with experiments carried out mostly along the Ligurian coasts, while in the meantime new instruments were studied and developed for collecting data relevant to the new scenario, although the improvement of data collection in deep waters continued. The Hi-Re-TOS (High Resolution Towed Oscillating System), a fine-scale oceanographic device developed by SACLANTCEN's engineering staff resulted in acoustic coverage of large areas with high resolution. The highly successful design of this unique mechanically oscillating system was used in multiple scientific missions.

In the late '70s, towed arrays made their presence in La Spezia. The Centre started testing the first experimental hydrophone linear array built by Hughes Aircraft Corporation, on loan from the U.S. Office of Naval Research. Noise generated by the towing vessel proved to be the ultimate limiting factor. However the directionality (due to its length) and the possibility of positioning it at the


NRV Alliance, under construction at Fincantieri shipyard in La Spezia, and at sea after 1988

optimal depth, as well as its passive and active capabilities, were the main advantages highlighted by tests. Based on studies carried out in 1976, the Bistatic Active Towed Array (BITOW) sonar programme was launched two years later . This system used a second vessel as auxiliary receiver, leading to a considerable increase of the detection range. The omnidirectional hydrophones used resulted in an inability to determine whether signals were coming from the right or left. SACLANTCEN resolved this problem by designing cardioid hydrophones which provided the left-right discrimination.

For towed arrays to be effective, the noise problem of the towing vessel needed to be solved. In 1984 the keel of a new research vessel specially designed for SACLANTCEN was laid at the Muggiano Fincantieri shipyard, a few hundred meters away from the Centre. The design priority for this 3,180 t ship was the reduction of ship radiated noise, obtained with a double hull and a specially designed propulsion system. The NRV Alliance was launched in 1986, and commissioned in 1988 replacing the Maria Paolina G. Since then it has retained its reputation as one of the quietest ships afloat, spending an average of 170 days a year at sea supporting the Centre's experiments.

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Staffing and facilities

The number of scientists at the Centre was authorised at a maximum of 50, hired mostly on limited-term contracts. This rotation of personnel enabled a regular inflow of new ideas, and over time, resulted in the establishment of a network of close contacts between SACLANTCEN and the national research centres as well as many universities and private companies, to which the scientists returned after their stint at the Centre. The scientific outputs from the Centre were especially valuable to the smaller nations, whose research capacities were behind those of the larger nations, thus helping to reduce the gap between their institutions and those in the U.S. and U.K., for example. Scientists were supported by administrative and technical teams, in particular, a top-notch engineering department which provided the means to carry out the experimental work needed to develop or verify scientific theories.

Research teams at the Centre were (and still are) supported by skilled engineering, administrative and technical staff

SACLANTCEN also features a unique facility in Europe: the Oceanography Calibrating Laboratory, created in the early '80s, which provides instrument calibration according to the World Ocean Circulation Experiment (WOCE) standard, supporting the Centre's activity as well as most NATO navies and research laboratories.

Beginning of the transformation period

In 1986 a five-year survey of the Greenland, Iceland and Norwegian Seas (GIN Sea) was started. New technologies were adopted in order to be able to collect data over long periods of time in a harsh environment, with problems ranging from thermal shock on sensors to difficulties in lowering the buoys into the water. A total of 31 buoys with 118 sensors were positioned which could record data over a period of one year, with a loss of buoys below 5 percent, a notable achievement in oceanographic research. During this experiment was underway, on 9 November 1989 the Berlin Wall came down, marking the end of the Cold War period. Suddenly NATO did not have a distinct enemy.

The Transformation Era

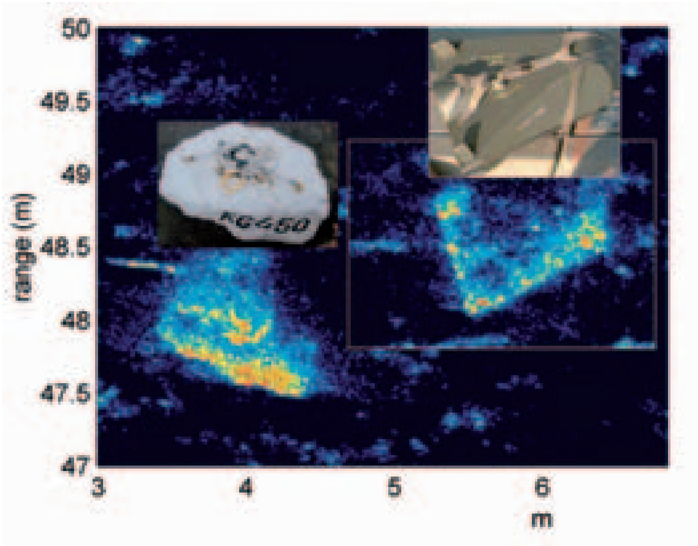
End of the cold war, end of mission?

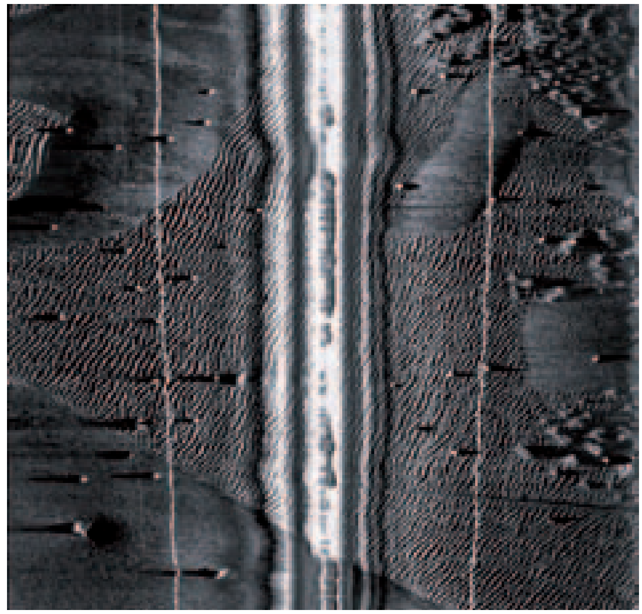
The Centre's name change in 1987 to the SACLANT Undersea Research Centre clearly indicated the shift in focus from "Anti-Submarine Warfare" to "Underwater" research. The Iran-Iraq war was a major event during that period; it led to the so-called "Tanker War", where oil tankers moving through the Persian Gulf were threatened not only by Iranian air and small boat attacks, but also by some 150 sea mines of various types, mostly vintage, laid by Iran. How much this had an influence in the change of the Centre's name, which underlined a widening of the Centre's research interests and competencies, is uncertain, but it certainly anticipated what was going to happen two years later, with the end of the Cold War and soon after that of the Warsaw Pact.

Both NATO and SACLANT were suddenly without a specific mission. The Centre's programme of work, mostly based on proposals from NATO nations, was no longer focused on an enemy who had disappeared and was becoming disjointed and fragmented. In the meantime funding had decreased considerably after reaching a peak in the early '80s. To cope with the cut in funding, there was a move to cut programmes and staffing. Questions were raised about the need for an organisation such as SACLANTCEN.

What was the Centre about? In previous years it was engaged in developing technologies to counter the submarine-launched ballistic missile threat. This was done in a multi-disciplinary approach, conducting theoretical and experimental research accompanied by the development of instruments and prototypes, thanks to its engineering capabilities, a collection of skills that made the Centre quite unique. SACLANTCEN had other advantages: it was able to work with military organisations and to request use of assets from partnering nations; it was not a national subject and therefore was considered an honest broker; it gathered together the best scientists, providing those from smaller nations the experience of working in a challenging environment; and it maintained a widening network of contacts throughout the scientific community. Although the enemy was gone and the military core of the Atlantic Alliance was fading little by little, its political importance as a link between the two sides of the Atlantic Ocean meant that it was still vital that both the military and the scientists continued to work together. The Centre had to survive, however it needed to adapt to the new scenarios and requirements.

NATO's call for the development of an expeditionary capability, including one in the maritime environment, was the impetus for a change in the Centre's research focus





One of the challenges in mine hunting is the ability to differentiate a rock from a mine-like object (left) and to identify mines in cluttered environment or challenging seabed (right)

New challenges, new directions: Mine countermeasures

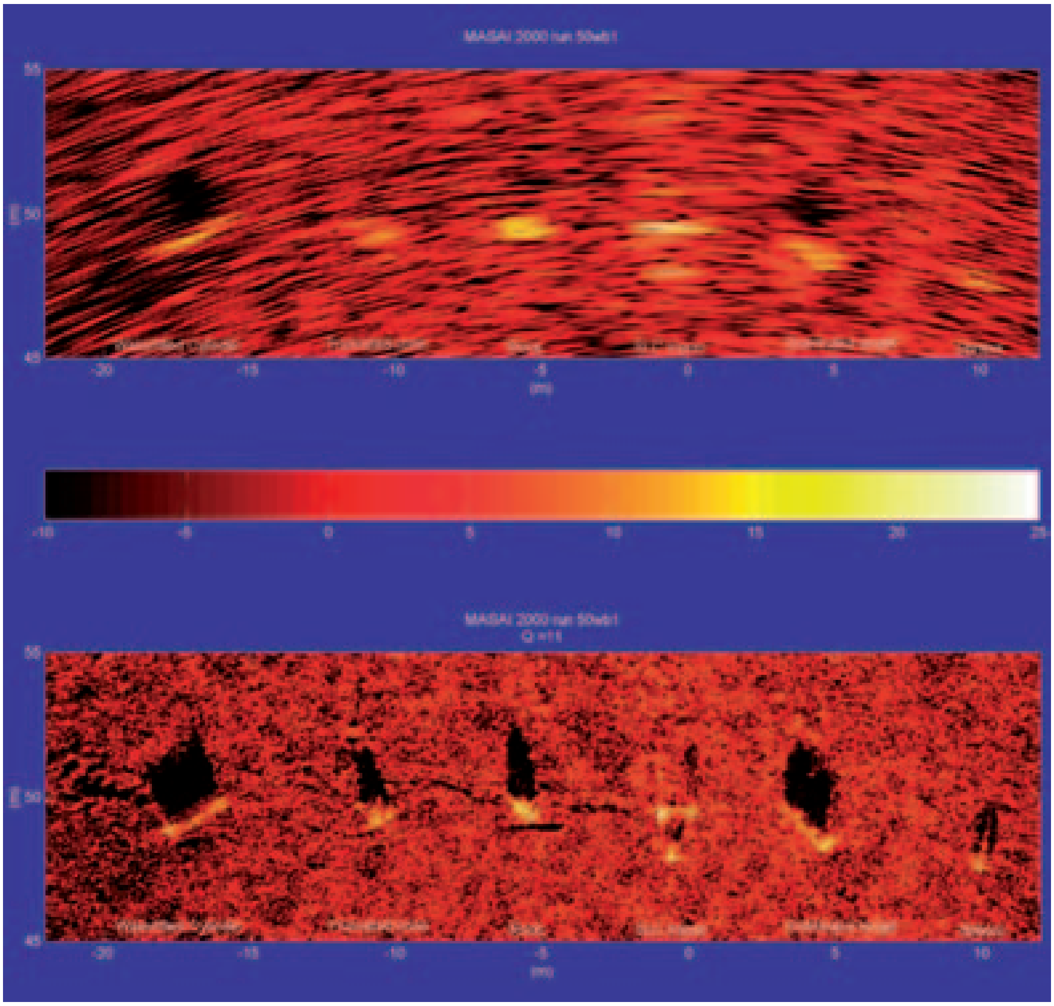
In the early '90s, NATO found itself in a position to confront new challenges and expanded its role beyond the limits of Article 5 which stated: "The Parties agree that an armed attack against one or more of them in Europe or North America shall be considered an attack against them all." Such a statement was to become soon part of history and this called for its navies to develop an expeditionary capability which the Centre had to take into account.

The Centre's research activity was concentrated mainly on minehunting techniques, i.e. finding mines on the sea floor, which might be partly buried, discriminating mines from other harmless objects

At the same time, the diminishing of NATO's strategic interest in anti-submarine warfare (ASW) was matched by a corresponding increase in the significance of mine countermeasures (MCM), especially in the context of expeditionary operations. This was highlighted by operations in the Northern Persian Gulf in 1990-91 when the projection of coalition power ashore was constrained by its maritime forces' ability to reduce, at an adequate rate, the risk posed by Iraqi mines. Although the new focus required higher sonar frequencies, the ability to identify mines masked by the environment, and an increase in the tempo of MCM operations, SACLANTCEN was able to draw on years of experience in ASW research and, very soon one third of the programmes carried out at La Spezia were related to MCM.

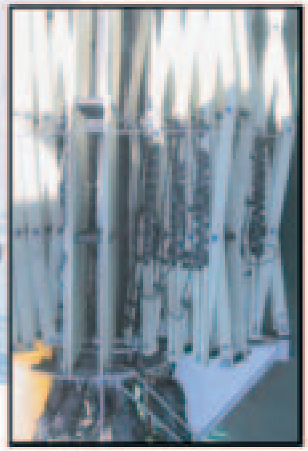
The Centre's research activity concentrated mainly on minehunting techniques, i.e. finding mines on the sea floor, which might be partly buried, discriminating mines from other harmless objects (called clutter), and classifying them in order to take appropriate actions. High quality images were needed, which required a high frequency, high resolution sonar imagery techniques.

Physical (above) and SAS (Synthetic Aperture Sonar, below) images of a dummy mine field showed significant improvement in image quality after applying the DPCA (Displaced Phase Centre Antenna) data-driven technique, which resulted from research started in 1998

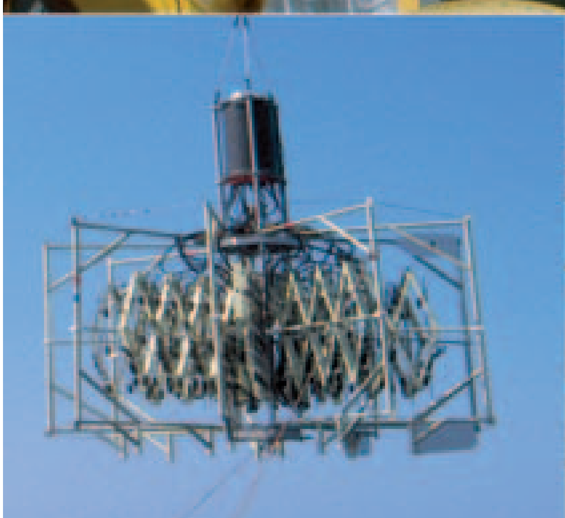


This in turn led to the development of automatic sonar interpretation systems which reduced the amount of time needed to train personnel for minehunting operations. The research focus shifted from manned minehunting to remote minehunting, with the ultimate objective of replacing a surface ship with a complement of over 30 people with robotic systems. The purpose of this was for risk-reduction reasons as well as for financial reasons, a minehunter being a more expensive ship in a Navy in terms of cost per weight. Gulf operations also showed that manned minehunters were slow to deploy in an operation taking place far away from their base, while much smaller robotic systems could be transported by strategic airlift. This led the Centre to revive some studies on Synthetic Aperture Sonar (SAS) which had been shelved in the early '70s, as technologies were not yet mature at that time. Those research programmes were initiated with the aim of following the path of Synthetic Aperture Radars (SAR), although the application of those principles in the water proved to be much more difficult. A demonstrator was built and then tested in various experiments and SACLANTCEN was at the forefront in this field, getting to the feasibility demonstration stage in early 2000.

Synthetic Aperture Sonar (SAS) research studies were initiated with the aim of following the path of Synthetic Aperture Radar (SAR) for object detection



The DUSS concept (left) improved over the years into the DEMUS (Deployable Experimental Multistatic Underwater Surveillance) system, used for submarine detection. Below, clockwise: the current DEMUS system includes the surface buoy, a transmitter, and receiver



Anti-submarine warfare research continues

Submarine detection and classification remained on the research agenda, although the focus shifted gradually toward shallow waters. Low Frequency Activated Sonar (LFAS) research started in the early '80s with the so-called Active Adjunct Project, using a passive towed sonar array and a high power, low to mid-frequency emitter, also towed. The project aim was to verify the feasibility of such a system, analysing typical performance-linked parameters such as propagation loss, signal coherence, noise, reverberation and target strength. SACLANTCEN links to military organisations were vital in obtaining support from the navies in terms of submarine services, and numerous experiments were carried out in the Mediterranean in both deep and shallow waters. Data and information exchanges with numerous nations took place with mutual benefit, while unexpected reverberation interferences in certain areas highlighted the need for a close mapping of some areas of interest for NATO. The Centre certainly had a vital role in closing the gap between paperwork and prototype developments in this field, reducing risks for those nations that developed their own systems. The NRV Alliance was the first unit with an LFAS to take part in a NATO exercise with highly successful results.

The Centre certainly had a vital role in closing the gap between paperwork and prototype developments in this ASW using LFAS

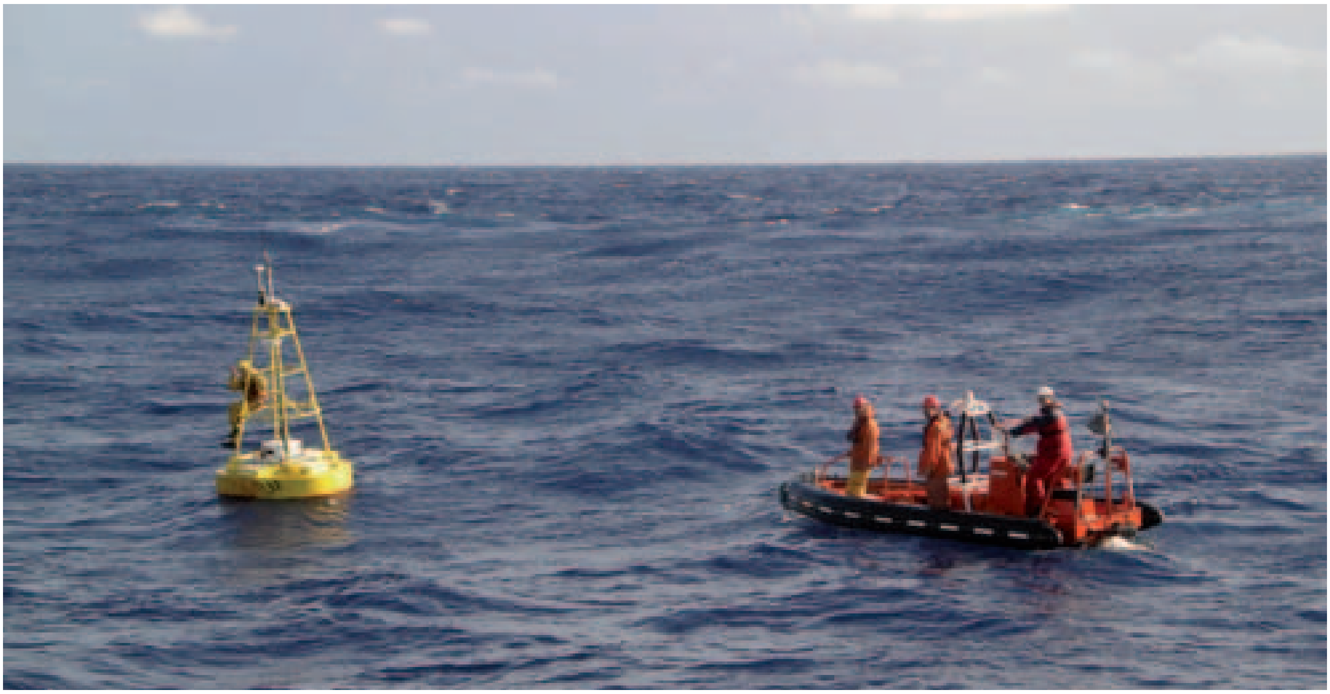
Although shallow waters were not the top priority in the '80s, testing continued into the early '90s with a constant upgrading of the system. The shift in focus from deep to shallow waters came with the advent of small diesel-electric submarines that can operate close to home base. Detection in shallow waters is difficult due mainly to signal interferences from reverberation and clutter. New programmes at the Centre investigated how to reduce the number of false alarms due to reverberation, directional interference and target-like clutter when LFAS was used closer to the coasts. Fixed feature removal methods were investigated, while studies on detection optimisation and information extraction were also carried out in order to automate and improve LFAS performances in shallow waters. The Alliance took part not only in experiments but also in several NATO exercises. Testing was not limited to LFAS in the monostatic configuration, that is with the active source located on the same platform as the receiver, but also in bi-static and multistatic forms, where the source and receiver(s) are on separate platforms. A new sound source, delivered in 2000, and upgraded towed arrays, allowed SACLANTCEN to study advanced systems concepts for signal data processing and information extraction, for instance, to overcome the inability of those systems to discriminate between echoes from port and starboard. This work was instrumental in the upgrade of national programmes related to active towed array sonar. The Centre also worked on large bandwidths sonar and on frequency optimisation in shallow waters.

While LFAS research was aimed towards providing nations with the necessary knowledge to design and improve their active sonar systems onboard ships, the Deployable Undersea Surveillance Systems (DUSS) programme aimed at developing a static deployable system for use in shallow waters. The DUSS concept was based on a network of small autonomous sources and receivers. Choke points of strategic importance and entry lanes into major ports, characterised by heavy maritime traffic, are prime examples where such a system would be used. SACLANTCEN intended to investigate and assess the performance potential of such systems, especially against silent, diesel-electric submarines and mining operations. The first phase of the DUSS project started in the early '90s with concept studies, followed by the development of a preliminary real time sonar system and the first testing at sea. Analysis of the results obtained led to the

NRV Alliance with the HS Triton (Hellenic Navy) in BASE '02

Highlighting the ability of the Centre to test concepts at sea, the ASW sea trials BASE'02 and BASE'04 were carried out in collaboration with navies from NATO nations who brought their submarines to the trials

NRV Alliance with ITS Leonardo da Vinci (Italian Navy) in BASE '04



Deployment of surface buoy in waters around the Malta Plateau, Italy during the DEMUS '04 sea trial

development of a technical demonstrator and to the establishment of specifications for the first prototype receiver to be used during scientific experimental campaigns at sea. The receiver was developed by SACLANTCEN engineers, and a series of four receivers and one DUSS emitter were built in 1994. DUSS feasibility was demonstrated in a set of sea trials conducted near Elba Island. Improvements to the prototype resulted in the DEMUS (Deployable Experimental Multistatic Undersea System) which was delivered in January 2003. During sea trials carried out in the shallow waters of the Malta plateau in 2004, DEMUS demonstrated that it could precisely track the route of an Italian submarine involved in the experiment. The system is still in use today at the Centre.

Marine mammal programme begins

The first aim of the SOLMAR programme was to monitor and acquire information on marine mammals living in Ligurian waters

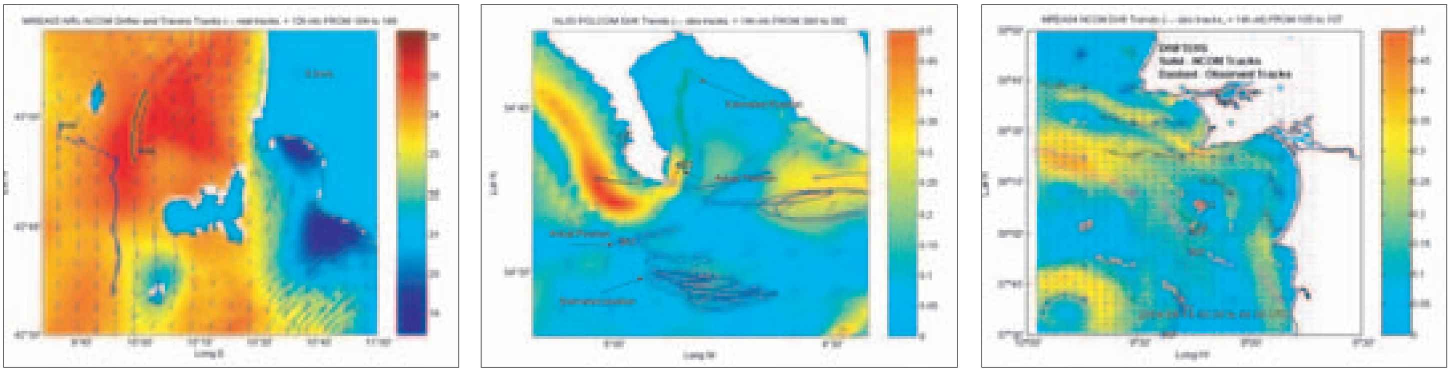
In May 1996 SACLANTCEN carried out a shallow water acoustic classification experiment in Greece, in the Gulf of Kyparissiakos, with the sound source towed by the NRV Alliance. During that time about 14 Cuvier's beaked whales stranded along the coast. As a result of the incident, SACLANTCEN hosted a bioacoustics panel with independent scientists to investigate the cause of the stranding. No clear-cut conclusions were made, as it was impossible to establish or to exclude a direct link between the experiment and the stranding. A recommendation was issued for environmental assessment procedures to be implemented, and this led in 1999 to the Sound Ocean Living Marine Resources (SOLMAR) programme at the Centre. Since SACLANTCEN's location, La Spezia, is close to the Ligurian Sea International Marine Sanctuary with the coasts of Italy and France as its northern boundaries and its southern limit of Corsica, the first aim of the SOLMAR programme was to monitor and acquire information on marine mammals living in that area. This was carried out both visually and acoustically during a series of annual sea trials known as SIRENA. During the 1999 experiment 869 individual animals were observed during 146 sighting events. Sonobuoys as well as towed arrays were initially used to locate the mammals underwater, with visual observation being carried out on the surface. Some whales were tagged with recording devices, and a whale finding sonar was also used.

From left: deployment of the EARS (Acoustic Recording System) buoys, marine mammals sighted, sighting team member at work during the SIRENA sea trials

One of the values of the project was that an increasing number of independent scientific and environmental organisations began to cooperate with the Centre in this research area

Controlled exposed experiments were undertaken to verify any possible relationship between noise and marine mammal behaviour. Oceanographic measurements were also carried out in order to better understand the environment where the marine mammals live. Following other strandings in 2000 and 2002 in areas where NATO exercises were conducted, high priority was assigned to mitigate risks to marine mammals during NATO naval exercises. In 2002 the SOLMAR programme became the Marine Mammal Risk Mitigation (MMRM) project. Activities continued focusing on the optimisation of the risk mitigation package designed by SACLANTCEN, which includes passive acoustic monitors, a predictive habitat model, a sound propagation model, a website with planning and training aids, and a guiding policy for the use of active sonar in experiments. The package was updated following the results obtained from each cruise, contributing to increased knowledge of marine mammal behaviour. A Human Diver and Marine Mammal Incident Action Team manned by personnel from the Centre was established and stood ready to deploy in case of stranding or diving incidents, although no strandings have been linked to SACLANTCEN operations since the SOLMAR/MMRM programme was established. One of the values of the project was that an increasing number of independent scientific and environmental organisations began to cooperate with the Centre in this research area.

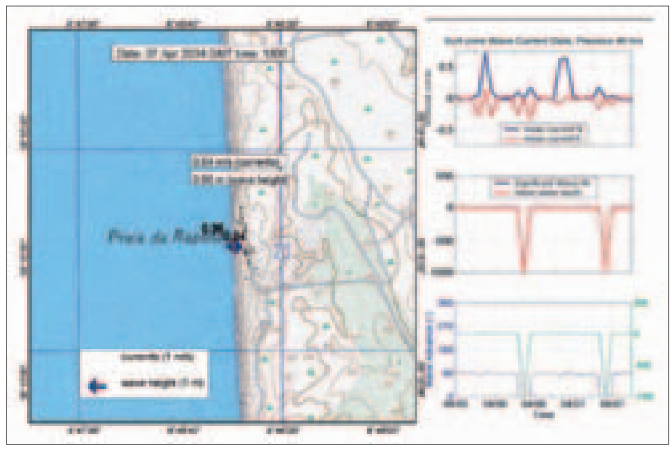
Researcher listening for acoustic signatures of marine mammals on the NRV AlIliance during the SIRENA 2002 sea trial



Operational models (integrating ocean, meteorological and wave forecasts) estimating surface drift can be highly uncertain, as seen here where real/observed tracks differ in varying degrees from estimated tracks during sea trials (from left) MREA'03, NL'03 and MREA'04

Military oceanography (MILOC) comes into focus

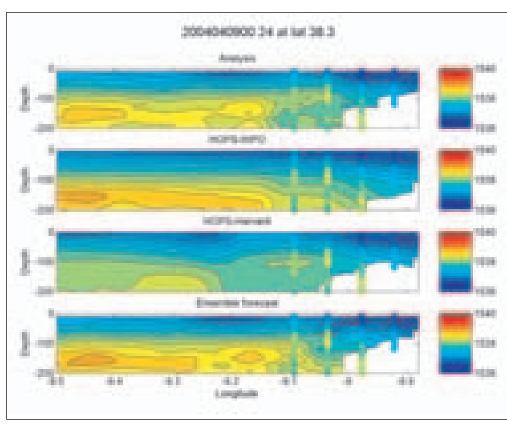
Oceanographic research did not stop with the shift towards shallow waters. Although both theoretical studies and MILOC operations partly covered shallow waters, such as the Shallow Meadow campaign in the Baltic in 1983-87, most of the activities during that period were dedicated to blue waters, oriented towards deep water antisubmarine warfare and the protection of sea lines of communication. The output of those activities were new concepts for the improvement of sonar or the development of underwater detection systems. MILOC activities also resulted in oceanographic and acoustic databases that supported modelling, resulting in improved exploitation of operational sensors. However time lag, from the data collection stage to the completion of the data analysis to obtain new exploitable data, could be measured in months if not years.



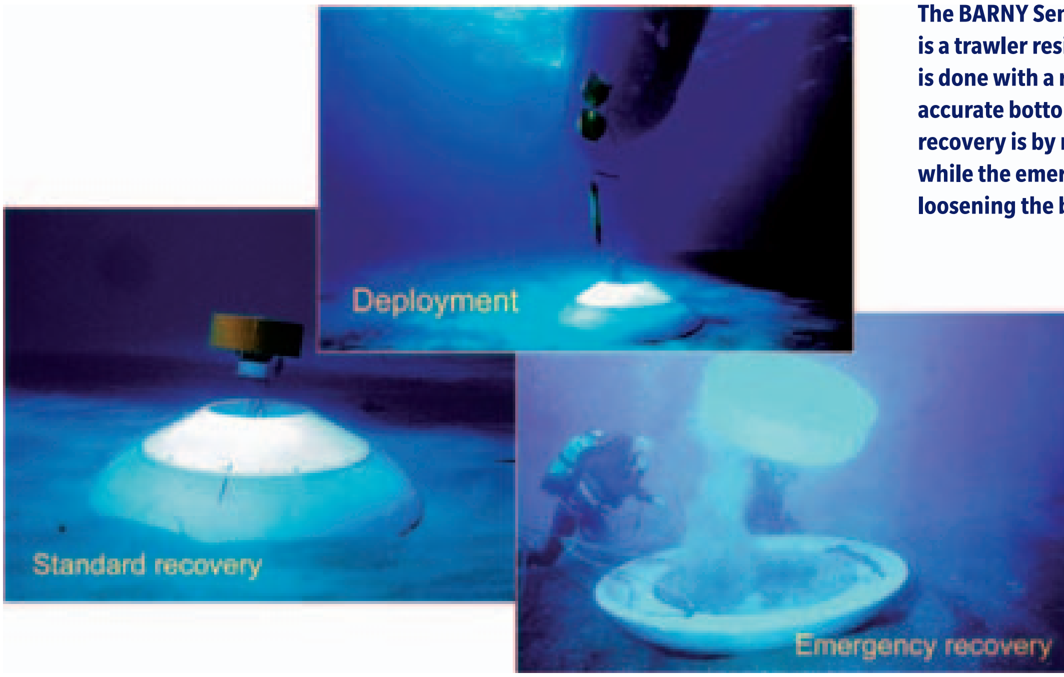
Monitoring of the beach environment can be used to support NATO amphibious operations

The post-1989 environment was totally different and required therefore a new approach. Crises tended to be regional, taking place in unknown coastal waters, with operations involving joint and combined forces. MCM and ASW activities related to those operations required different knowledge of the related environment, silent diesel-electric submarines and mines becoming the dominant threat. Higher resolution models were needed as well as Geographical Information Systems (GIS) containing all possible information related to the area. The GIS programme started at the Centre in 1993, based on previous data which had been transformed into digital format and updated constantly with new digital data. However what changed the most was the timeframe for producing the usable data, which was reduced by one if not two orders of magnitude, from years to months or more likely weeks – the actual goal was to produce a data base in six weeks. The new name of this task became Rapid Environmental Assessment, or REA, which was identified by SACLANT as a new underwater operational requirement in 1995.

Ensemble forecasts, combining the advantages multiple models, have proven to provide more accurate prediction



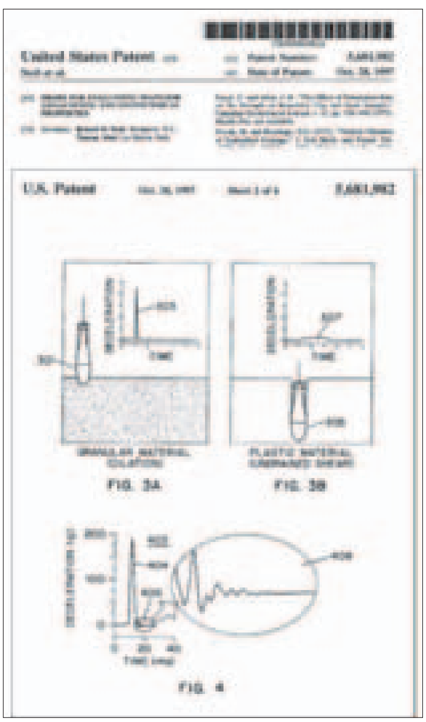
The Adriatic Sea became the focus of attention in 1992 when NATO took part in a monitoring operation to verify sanctions imposed to Serbia and Montenegro by the United Nations. It was the start of the Balkan



The BARNY Sentinel, developed in 1996, is a trawler resistant ADCP. Deployment is done with a releaser and a tilt unit for accurate bottom positioning. Standard recovery is by means of a popup top, while the emergency recovery involves loosening the ballast ring

crisis which would see NATO naval forces involved in that area for several years. A shallow water environment with intense trawler fishing activities, such as the Adriatic, required robust new instrumentation for oceanographic surveys conducted to support naval operations. SACLANTCEN designed an Acoustic Doppler Current Profiler (ADCP) with a low profile that is resistant to fishing trawlers. Named Barny, the ADCP sensors were at 0.5 m from the bottom providing optimal boundary layer coverage. Following tests of the prototype built at SACLANTCEN it was mass produced by a commercial company under the Centre supervision. The original model was equipped with a self-recoding device and had to be picked up for data retrieval after six months. An enhanced version better suited for small boat operations was developed together with the U.S. Naval Research Laboratory in 1996.

In the early '90s the MILOC department in conjunction with the Engineering Technology Department (ETD) developed a number of instruments to carry out REA surveys effectively. The Expendable Bottom Penetrometer (XBP), developed in collaboration with Columbia University in the United States, could be launched from a ship, an aircraft or a submarine. The XBP is used to assess seafloor geotechnical properties and to classify its parameters in relation to mine burial. The first REA MILOC survey was carried out in 1996 in support of a naval exercise, Rapid Response 1996, involving naval and air assets provided by many NATO countries. The XBP and a backscattering technique were used to identify non-uniformity of the seafloor, providing a quick estimate of its acoustic properties, while satellite sensors were used for a rapid monitoring of surface parameters, such as wave height. Data were also used to develop and validate simulation models mostly based on propagation, ambient noise and reverberation, in order to allow military forces to predict the conditions and optimise the use of their sensors even when, in operational conditions, specialised assets would not



The XBP (Expendable Bottom Penetrometer) is the only Centre invention to earn a US patent, filed by research partner, the University of Columbia, under a formal agreement with SACLANTCEN

The NURC SEPTR prototype (left) was developed in 1999, combining the best features of the BARNY and the SWEEP. Technical improvements for a new prototype (right) were developed under a cooperative agreement with the US Naval Research Laboratory (NRL), with 4 new units delivered to NRL in 2005

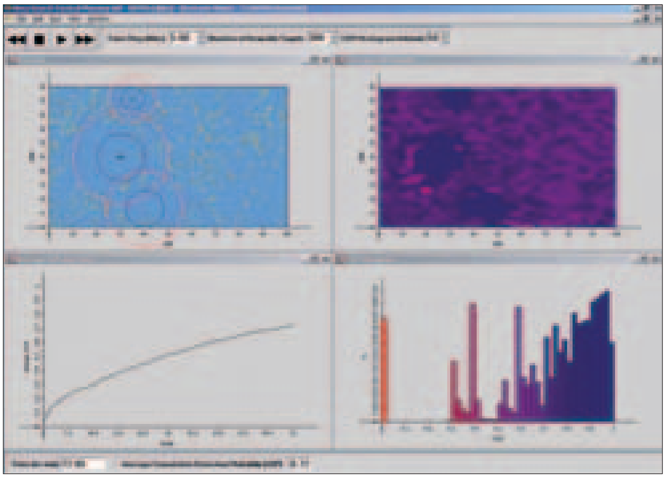
be available. Data fusion, geographic information systems and distribution methodologies were also developed for REA trials and exercises and used in various sea trials, including one in 2001 off the west coast of the United States, ASCOT01.

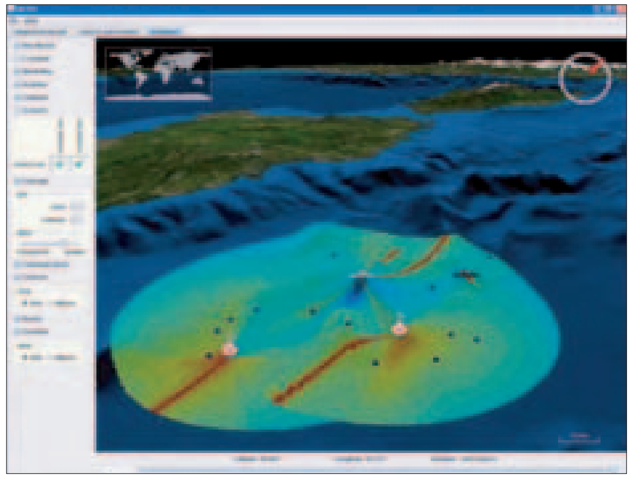
The need to measure ocean properties, in the shortest possible time with expendable equipment, led to the development of the Shallow-Water Expendable Environmental Profiler (SWEEP). It could operate in waters up to 100 m deep, which was moored to the bottom and at pre-programmed intervals would surface to transmit physical data collected both on the bottom, during the travel up and down the surface, and when surfacing. However, SWEEP was not usable in areas with trawling fishing activities. SACLANTCEN merged the features of the Barny and the SWEEP, developing the Shallow water Environmental Profiler Trawl-safe Real-time (SEPTR), a buoy with a profile similar to the Barny, but with a profiler which would surface at fixed intervals as the SWEEP. Tested in the year 2000, the SEPTR was available for use in the ASCOT01 sea trial.

Operations research and analysis matures

Operational research has been a key activity at SACLANTCEN since its creation. Mostly dedicated towards operational analysis and operational support, numerous software aids developed in the '90s were provided to NATO nations through the Centre's Scientific Committee of National Representatives (SCNR). Leveraging on the knowledge acquired from different areas of activities, and showing how a multidisciplinary approach can produce useful tools for warfighters, SACLANTCEN was asked by several naval commands to provide them with antisubmarine warfare planning tools. The Centre was also involved in studies related to changes in naval forces after the end of the Cold War, as well as in exercise evaluation. In 1993 the Commander Allied Naval Forces Southern Europe requested support for planning ASW operations in the Mediterranean, in order to optimise the protection of shipping in the Mediterranean. Two years later SACLANTCEN delivered a prototype software, known as WESTMED, which was then extended to the whole Mediterranean and in 1999 was released as MEDOPS. Based on sensor performance data acquired over years, it enabled commanders to assess ASW mission effectiveness, providing guidance to generate safe convoy routes or search planning. MEDOPS was

MEDOPS and PLANET, two software products from the Operations Research group





Screen shot on an early version of the tactical planning aid, ASTPA, used for ASW

identified by the Atlantic Alliance as the reference planning software to be extended to all the areas of interest within the NATO Maritime Command and Control Information System (C2I).

Since the early 2000's SACLANTCEN has been involved in the development of the Planning Expert Tool (PLANET), a tool used to provide NATO and national HQs with a support system for planning underwater warfare operations for crisis operations, where neither the timing nor the area can be predicted in advance. Incremental versions of the PLANET have been released since 2002.

In the same timeframe other tools were provided to ASW operational forces. Among those is the Area Search Tactical Planning Aid (ASTPA), which helps the commander define the best deployment of the available assets taking into consideration the area of search, the environment and the target type. ASTPA not only considers traditional search patterns, but based on modelling, also proposes the best search tactics for reducing uncertainty in the target location. The Multistatic Sonar Tactical Planning Aid (MSTPA) was another Centre product for the ASW community which enables the optimisation of sonar source/receiver deployment on different platforms.

With the increase in mine-related activities, SACLANTCEN also took part in the development of MCM Exclusive Planning and Evaluation Tool (EXPERT), led by NATO Consultation, Command and Control Agency (NC3A). MCM EXPERT helps commanders optimise mine search operations. Similarly, the Electronic Minefield referee (EMIR) tool, developed by the operational analysis group, was widely used in NATO and national exercises. Experts from the Centre often deployed onboard MCM vessels during such exercises in order to compare predicted performances with actual minehunting results. They also provided advice on and pointed out where a better use of the knowledge on environmental conditions would have resulted in higher clearage percentage.

The Centre developed a methodology to quantify shortfalls and cost benefits of new ASW systems

Since 1994 SACLANTCEN was deeply involved in the MO2015 study which looked at identifying shortfalls in the antisubmarine and mine warfare fields. Among other activities, the Centre developed a methodology to quantify shortfalls and cost benefits of new ASW systems, and produced studies on the detection of buried mines and mine-ship interaction. That same year a three-phase study on the operational use of LFAS was sponsored by SACLANT in order to optimise the use of such an asset especially in shallow water operations.

CRV Leonardo, commissioning ceremony in 2002 (left) and at sea (right)

CRV Leonardo joins the fleet

Most of the activities required the support of the ship assets managed by the SACLANTCEN Ship Management Office. At the turn of the century the T-Boat Manning totalled over 45 years of activity. The advantage of operations carried out with a silent ship were highlighted by the activity of NRV Alliance, which had a record of about 170 days per year at sea, mostly dedicated to the Centre's activities but partly also chartered to other organisations. In the late '90s, the Ship Management Office developed the mission profile and requirements for a new ship with a size comparable to that of the Manning, but with characteristics close to those of the Alliance in terms of silent movement and scientific support capabilities. Once funds were obtained from NATO, a contract with McTay Marine Ltd. was signed in the year 2000 and the Coastal Research Vessel Leonardo was delivered to NATO in the UK on 31 July 2002, a few months after the lease of the Manning had expired. CRV Leonardo was commissioned in La Spezia on the following 6 September as the first Italian public vessel. The new ship is 27.5 m long, with a 260 ton displacement, and can sail between 0 and 5 knots in silent mode, while remaining on station thanks to a dynamic positioning system. With a berthing space for up to 10 people, she can host up to 15 persons for a day cruise, and has been designed to integrate a 20 feet laboratory container which augments the 35m2 on-board laboratory. As the use of unmanned or remotely operated vehicles was becoming more and more frequent, the CRV Leonardo turned out to be a perfect support ship for those systems.

Coming into the new millennium

During the 2002 Prague Summit, NATO's military command structure was reorganized with a focus to become leaner and more efficient. Supreme Headquarters Allied Power Europe was to become the single strategic command focused on NATO field operations under the name Allied Command Operations (ACO), while Supreme Allied Commander Atlantic would be focused on transforming NATO operations, changing its name to Allied Command Transformation (ACT). ACT was formally established on June 19, 2003, and the same day SACLANTCEN changed its name to the NATO Undersea Research Centre, NURC in short. The further evolution in the global situation would not be limited to a change in the Centre's name, but would considerably extend its field of activities.

Indian Ocean, 3 November 2008 - The Italian Destroyer ITS Durand de la Penne escorting the merchant vessel As Salaam, chartered by the World Food programme to deliver humanitariuan assistance to Somalia. The destroyer is the flagship of the NATO Task Group which conducted NATO's Operation Allied Provider, providing safe passage of ships against attacks from pirates.

(NATO photo by PO Luigi Cotrufo, ITA Navy) -- from the Allied Maritime Component Command Naples website, http://www.afsouth.nato.int

Today and the Future

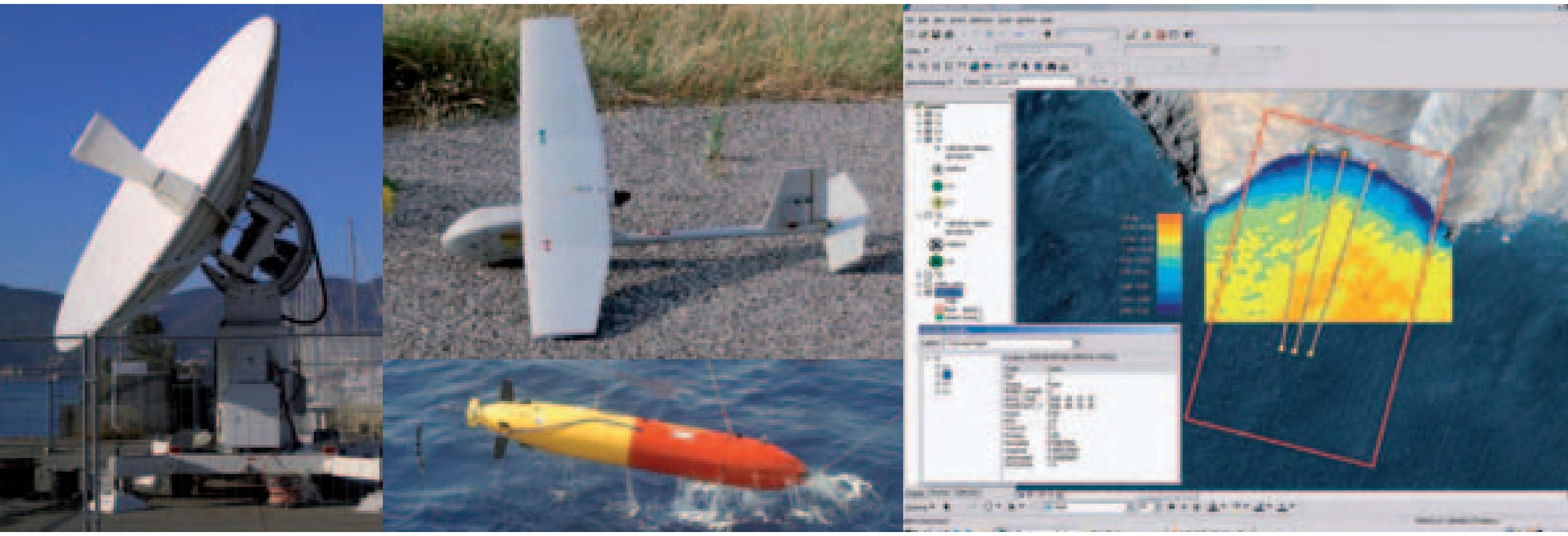
Transformation of NATO

The 2002 NATO Summit in Prague set the pace for the transformation of the Atlantic Alliance. The final declaration stated that NATO transformation and adaptation should not be perceived as a threat by any country or organisation, "but rather as a demonstration of NATO's determination to protect its populations, territory and forces from any armed attack, including terrorist attack, directed from abroad." The Prague meeting was marked by the invitation to seven new countries to join the Alliance. Among the major decisions taken by the Heads of State and Government of the member countries were the creation of a NATO Response Force (NRF) and the streamlining of NATO's military command organisation. Both had an impact upon SACLANTCEN.

SACLANT, the Supreme Allied Command Atlantic, was involved in operational requirements, and was responsible for an annual document known as Underwater Warfare Statement on Operational Requirements. With the change of SACLANT into ACT, Allied Command Transformation, these operational requirements turned into a Statement on Operations and Transformation Research Requirements, which was linked to Long Term Capability Requirements. However the new command's focus is on joint operations, and the underwater component is mostly subsumed under new priorities. In order to better understand the current naval and undersea requirements of NATO members, the Centre, now renamed NURC, began to establish closer contacts with the naval elements within NATO, in particular under the Conference of National Armaments Directors (CNAD). The entity closest to NURC's research interest is the NATO Naval Armaments Group (NNAG) which comprises nine Maritime Capability Groups (MCG). Before the command structure transformation, MCGs had been kept updated on the Centre's activities, but now they are actively solicited to provide input into the Centre's programme of work (POW). MCG/2 on Under Sea Engagement and MCG/3 on Mines, Mine Countermeasures and Harbour Protection have direct links to NURC's work, although other groups such as MCG/4 on Maritime Air Delivered Superiority also started to collaborate with the Centre.

The Centre's new name and logo reflected in its flag, flanked by the flags of ACT, NATO and host country, Italy

The creation of the NRF shifted the focus from regional crises to expeditionary and asymmetric warfare, with operations on sea, air and land, and an increasing attention to undesired collateral damages. Due to typically short reaction times, the timescale for providing exploitable data to NRF units was further compressed, shifting from months-weeks to days-hours. To conduct research that will support NATO forces facing new maritime threats, the Centre started to move into areas that are not limited to the undersea world, covering maritime, coastal and surface problems, for example, to support amphibious landings. Realising that the name "NATO Undersea Research Centre" may be a misnomer, the Centre is now mostly known by its acronym, NURC.



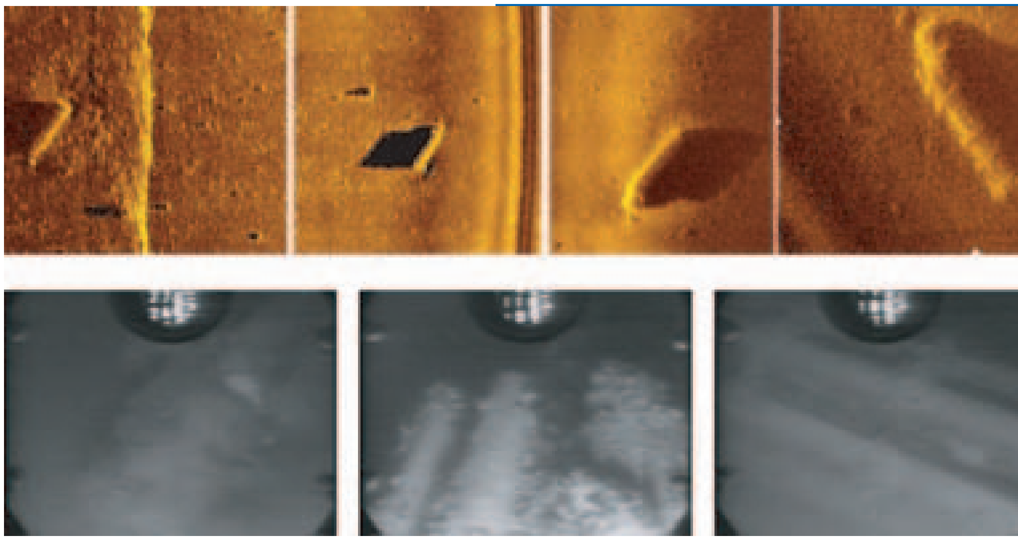
Satellite data from NURC's ground station (left) fused with data from an SUAV (centre top) and an AUV (centre bottom) can provide a more accurate recognized environmental picture, to be used in a tactical decision aid for amphibious landings (right)

From MILOC to REP-COP

New NATO missions required a more comprehensive view of the environment, and a shift was made from MILOC to METOC, Meteorology and Oceanography, as the interaction between the ocean and the atmosphere becomes more significant closer to the coast, and weather forecasting becomes more uncertain. The need to provide the commander with integrated data from oceanography, geography and meteorology, to support effective decision-making, generated a second shift, from REA to REP, i.e. Recognised Environmental Picture, often also referred to as REP-COP (REP-Common Operational Picture) or HMetoc for Hydrographic METOC.

In 2004 these activities became part of the Expeditionary Operations Support (EOS) research area. Research in this area included investigations to improve ocean modelling, to better understand phenomena that could influence operations both with real time data collection and numerical simulation, while new observation techniques were also tested such as satellite remote sensing and other systems which allowed very quick data gathering. Some of these had already been tested for REA purposes but had to be refined in order to deal with the reduced response time for application on new platforms, such as UUVs. In the 90's the Centre acquired a modified Ocean Explorer, a modular UUV equipped with a side scan sonar, that was initially used for evaluating its usefulness in REA operations. New equipment was acquired, and battlespace preparation with autonomous underwater vehicles (AUVs) became a core research project starting in 2002-03, in collaboration with Woods Hole Oceanographic Institution (WHOI) and the Groupe d'Etudes Sous-Marines de l'Atlantique (GESMA). For the first time, the Centre was engaged in experimentation with small unmanned aerial vehicles (SUAVs), used to provide airborne surf zones imagery of better quality than that captured by land based camera systems. Air-sea interaction effects on expeditionary warfare, surf modelling, the development of the NATO Tactical Ocean Modelling System, acoustic monitoring and prediction capability deployment, fusion and exploitation of geospatial information and imagery became the focus activities, with the purpose of providing covert data collection and battlespace characterisation. AUVs and remote sensing, aimed at an integrated Meteorological and Oceanographic (iMETOC) support concept, found a place in NURC's POW.

For the first time, the Centre was engaged in experimentation with small unmanned aerial vehicles (SUAVs)



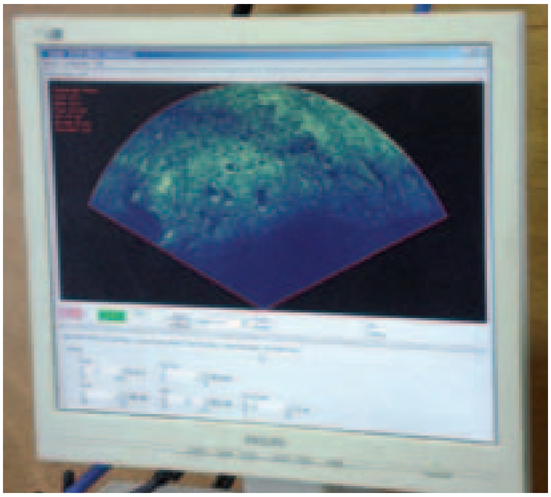
Unmanned mine-hunting involves the use of AUVs such as the Centre's MUSCLE AUV, and accurate automatic target recognition (ATR) processing and algorithms

MCM goes unmanned

Unmanned vehicles and the use of high resolution remote sensing were also relevant to another NURC research area, MCM (mine countermeasures), which remains a high-priority topic. Mine-hunting sonar performance models, advanced mine-hunting concepts for UUVs, mostly related to the detection and classification of buried mines, the improvement of synthetic array sonar with increased detection range and maximum platform speed, were some of the programmes developed at NURC in mid 2000's. In 2005 a new version of DARE (Decision Aid for Risk Evaluation), a software tool used to assess risk to transiting vessels after MCM operations, was delivered to the nations. NURC also developed ESPRESSO (Extensible Performance and Evaluation Suite for Sonar), the mine-hunting sonar performance prediction tool that interfaces directly with the NATO MCM EXPERT planning and evaluation tactical decision aid. The use of UUVs equipped with sidescan sonar was investigated in a joint research project with industrial and academic partners, with the goal of providing NATO with a planning and evaluation tool for an unmanned MCM system. Studies on navigation systems for UUVs and the application of artificial intelligence on such systems dedicated to MCM operations were also carried out. To verify the results of UUV operations in the MCM field, NURC scientists took part in several exercises carried out at NATO and national levels. These activities marked the beginning stage towards the development of systems based on several networked MCM-UUVs, possibly equipped with sonar and non-acoustic sensors and a data fusion capability, in order to improve the deployability, speed and accuracy of MCM operations, especially in littoral regions.

Mine-hunting sonar performance models, advanced mine-hunting concepts for UUVs... the improvement of synthetic array sonar... were some of the programmes developed at NURC in mid 2000s

At NATO's Harbour Protection Trials 2006, NURC researchers participated in the evaluation of new technologies
Left, scientist explained the use of an unmanned surface vehicle for port protection

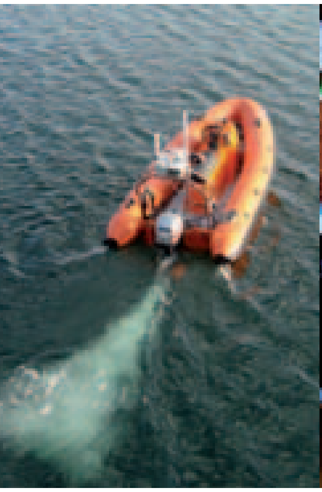


Harbour protection: under and over water

Simulation of diver intrusion (left) was captured on sonar (centre), and an unmanned surface vehicle was sent to investigate, in two separate sea trials for harbour protection

With NATO's attention drawn toward Defense Against Terrorism (DAT), counter-terrorism MCM operations in ports and harbours became a new research focus in 2004. The terrorist threat against ports and harbours was not only related to mines—its reach went beyond military boundaries, for example, force protection during expeditionary operations. DAT includes protection against underwater intruders, damage to critical infrastructure and touches civilian and legal aspects. Current convention states that harbour protection activities are all those which take place within one mile of a port or harbour. The initial involvement of NURC started in 2004, when the Centre took part in military experimentation in the harbours of Varna and Burgas, Bulgaria. Funded by ACT, the experiment demonstrated and assessed the effectiveness of commercial-off-the-shelf (COTS) AUVs, combined with computer-aided detection to counter terrorist placement of underwater improvised explosive devices (UWIED) in ports and harbours. In 2005 a harbour protection exercise was conducted in La Spezia using COTS technologies. At the same time, a test was conducted with the Royal Netherlands Navy on a method for measuring the target strength of divers, aimed at reducing false alarm rates when detecting underwater intruders. ACT sponsored a high performance AUV (HPAUV) experimentation project to assess the military value of available AUVs for DAT and MCM applications. The MX3 sea trial saw the use of six different types of AUVs operating in four different target areas, demonstrating the maturity of the various systems. This led to NATO's Harbour Protection Trials (HPT06), hosted by NURC at La Spezia in April 2006. The trials demonstrated systems for hull search, underwater pier inspection, mine and IED detection, and harbour surveillance. Active sonar, passive sonar, and passive magnetic "trip-wire" systems were installed and tested while divers staged simulated intrusions toward each system.

Harbour protection research also focused on multiple sensors and a multi-layered architecture in order to establish synergies among the various sensors. Physical barriers and acoustic networks can be used as a first layer, and in 2007 NURC demonstrated the use of an algorithm allowing simultaneous detection and localization of multiple submerged targets crossing an acoustic tripwire, based on forward scattering. In that same year the Italian MINEX 2007 exercise provided an opportunity to use

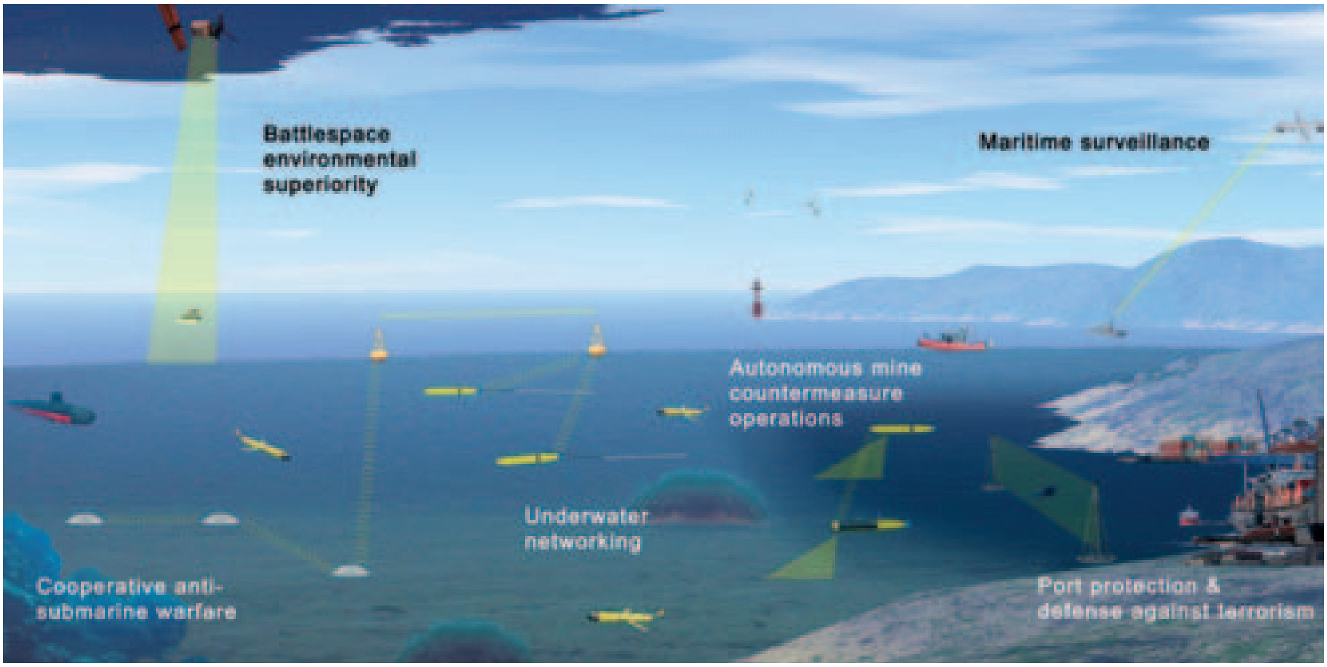


NURC USV responding to an intruder detection incident during a sea trial (left), the USV control station on-shore displaying command and control, real-time sonar and video images (centre), and a merchant ship deploying self-protection measures in the Gulf of Aden during Operation Allied Provider (right, photo from the Allied Maritime Component Command Naples website, http://www.afsouth.nato.int)

a side-looking sonar for the reacquisition and classification of an intruder by a response team, vectored into position by a large-area surveillance sonar. NURC also carried out a technology survey of unmanned surface vehicles (USVs) and assessed the utility of USVs in the context of harbour protection missions. In 2008 work started on USVs: two rigid inflatable boats (RIBs) were acquired by the Centre and transformed into USVs, equipped with forward and side looking sonar. These USVs were tested for missions such as sea floor imaging and peer inspection, in search of possible UWIEDs, as high readiness response tools against intruders, or to counter surface vehicles by enforcing an above water exclusion zone. While there are a lot of tools on the market related to surveillance, not many are available in terms of response to possible threats. Although hardware is available off the shelf, the problem lies in the concept of use, which has been developed in an ad hoc manner. However this will change, as a more systematic approach in this area will be adopted, beginning in 2009. Problems to be solved involve how to coordinate surveillance assets, how to increase the autonomous behaviour of both surface and underwater vehicles, and how to divert or stop a non-cooperative target. In most cases the response will have to adopt a soft defensive posture based on warning, proof of intent and the use of proportional force. The effectors currently considered are mostly USVs equipped with acoustic or visual warning devices. An extension of such a mission is anti-piracy: the deployment of a European Union anti-piracy force off the coasts of Somalia, and previous attempts to stop the threat against merchant vessels in that area and on others made news headlines. A broadcasting device was successful in driving back pirates from a cruise liner in 2005, and studies are being conducted to improve the effectiveness of soft defence, i.e. non-lethal, methods. Audio emitters connected to surveillance radars, or forward looking infrared (FLIR) systems, capable of broadcasting voice warning messages to painful incapacitating signals, are being considered, as well as laser dazzlers capable of warning and disturbing without causing permanent damages.

Underwater networking

Underwater communications and data fusion are becoming increasingly important topics. Harbour protection, MCM operations and anti-submarine missions are completed with the aid of UUVs. These missions are enhanced by the use of underwater communication and networking techniques. NURC is assuming a pivotal role in advancing communications between underwater systems leading towards extending net-centricity deep into the sea. Currently there is no Standard NATO Agreement (STANAG) on underwater networking or messaging. The Centre has become the focal point in a draft STANAG for underwater communications which is expected to become reality in the coming years.



Pictorial representation of an autonomous network (AUVs, gliders, bottom sensors and communication buoys) for use in environmental monitoring and underwater surveillance.

The work has gained broad support and collaboration from military, academic and industrial partners. The ocean is complex in nature. This complexity includes temperature, salinity and sound speed variations. The ambient noise fluctuations generated from high sea states, combined with the echoes and absorption from the seafloor heavily influence signals. These phenomena present signal communication problems, many of which are still to be solved. These considerations led NURC scientists to work on a robust standard that can withstand the most diverse environments.

A dense underwater communications network will become saturated and rendered useless if not properly managed. A solution is the 'media access control' (MAC) set of rules, establishing how messages are to be sent and received. To complicate things even more, physical dimensions of assets dictate the transmission frequencies that can be used. Small UUVs cannot use low frequencies (which require large transducers) for communications and hence have shorter transmission ranges. Larger assets like submarines can use the lower frequencies and therefore have longer ranges. The GLINT 08 experiments in the summer of 2008, south of Pianosa Island, off the coast of Italy, verified fundamental methods and standards including 'JANUS', a protocol developed at NURC. The Centre, in collaboration with numerous other research and academic institutions, completed the most complex experiment ever in terms of number of mobile and fixed assets, with seven UUVs and three ASVs all with underwater communications, performing broadcast messaging and peer to peer communications. The clusters of vehicles communicated among themselves and autonomously performed tasks that normally would have required direct human intervention. The aim was to provide a system that would allow large and expensive manned naval assets to deploy smaller and unmanned systems several miles in front of them, in order to avoid unanticipated engagements. The seamless flow of information will soon be a reality, from satellite to surface vessels, then downward to autonomous vehicles and stealthy submarines, all enhanced with additional knowledge transmitted through the opaque liquid world around them.

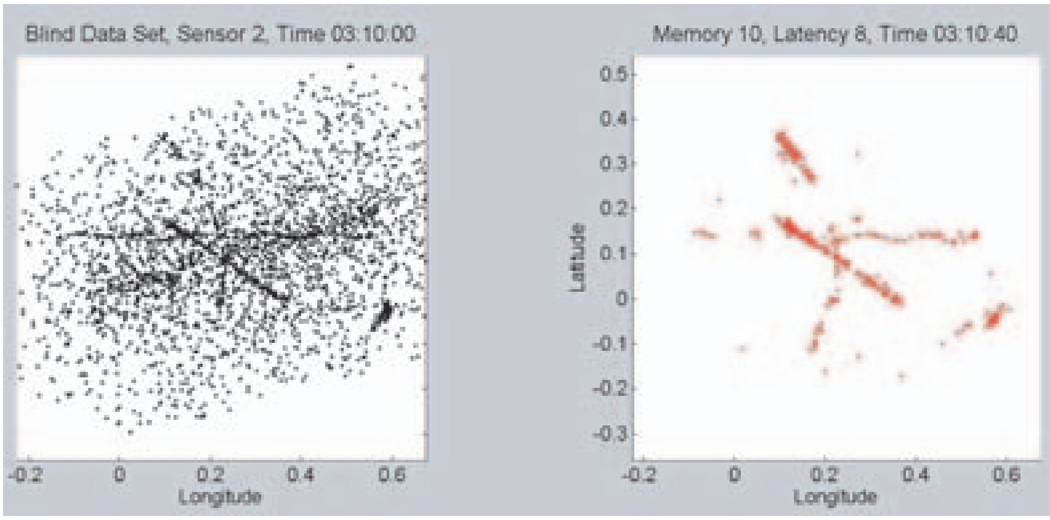
NURC engineers designed and successfully tested this "modem-on-a-rope" for robust underwater communication

After applying NURC developed algorithms to shipping traffic, anomalies may be detected and viewed using a GIS client such as GoogleEarth

Maritime Situational Awareness

Maritime Situational Awareness or MSA is the latest add-on to the Center's portfolio of research programmes. It includes all activities carried out beyond the one mile limit from the coast and from a harbour. Work on that subject started on a small scale at NURC in 2007 through collaboration with other organisations. The early start enabled NURC to be ready when NATO ventured into this arena, drafting an MSA Concept Development Plan in November 2008. Such work was a natural extension from projects in surf zone monitoring and REP, leveraging NURC expertise in underwater acoustics, exploiting the same tools with a different set of parameters. In the past two years, NURC developed a number of tools that were useful for MSA capabilities, such as performance evaluation systems and automatic identification systems for ships of over 500 tons displacement. Work with coastal radars and high frequency long range radars was also carried out as well as on SAR satellite imaging. The objective was to develop tools based on software and algorithms to detect abnormal movement (anomalies) in ships, fusing data coming from different sensors. A Maritime Data Simulator is being developed to help the optimisation of surveillance assets needed to cover a specific area, or to predict possible impact of the unavailability of one or more sensors at a given time.

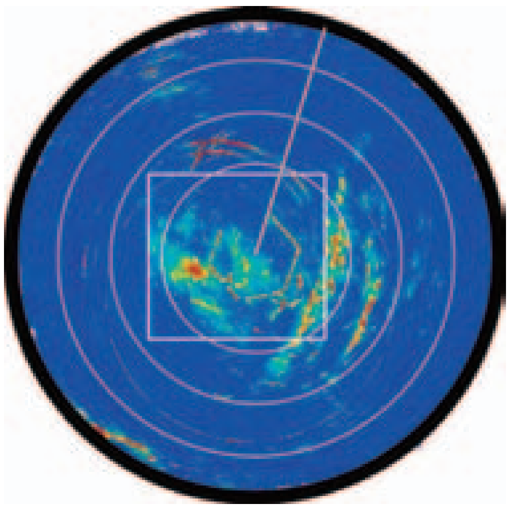
NURC works closely with Maritime Component Command Naples (CC-MAR) which leads Operation Active Endeavour since 2001, the counter terrorism operation carried out throughout the Mediterranean. CC-MAR Naples provides NURC scientists with the ability to engage in operational scenarios. Scientists working on the MSA programme carried out data collection and analysis, leveraging on information gained from other missions, but recently thanks to the official endorsement of a NATO MSA programme in 2009, will see dedicated missions at sea. A roundtable is planned to bring together the NURC, ACT and CC-MAR Naples experiences with the understanding of the advantages of an integrated effort. To better understand the potential of the multiple sensors and of the data fusion of all their outputs, a live demonstration is planned in 2009. BELCOAST 09 will bring together numerous sensors such as maritime surveillance radars, high frequency radars, synthetic aperture radars onboard flying assets, maritime patrol aircraft, unmanned air vehicles, and other MSA tools currently available. Apart from military applications, MSA developments can find applications for the protection of events of worldwide relevance.



Data from SEABAR'07 was used to compare and evaluate different sensor setup. On the right side, the drastic improvement in terms of false alarm reduction by the exploitation of multistatic sonar. Target tracks that were unknown became clearly visible.

ASW still very much in focus

The attention given to the new areas of port protection and MSA does not mean that the original research mission of the Centre has been forgotten. Recent advances in technology have led to the commissioning of new classes of submarines that are very silent and highly manoeuvrable. The proliferation of submarines is increasing and the northern routes are being patrolled once again: the submarine threat has not disappeared. NURC researchers continue to focus on submarine detection by improving target detection, tracking and classification, and by reducing false alarm rates caused by clutter. The Centre was a pioneer in the field of multistatic sonar and conducted extensive research and sea trial evaluation of multistatic sonar fusion and tracking algorithms and technology. This work was augmented by research findings in reverberation and clutter. Recent sea trials BASE'07, CLUTTER'07, SEABAR'07, MARES'08 and upcoming CLUTTER'09 and CASW'09 underscore the continuing importance of ASW research at the Centre. In particular the CASW (Cooperative Anti-Submarine Warfare) programme, started in 2009, investigates novel and innovative approaches to counter the proliferation of quiet, small, diesel-electric submarines which pose a threat to NATO and national forces. This programme takes an integrated approach to ASW that focuses on sensor networks with distributed intelligence. It incorporates research topics in sensor autonomy, communication and networking, sensor improvement including clutter classification, real-time processing and data fusion, and operations analysis.



Reverberation and clutter influence target detection, tracking and classification: this scatterer map indicates clutter-like signals received from a towed array.

NURC engineers designed a high-frequency nested towed array for use with AUVs during ASW operations. First tested in November 2007, the SLITA (Slim Towed Array)'s performance has been validated in subsequent sea trials as easily meeting ASW requirements.

Staff members in a Hail and Farewell gathering in 2005. About 900 people from 15 different nations have contributed to the success of the Centre over the past 50 years

Moving forward: NATO's corporate maritime research laboratory

The increasing presence of unmanned and autonomous vehicles, under and above the sea, and the networking of systems and sensors thanks to improved communications, will certainly mark the future of NURC's research. Even so, the core scientific work on underwater acoustics will remain one of the Centre's fields of expertise.

As NATO member nations cut funding for defence research and development (R&D), it has become more difficult to prepare for tactical advantage in maritime defence and security. An international research facility such as NURC, with its sea-going and engineering assets is a hub where national scientists can gather to exchange ideas, and to develop and test future technologies. Even as individual nations reduced defence R&D spending, the Centre itself faced similar challenges in maintaining its technological and research edge due to funding constraints. The 2005 NURC charter contained provisions permitting the Centre to perform work for others on a reimbursable basis up to 20% of its budget, under what was called the supplementary work programme (SWP). Since 2007, the Centre has accepted several projects under the SWP in order to make up for shortfalls in its budget and to maximise the utilisation of assets. In late 2008, the Centre began work on a hybrid funding plan that formalised the SWP into a re-structured customer work programme (CWP) that will adopt an organised and business-like approach to perform reimbursable work for NATO member nations. The hybrid funding plan was issued in early 2009 and is being reviewed by the North Atlantic Council. Although some of NURC's assets and expertise may be funded outside of NATO common funds, the Centre's mission, as established 50 years ago, is essentially to serve the requirements of NATO, even though the focus may have changed to adapt to the times. NURC continues to support the Alliance through the provision of unbiased scientific support, and by conducting a broadly-based multidisciplinary programme of collaborative scientific research and advanced technological development directed toward maritime applications, with a specialty in undersea warfare technologies. With its unique assets, backed by the skills, expertise and dedication of its personnel, the Centre anticipates many more years of "taking the future to sea".

Partnering for Maritime Innovation

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