
2019
1959
CMRE
60th ANNIVERSARY

This book has been published in recognition of the significant accomplishments achieved by the Centre for Maritime Research and Experimentation over the past 60 years. Thank you to the Centre's staff, scientists, engineers, partners and alumni for their incredible hard work and dedication.


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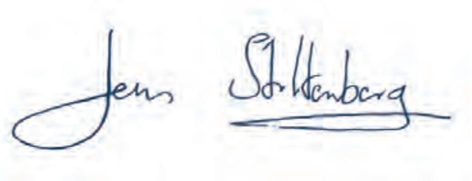
Foreword

For sixty years, the Centre for Maritime Research and Experimentation (CMRE) has provided a platform for Allies and partners to develop, share, test, and certify their science and technology (S&T) solutions in an operational environment. Since its foundation, the Centre has evolved into an internationally recognized state-of-the-art research and technology centre, whose prototypes and field tested S&T technologies provide tested scientific solutions tailored to the defence and security needs of NATO and its Allies.

The world's oceans are increasingly busy maritime highways. Today, 85% of all international trade in raw materials and manufactured goods travel by sea, and tankers carry more than half of the world's oil. The maritime domain is of strategic importance to NATO and NATO is determined to help protect its Allies from any possible threats at sea or from the sea. As an Alliance, which includes a large number of maritime nations, NATO continues to recognize the strategic importance of the maritime domain, and the imperative to continue to invest in the modernization of maritime technologies and capabilities.

During the past decades, the Centre has maintained a technological edge, cementing itself as a global leader and well-established reference in key areas such as oceanography, artificial intelligence and the development of autonomous underwater vehicles conducting mine countermeasures missions, systems to support antisubmarine warfare, and the use of big data analytics. With the ability to carry out at-sea research and develop technological solutions in operational settings, the Centre for Maritime Research and Experimentation will continue to play a key role as a hub for maritime innovation, research, and development, for the benefit of the Alliance and its partners.

In celebration of the Centre's 60th anniversary, I pay tribute, on behalf of NATO, to all Centre for Maritime Research and Experimentation staff for their professionalism, dedication, and enduring commitment to our common purpose and shared values. I wish you all continued success for the future.



Jens Stoltenberg
Secretary General of NATO

Introduction

I consider it a privilege to serve as Director, Centre for Maritime Research and Experimentation (CMRE), and in particular, during the year of the Centre´s 60th Anniversary. Since 1959, the Centre has been a collaboration hub for scientists from all NATO Nations to work together to maintain NATO´s technological edge.

CMRE has consistently used science, technology, and engineering expertise to meet the challenge of advances in adversary capability. Today the Centre´s scope encompasses the domains of big data, artificial intelligence, and autonomous systems.

Underpinning CMRE´s success in maritime research over the years is its sea-going capability. In the pages of this book, you will see all of the research vessels the Centre has operated over the years. Today NATO has two research vessels, the Coastal Research Vessel (CRV) *Leonardo* and the NATO Research Vessel (NRV) *Alliance*, which continue to allow us to do research and demonstrate science and technology at sea. Since 2016, both ships are under the Italian Navy flag, operated by Italian Navy crews, for which NATO is grateful.

Looking towards the next years, CMRE undoubtedly will remain a vital organization to NATO and the Nations as maritime security challenges increase, in part due to technological advances by our adversaries and to the rapidly changing environment of the Earth´s oceans. The Centre has a key role to play as the maritime collaboration hub for NATO – both in the laboratory and in operational settings at sea.

In closing, I echo the words of the Secretary General of NATO, Jens Stoltenberg, in paying tribute to the hard work of CMRE staff both past and present. I have no doubt that this dedicated team will continue its pursuit of excellence for decades to come.

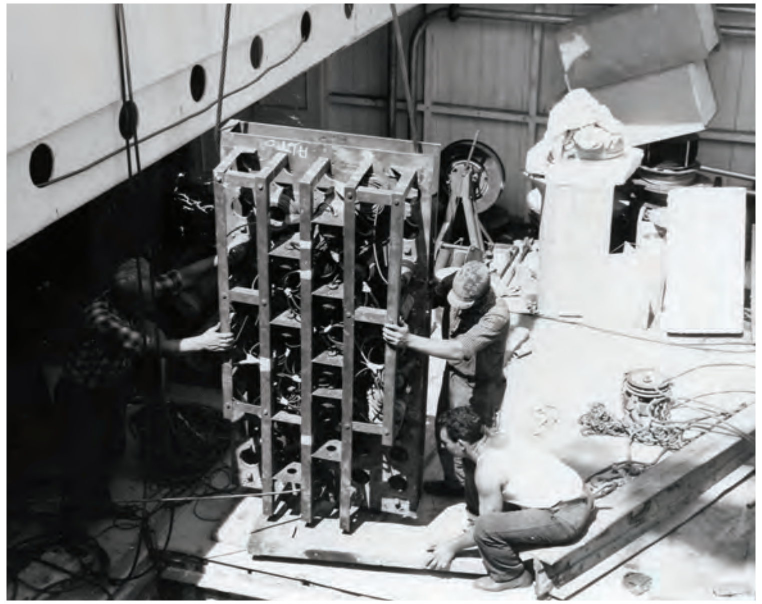
Dr Catherine Warner
Director, CMRE

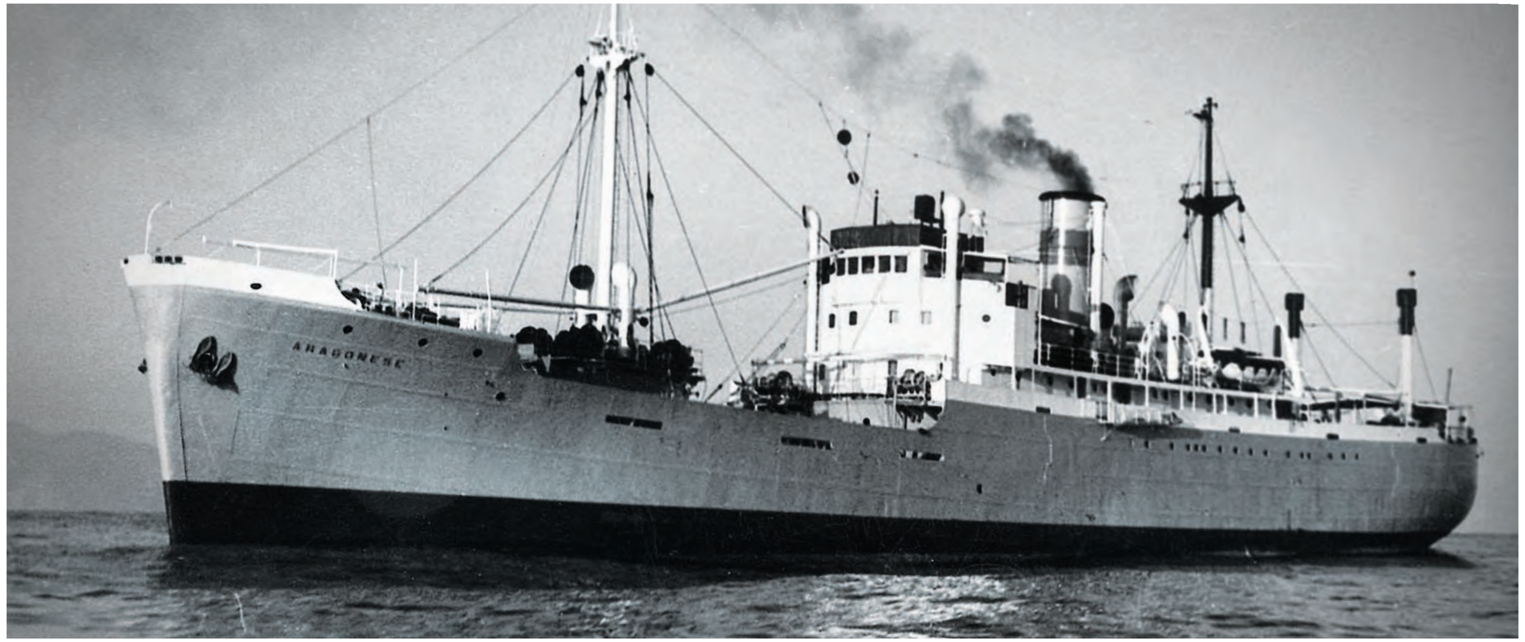
The Early Years:
1950s – 1960s

The Centre for Maritime Research and Experimentation, originally known as SACLANT ASW Research Centre or SACLANTCEN, was established in response to growing geopolitical tensions and technological advancements in naval warfare that occurred during the Cold War. In the late 1950s, NATO realized that greater scientific knowledge of the undersea environment was essential in safeguarding the fleet, providing stronger protection to Alliance Nations and restricting the movements of Soviet naval forces. With the initial funding contributed by the United States Secretary of Defence, on 02 May 1959 the Centre was officially commissioned. The flags of the nine NATO Nations that provided personnel were raised for the first time with that of NATO in the Italian naval compound in La Spezia, which still hosts the Centre today. On 20 October 1962, the North Atlantic Council adopted a charter that recognized the Centre as a NATO organization.

Right: 02 May 1959. The official commissioning ceremony of the SACLANT ASW Research Centre or SACLANTCEN, now known as the Centre for Maritime Research and Experimentation, featuring an address by Supreme Allied Commander Atlantic (SACLANT) Admiral Jerauld Wright of the United States Navy.

29 September 1962. Italian President Antonio Segni (middle) visits the Centre.

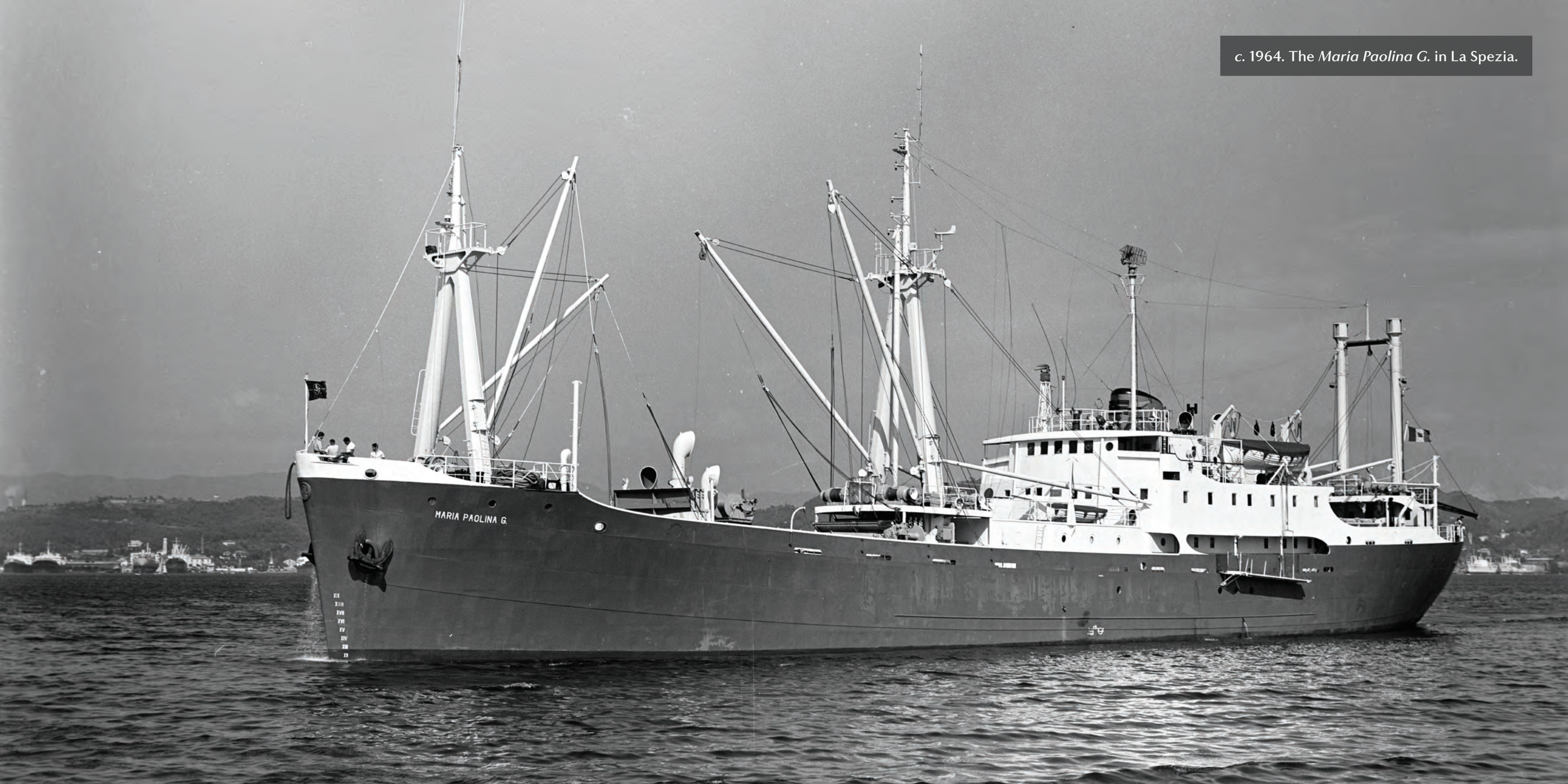




Above: *c.* 1960s. The *Aragonese* in La Spezia.

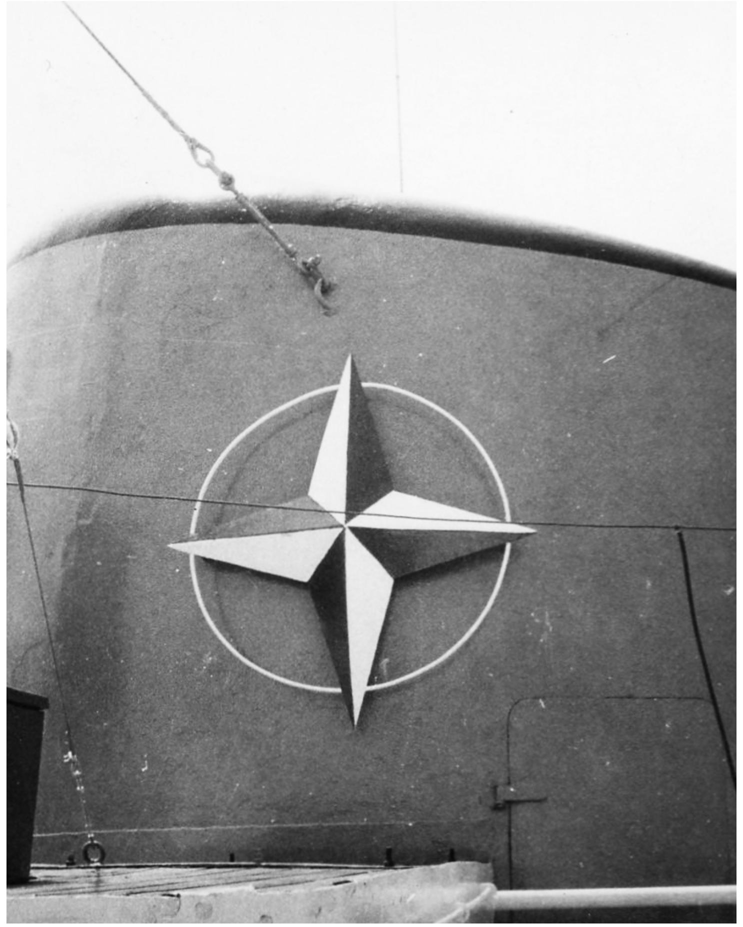
The Centre was called upon to assist NATO Nations in the undersea domain, especially in deep ocean locations where Soviet nuclear submarines prowled for possible attacks on the continental United States or to disrupt the sea lines of communications between North America and Europe. In the early years, the Centre's mission was to conduct research and provide scientific and technical advice to NATO in the field of antisubmarine warfare. 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 organization a sea-going capability.

Left: 1961. Installation of a transducer mount in the well deck of the *Aragonese.*

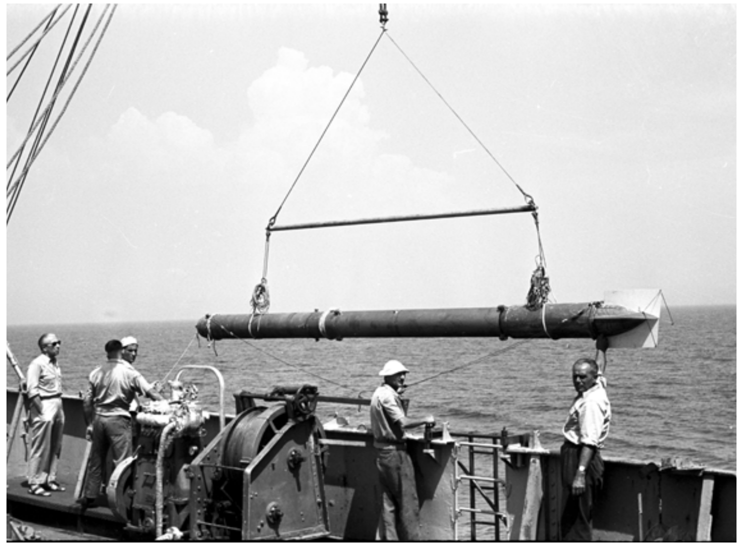


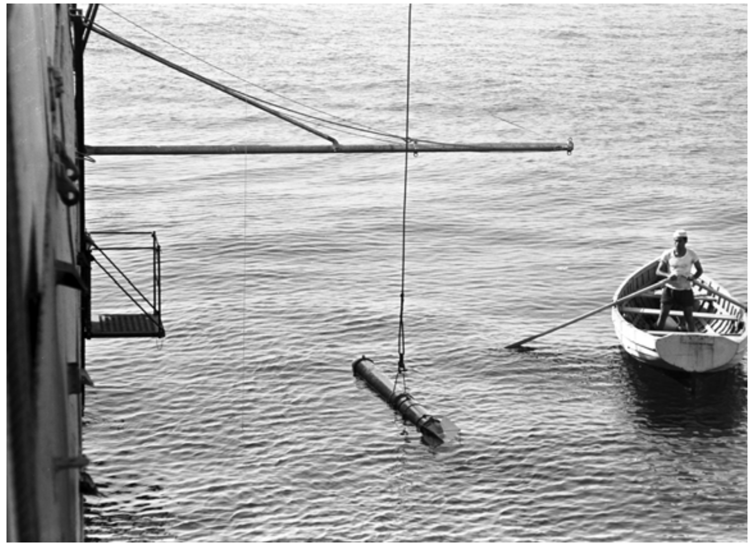
c. 1964. The *Maria Paolina G.* in La Spezia.

In 1964 the 2,800t *Maria Paolina G.* was chartered, replacing the ageing *Aragonese*. The new ship strengthened the Centre's sea-going capability, improving its ability to conduct research in systems concept evaluation, oceanography, and underwater acoustics that underpinned its antisubmarine warfare mandate.



Left Page, Top: *c.* 1964. The NATO logo atop the *Maria Paolina G.*
Right Page, Top: *c.* 1960s. **Front row, from left:** Maria Pia Loris, Giancarla Bertoni, Rosa Losito, Adriana Poletti. **Back row, from left:** Audrey Carr-Jones, Giorgio Zaccari, Gilberto Guaschino and Mario Carubbi.
Below: *c.* 1967. Engineers conduct experiments at sea.





Above: *c.* 1960s. Teaching staff of the Centre school led by Kate Mears.

Above: *c.* 1960s. Students of the Centre School. **Photos by:** Tom Allan.

In the 1960s, an English language elementary school, organized primarily for the children of non-Italian families at the Centre, was established in a joint effort between Italy, NATO and the parents. Initially held in a villa overlooking Lerici, the school was later moved closer to the Centre to Muggiano, a small suburb of La Spezia. The school was under the direction of a school board comprised of Centre staff and directed by Kate Mears, a British teacher.

Above: *c.* 1960s. Students of the Centre School perform in a holiday concert.

Above: *c.* 1960s. Lois Allan attends the Centre School. **Photos by:** Tom Allan.

Above: *c.* 1960s. Scientists work with a waverider on the SACLANTCEN workboat.

Understanding the complexity of underwater sound propagation is the basis for detecting and classifying submarines. In the 1960s, this goal was achieved through the development and engineering of new oceanographic scientific instruments that gathered data in the harsh ocean environment.

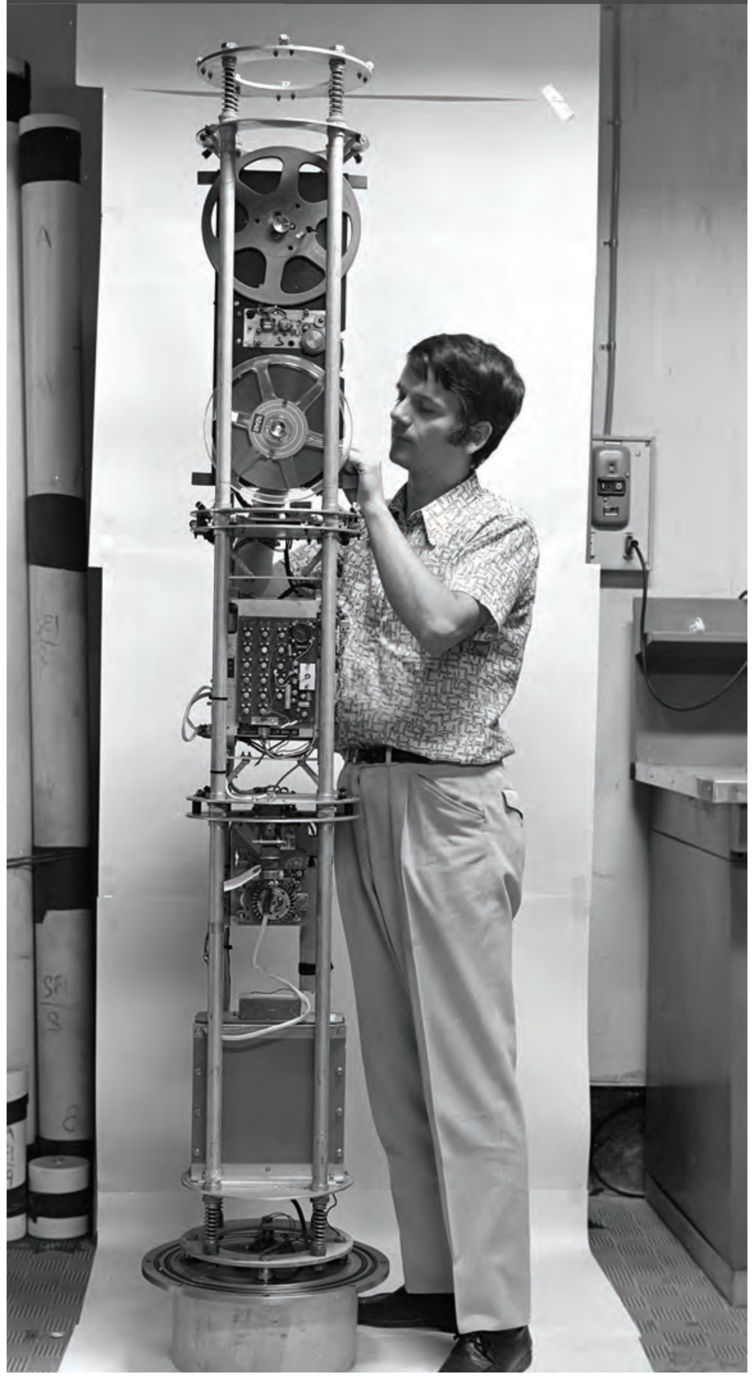
Above: *c.* 1960s. Silvio Bongi calibrates a hydrophone.

In particular, the Strait of Gibraltar, an area with high currents and intense internal waves, challenged oceanographers and engineers to develop robust equipment that could survive deployment. During this period, the Centre also constructed a laboratory to test and evaluate instruments being built, marking the start of the Centre´s calibration capability.

Above: 1968. Gabriella Parmigiani and Alvaro Carrara work on a mission for the *Maria Paolina G.*

c. 1960s. Franco Ravera operates a milling machine.

c. 1960s. Roberto Della Maggiora works with a current meter.



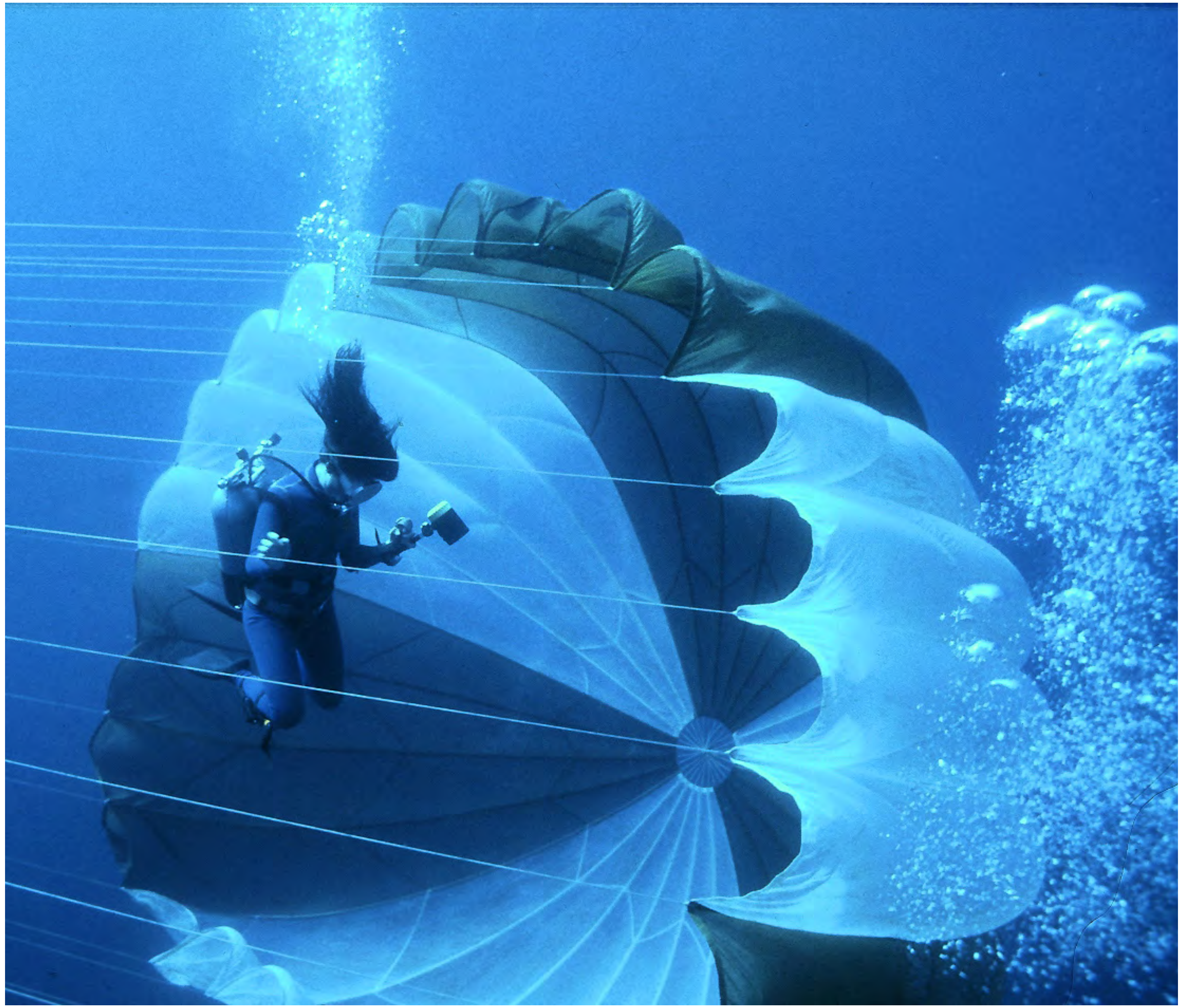
Above: *c.* 1960s. Crews deploy a towed transducer.

Above: *c.* 1960s. Crews deploy a hydrophone array.

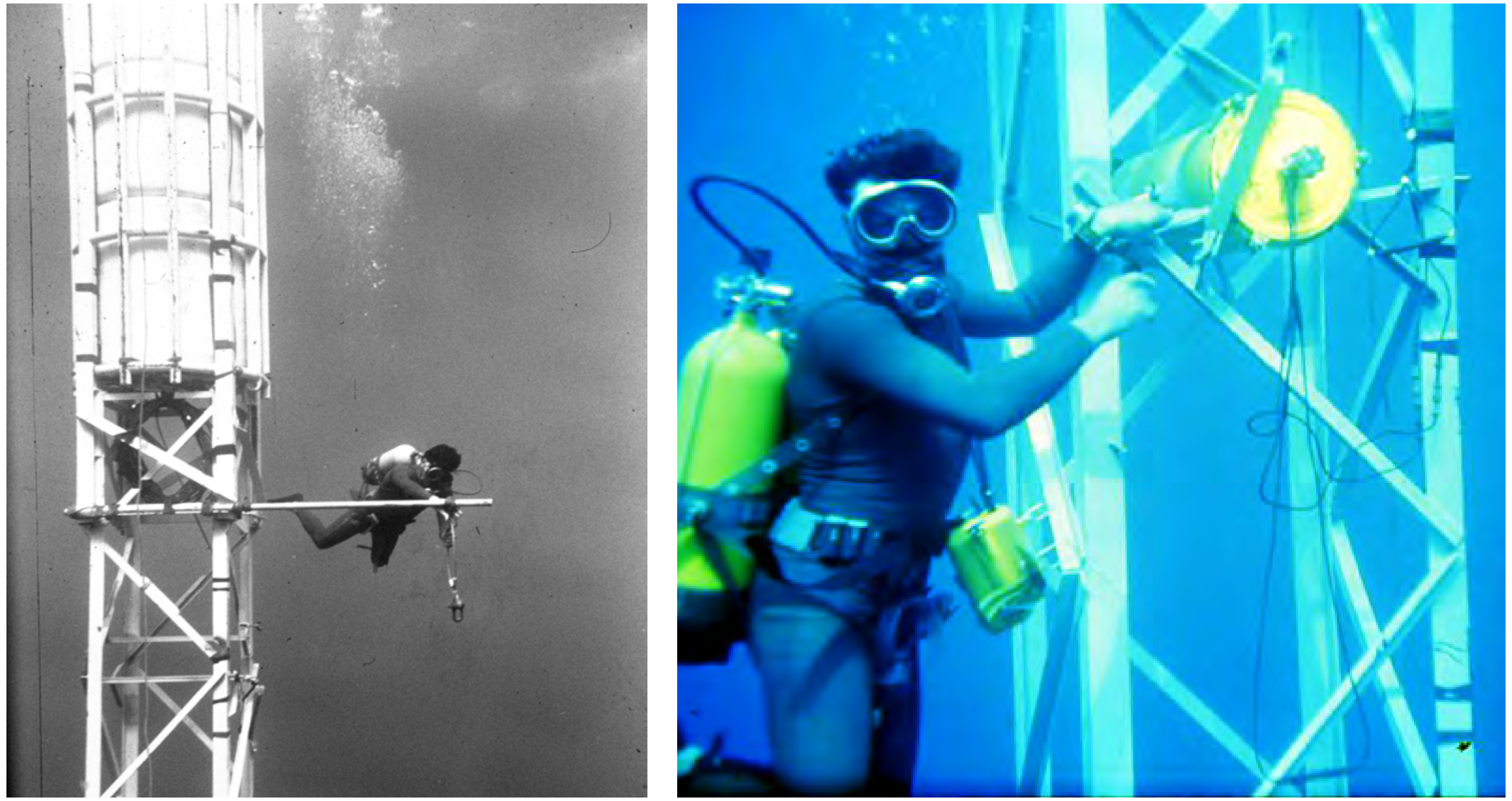
Underwater acoustic sensors, or hydrophones, and arrays of hydrophones are the key to detecting submarines underwater. In 1961 the Centre began to develop its own hydrophones, establishing a calibration facility and implementing standardized approaches among the NATO countries.

In 1968 the Centre developed a meteo-oceanographic spar buoy to collect data on air-sea interactions, which strongly influence the underwater acoustic environment.

Above: *c.* 1970s. Crews deploy a meteo-oceanographic spar buoy from the *Manning*.
Photos by: Federico de Strobel.



Above: *c.* 1960s. A number of scientists became certified divers, making it possible for them to work in the underwater environment. **Photo by:** Federico de Strobel.



Above: *c.* 1960s. A meteo-oceanographic spar buoy being equipped with sensors by Centre divers.
Photos by: Federico de Strobel.

In the late ´60s, the need to increase the efficiency of buoy operations at sea resulted in a new activity, scientific diving. The adoption of mateable connectors for underwater work made it easier for scientists to connect and disconnect various modules to the instruments. All of these initiatives resulted in more effective operations, enabling scientists to verify how prototypes function in real time. Scientific diving as a professional activity, first practised by the Centre´s scientists in 1969, became recognized by NATO in 1974.

Into Shallow Waters: **Research in the 1970s**

By the 1970s it was widely recognized that addressing the challenge of detecting submarines in shallow or littoral waters was a NATO priority. However, not only is the oceanography more complex in shallow waters but underwater sound interacts much more with the seabed and sea surface than it does in deep water, resulting in many sources of false targets, such as seabed features and shipwrecks. These factors make it much more difficult to detect and localize submarines in shallow water than in deep water.

At the same time, the advent of digital computing enabled processing of the rapidly increasing stream of scientific data that would make it possible to better understand the acoustical environment of shallow water regions. The Centre recognized the importance of digital computing and created a new facility to host a centralized computer system.

Right: *c.* 1970. Giancarlo Vettori (left) meets with a journalist onboard the *Maria Paolina G.*

The scientific side of the Centre was then reorganized into two main divisions: the Environmental and Systems Research Division and the Operational and Analytical Research Division. To support programming in the new divisions, the number of scientists at the Centre was increased to about 50, with most working on limited-term contracts. This rotation of personnel enabled a regular inflow of new ideas, and over time, resulted in a network of close contacts between the Centre and national research bodies as well as many universities and private companies.

While advanced technologies were assisting scientists and engineers inside the Centre, activity at sea remained intensive. The new emphasis on shallow waters, prompted by the proliferation of quieter submarines, led to the requirement for research on shallow water oceanography and acoustics with the majority of experiments being carried out along the Ligurian coast outside of La Spezia.

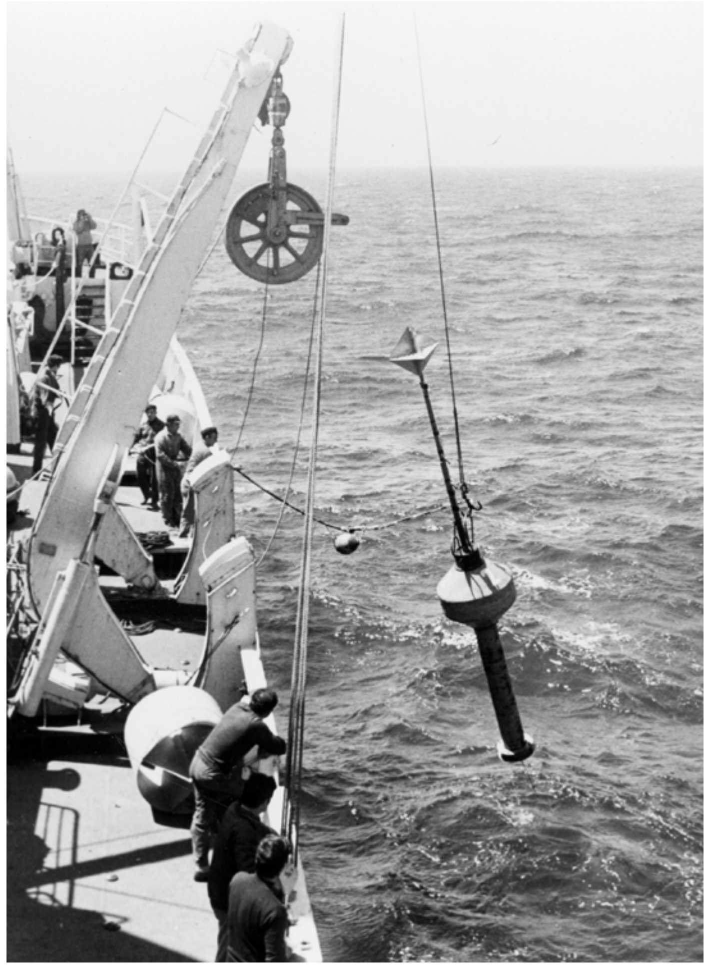
In 1974 the *Manning*, a boat built for the United States Army and previously used by Columbia University for oceanographic work, joined the Centre´s fleet.

Left, Top: *c.* 1990s. The *Manning* docked in Marciana Marina (Elba Island).
Below: *c.* 2000s. **Front row, from right**: Mauro Lombardi, Emilio de Cola, Andrea Iacono, Umberto Fabiani, Umberto Varlese, Chris Gobey, Mauro Pini, Sauro Giusti. **Back row, from left:** Giuliano Bertoli and Salvatore Cuciniello next to the *Manning* on Formiche Island.

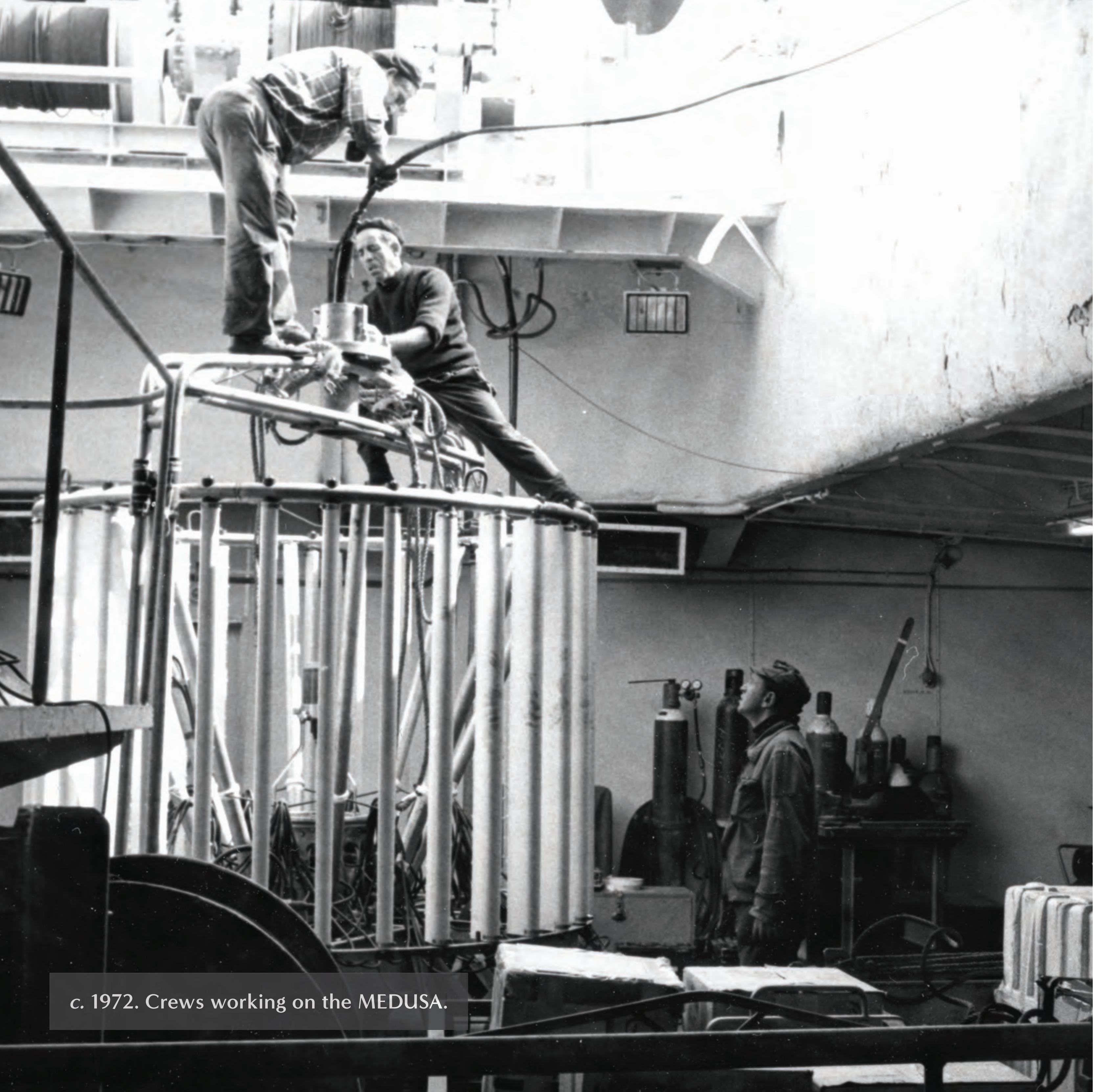
c. 1970s. The *Maria Paolina G.* was fitted with the most advanced research equipment of the time.

Above: *c.* 1972. Researchers onboard the *Maria Paolina G.*

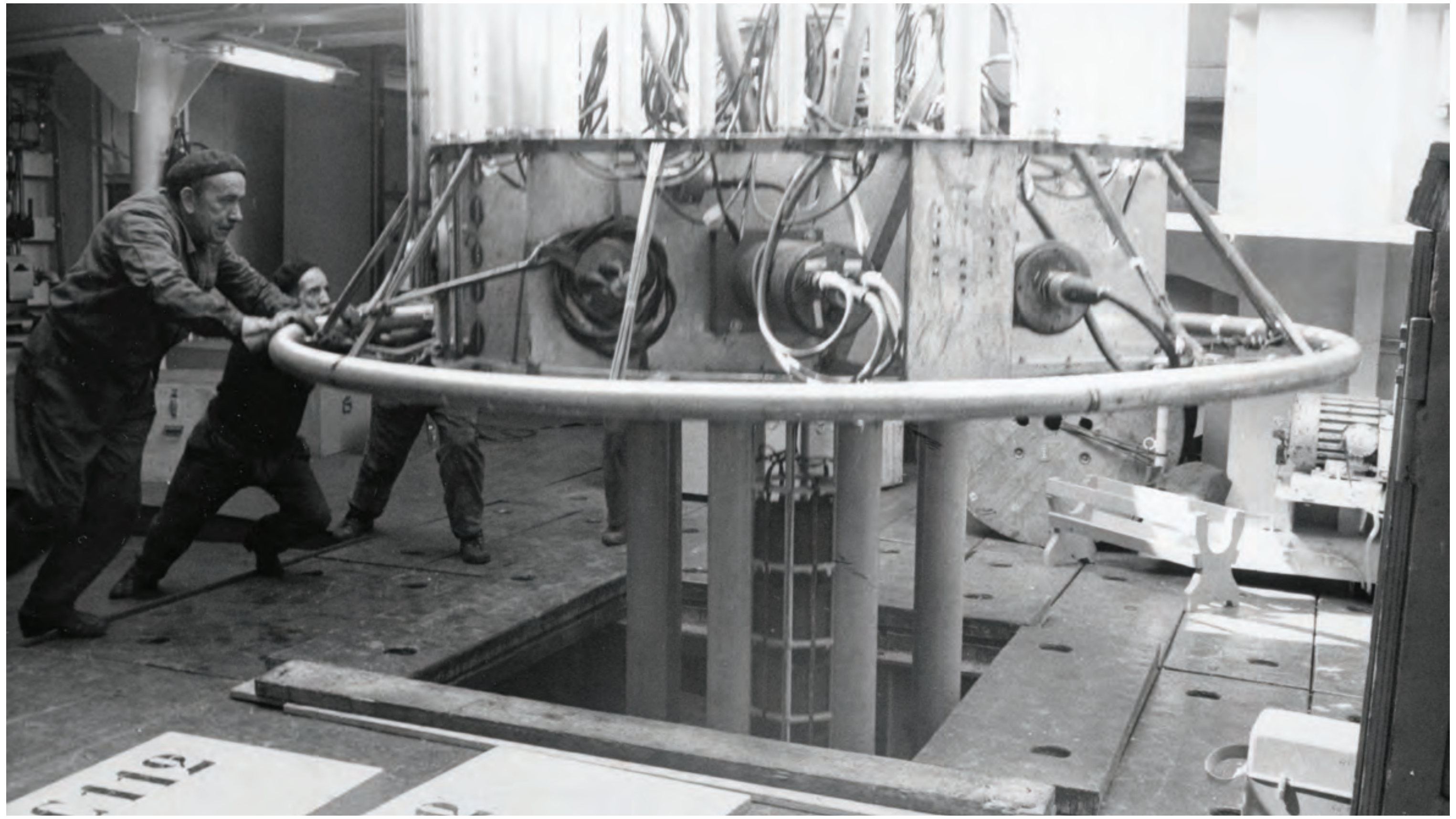
During this time new shallow water data collection instruments were developed, while data collection techniques for deep water also continued to improve. In the early ´70s, researchers experimented with vertical arrays of acoustic sources and receivers to exploit some of the shallow water sound channel´s characteristics. Later, the Centre started testing its first experimental towed hydrophone array built by Hughes Aircraft Corporation.



Right: *c.* 1972. Crews preparing to deploy a vertical array and antenna from the *Maria Paolina G.*



c. 1972. Crews working on the MEDUSA.



Above: *c.* 1972. Crews working on the MEDUSA.

Space-frequency interference patterns of continuous waves, frequency-modulation sonar techniques and reliable acoustic paths were some of the fields investigated in these years. 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 that exploited deep sound propagation paths resulted in the construction of the Deep Panoramic Sonar based on the Mediterranean Experimental Deep Underwater Sonar Apparatus (MEDUSA) multiple array system, the first active sonar developed at the Centre.

1 July 1974. One of the first trips to the Arctic onboard the *Maria Paolina G.*

8 May 1979. The Centre celebrates its 20th anniversary.

In the mid-70s, the Centre's engineering staff developed the first variable-depth towed Conductivity-Temperature-Depth (CTD) system. Measuring conductivity and temperature of the sea water, it allowed researchers to determine density, a fundamental oceanographic measurement. The system, known as the High Resolution Towed Oscillating System, also provided the speed of sound in water, a key variable for antisubmarine warfare, and proved to be indispensable in supporting Centre experiments at sea by characterizing the ocean environment in great detail over large areas.

The Bistatic Active Towed Array Sonar programme was launched in 1978. This system used two vessels, one to tow the acoustic source and the other to tow the receiving hydrophone array. The programme demonstrated that separating the source and receiver led to a considerable increase in detection range.

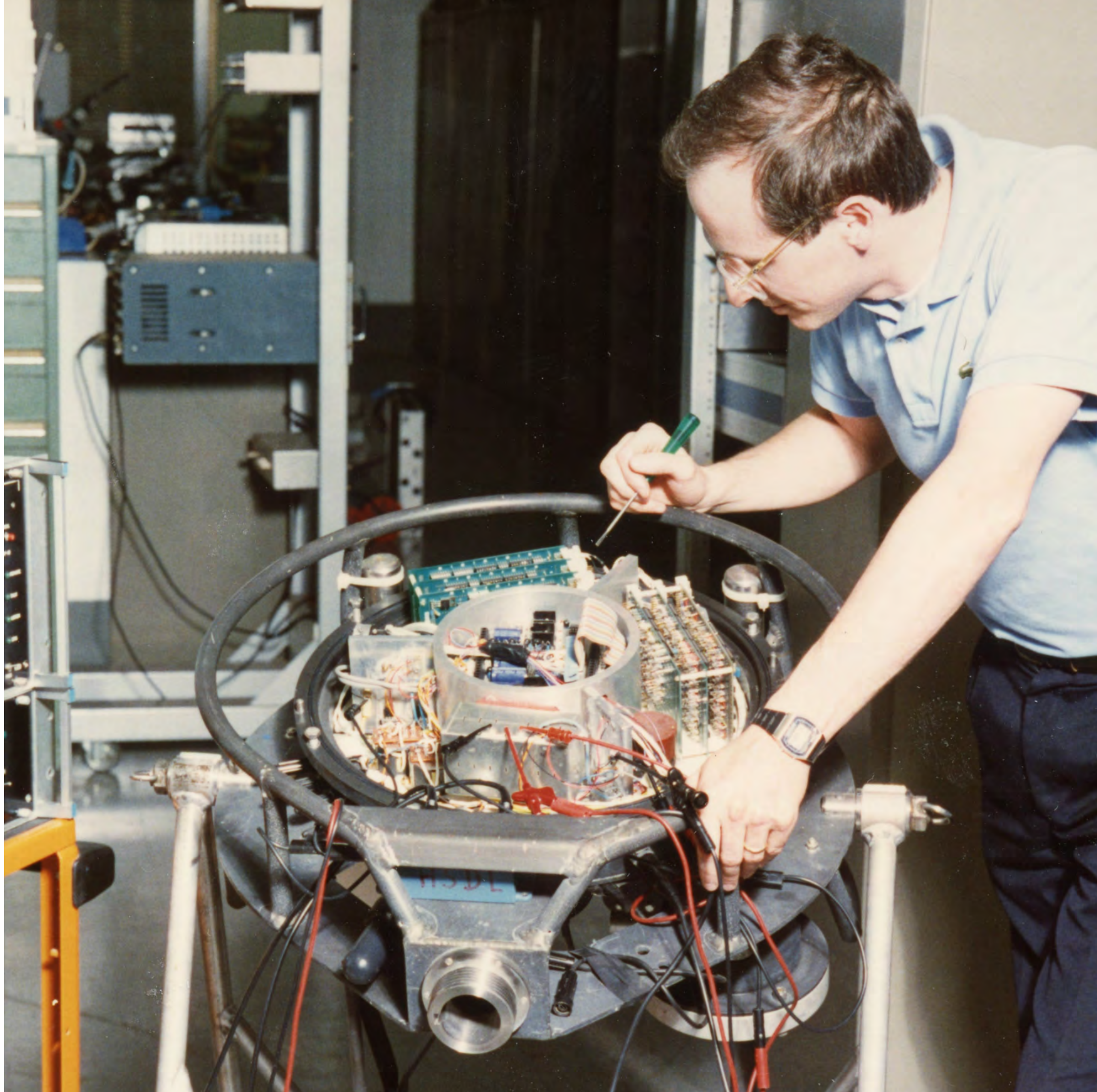
The Centre has always been especially beneficial to smaller NATO Nations who have less resources for defence research, particularly expensive at-sea experimentation. Through the Centre, not only do these Nations have access to the scientific and technical output, but their researchers can join the Centre, work with other world-class scientists and benefit from the support of a highly experienced engineering department and at-sea experimental capabilities.

Left: *c.* 1976. Pietro Zanasca works with the towed oscillating CTD system. **Photo by:** Federico de Strobel.

The 1980s

Since its inception, the Centre has taken pride in being at the leading edge of maritime research and experimentation, often creating unique scientific instruments and executing complex experiments at sea. The legacy of dedication to the fundamentals of research was further cemented in the early 1980s with the establishment of the Oceanography Calibration Laboratory. Still in operation today, the laboratory provides calibration services according to the World Ocean Circulation Experiment and continues to support the Centre's activities as well as those of other NATO navies and research laboratories.

Although the Centre's research focus shifted toward shallow waters in the 1970s, its mandate to focus on submarine detection and classification continued. The increasing stealth of Soviet submarines meant that passive acoustic detection was not always reliable. The 1980s saw renewed interest in active sonar but at lower frequencies, which have greater detection range. The Centre began its experimentation with low-frequency active sonar with the Active Adjunct Project. This project used a passive towed sonar array as well as a towed high power, low to mid-frequency emitter, in order to determine performance in terms of signal coherence, system noise, reverberation rejection, detection range and target strength.



Right: 1988. Paolo Saia calibrates a magnetometer.

Above: 1980. A diver deploys a bottom-mounted platform with scientific sensors.

Above: 1983. A diver checks a drifter buoy shortly after deployment.

Above: 1983. Antonio D´Agostino works with a drifter in the calibration lab. **Photos by:** Federico de Strobel.

The Centre´s links to military organizations were vital in obtaining the support of submarine services for the numerous experiments that were carried out in the Mediterranean, both in deep and shallow waters. Mutually beneficial data and information exchanges with multiple nations took place, with the Centre playing a central role in closing the gap between concept and sonar prototype development, reducing risk for the nations developing their own systems.

Above: 1989. Crews work on a vertical array on the NRV *Alliance*.

c. 1980s. With an extensive collection of scientific reference books and journals, the Centre's library is an important resource for research activities.

Above: 1988. Alessandro Barbagelata explains hydrophone technology.
Right: 1988. Bruno Miaschi works on a towed array section in the cabling area.
Right Page, Top Left: 1988. Centre conference area.
Top Right: 1988. Domenico Galletti works on chemical calibration.
Below: P. Angiolo Boni studies collected acoustic data.

1984. NRV *Alliance* under construction at the Fincantieri shipyard in La Spezia.

Above: 1984. The NRV *Alliance* under construction at Fincantieri shipyard.

In 1984, the keel of a new research vessel, specifically designed for the Centre, was laid at the nearby Fincantieri shipyard. The design priority for this 3,180t ship was the reduction of ship radiated noise, obtained with a double hull and a specially designed propulsion system. The NATO Research Vessel (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 at-sea experimentation.

The NRV *Alliance* at sea.


Above: 1988. The NRV *Alliance* sailing in Iceland. **Photo by:** Angelo Spairani.

The focus on shallow water continued through the 1980s culminating in the Shallow Meadow campaign in the Baltic in 1983. But by the late ´80s attention began to shift back to deep waters in response to the need to protect sea lines of communications. In 1986, a five-year survey of the Greenland and Norwegian Seas began, for which new ocean sensing technologies were developed in order to be able to collect data


Above: 1989. The NRV *Alliance* sailing in Iceland. **Photo by:** Angelo Spairani.

over long periods of time in a particularly harsh environment. A total of 31 buoys with 118 sensors that could record data over the course of a year were deployed, facing challenges ranging from thermal shock on sensors to difficulties in deploying and recovering the buoys. The recovery rate of the buoys was 95 per cent, which was a notable achievement in oceanographic research.

The Iran-Iraq war was a major event of the 1980s with a maritime component known as the Tanker War. Oil tankers moving through the Persian Gulf were threatened not only by Iranian air and small boat attacks, but also by sea mines. This shift in maritime threat was partly responsible for broadening the Centre´s mandate beyond antisubmarine warfare to include naval mine countermeasures and maritime surveillance and analysis. Reflecting a wider scope of activities, in 1987 the name of the Centre changed to SACLANT Undersea Research Centre.

Right: 1988. Naval officers and scientist review nautical charts.

1989. Scientists work in the lab onboard the NRV *Alliance*.

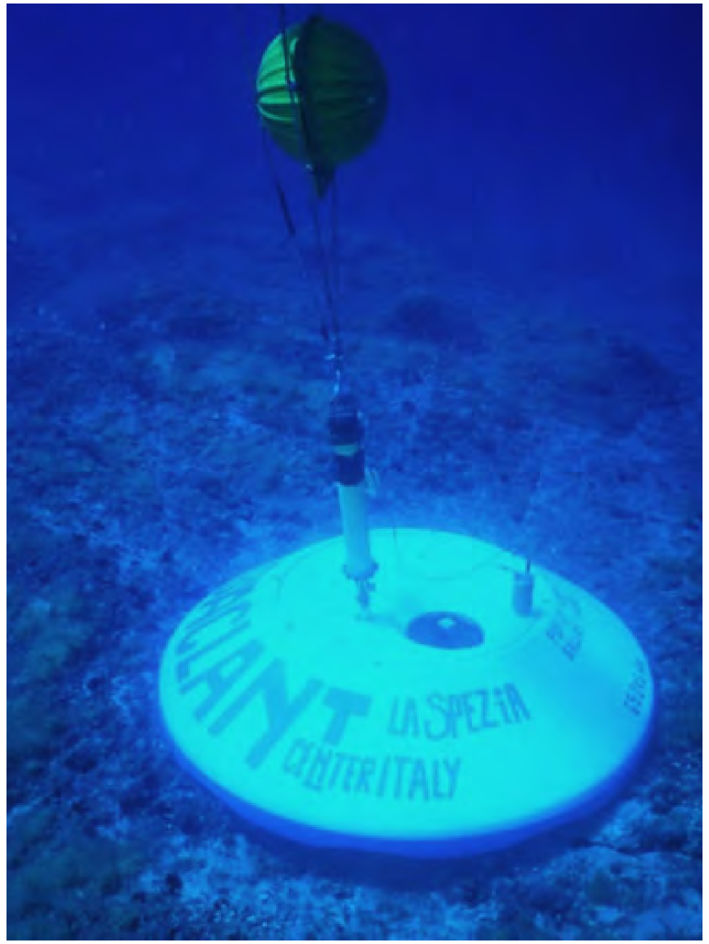
Above: 1989. Crews onboard the NRV *Alliance*.

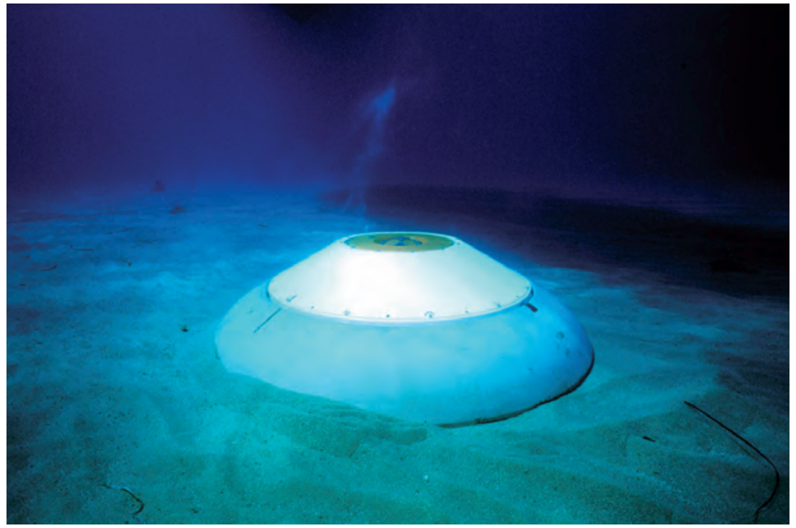
The fall of the Berlin Wall on 09 November 1989 marked the end of the Cold War. The consequent geopolitical environment was characterized by regional conflicts that took place in new areas, with operations involving joint and combined forces. Mines and very quiet diesel-electric submarines were challenging threats for NATO maritime forces.

The 1990s

The semi-enclosed basin of the Adriatic Sea became the focus of attention in 1992, when NATO took part in a monitoring operation to verify sanctions imposed on Serbia and Montenegro by the United Nations. It was the start of the Balkan crisis that would see NATO naval forces involved in that area for several years.

In its northern and central portion, the Adriatic Sea is a shallow water environment with intense fishing trawler activities that required robust new instrumentation for oceanographic surveys conducted in support of naval operations. The Centre designed a recoverable bottom-mounted underwater platform hosting an Acoustic Doppler Current Profiler that sat on the seabed. The platform was capable of measuring the currents in the layers above, with the desired feature of being resistant to fishing trawlers due to its low-profile design. Following tests of the prototype built at the Centre, the device was mass produced by Proteco Sub, a local commercial company, under the Centre's supervision and was successfully used in many oceanographic measurement campaigns all over the world.





Right: *c.* 1992. Crew members onboard the *Manning* deploy the BARNY family of bottom-mounted Acoustic Doppler Current Profilers.
Photos by: Federico de Strobel.

The proliferation of small, quiet diesel-electric submarines gave rise to the requirement to assess quickly the acoustic conditions in waters anywhere in NATO's areas of responsibility. The availability of more oceanic data from innovative sensors and from remote-sensing satellites, combined with rapidly increasing computing power and geographical information systems, allowed the Centre to demonstrate successfully the concept of Rapid Environmental Assessment (REA), that was identified by NATO's Supreme Allied Commander Atlantic as a new maritime operational requirement in 1995.

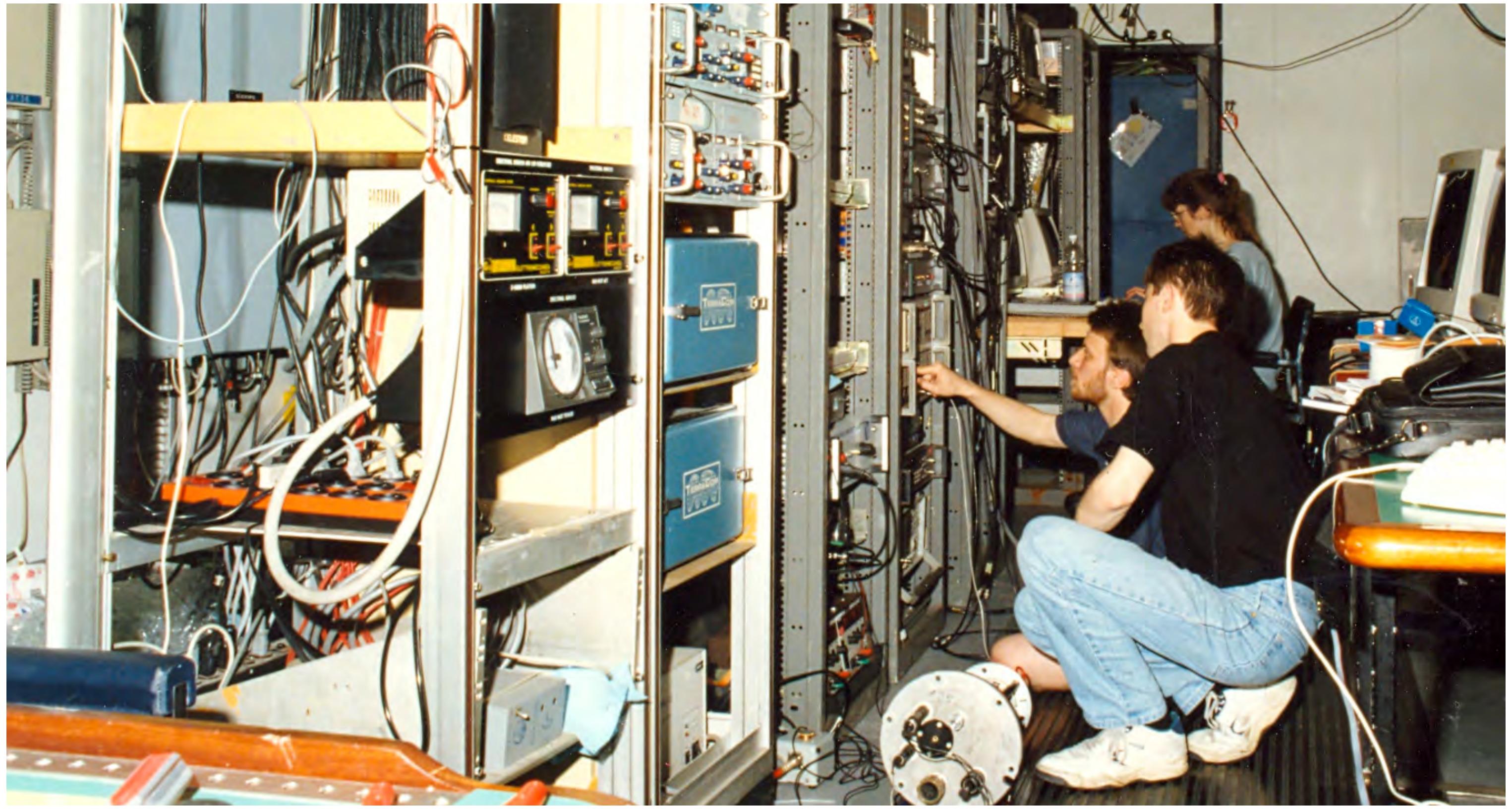
Left Page: *c.* 1990s. Antonio D'Agostino with oceanographic equipment.
Right Page, Top: *c.* 1990s. Centre print shop staff.
Below Left: *c.* 1990s. Oddbjørn Bergem gives a tour of the Centre.
Below Right: *c.* 1990s. Roberto Della Maggiora uses the calibration bath.

Above: *c.* 1990s. Piero Guerrini and Mauro Vittozzi run experiments at sea.

In the early ´90s the Centre´s Military Oceanography and Engineering Technology departments developed a number of instruments to carry out REA surveys more effectively. The Expendable Bottom Penetrometer, developed in collaboration with Columbia University in the United States, could be launched from a ship, an aircraft or a submarine, and was used to assess sea floor geotechnical properties of relevance to mine burial. The first survey was carried out in support of naval exercise Rapid Response 1996, involving naval and air assets provided by many NATO Nations.

c. 1990s. A crew member deploys undersea calibration targets.

Above: *c.* 1990s. Claudio Sisti works in the computer lab onboard the NRV *Alliance*.



Above: *c.* 1990s. Researchers work with digital equipment onboard the *NRV Alliance*.

In addition to research in antisubmarine warfare and military oceanography, operational research was an important activity at the Centre. Mostly dedicated to 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. Leveraging the knowledge acquired from different areas of expertise, and showing how a multidisciplinary approach could produce useful tools for warfighters, the Centre was asked by several naval commands to provide them with antisubmarine warfare and mine countermeasures planning tools. The Centre was also involved in studies related to changes in naval forces and in exercise evaluation. In order to optimize the protection of shipping vessels in the Mediterranean, the Commander Allied Naval Forces Southern Europe requested support for planning antisubmarine warfare operations. In 1999, the Centre delivered a prototype software that provided guidance on safe convoy routes and search planning, enabling commanders to assess antisubmarine warfare mission effectiveness.


1991. Aerial view of the Centre.

Above: *c.* 1990s. Pilot whales swim near the NRV *Alliance* during a sea trial.

Through the Sound Ocean Living Marine Resources programme, established in 1999, researchers visually and acoustically monitored and acquired information on marine mammals living in a vast area in the north-west Mediterranean Sea. During the 1999 experiment, 146 sighting events occurred and 869 individual animals were observed.

Above: Dolphins swim near the NRV *Alliance*.

c. 1990s. Researchers and crew onboard the NRV *Alliance*.

A New Millennium: The Early 2000´s

One of the declarations of the 2002 Prague Summit was a commitment to reorganize NATO´s military command structure to become leaner, more efficient and more effective. One result of the reorganization was a broadening of the mandate of the Centre to include above water warfare and maritime asymmetric warfare. On 19 June 2003 the Centre´s name was changed from SACLANTCEN to NATO Undersea Research Centre, referred to as NURC.

In response to its refreshed mandate, the Centre began new work in underwater communications, big data analytics and autonomous systems that together led to powerful new concepts in antisubmarine warfare, naval mine countermeasures and maritime situational awareness. The Centre assumed a pivotal role in advancing communications between autonomous underwater systems culminating in networked squads of collaborating underwater autonomous vehicles.

Right: *c.* 2000s. Italian, NATO, NATO Allied Command Transformation and NURC flags raised in La Spezia.

The new areas of research required a suitable support ship. The Centre´s Ship Management Office developed the mission profile and requirements for a new ship comparable in size to the *Manning* but with capabilities similar to the NRV *Alliance*, such as low acoustic radiated noise. The Coastal Research Vessel (CRV) *Leonardo* was commissioned in La Spezia on 06 September 2002. The new ship, measuring 27.5 m long, with a 260 ton displacement, was equipped with a dynamic position system and could sail in silent mode at speeds up to five knots. With berthing space for 10 people, CRV *Leonardo* can host up to 15 persons for a day cruise and can host a six metre laboratory container that augments the 35 m^2 onboard laboratory space. The design of CRV *Leonardo* anticipated the requirement to support the Centre´s rapidly growing use of autonomous vehicles.

Left: *c.* 2002. The CRV *Leonardo* sails in La Spezia.

2013. The NRV *Alliance* and CRV *Leonardo* sail together in the Ligurian Sea.

Above: 2002. Centre staff document deep sea communications tests.

The Centre remained at the forefront of military oceanography by expanding its domain into coupled atmospheric-oceanographic measurement and modelling. Aided by ever-increasing computational power and the availability of satellite remote-sensing data, better predictions of ocean conditions were achieved. This improved NATO's ability to plan for maritime missions, especially in coastal waters.

Above: *c.* 2000s. Researchers onboard the NRV *Alliance* run deep sea communications experiments.

Above: 2010. Staff recover the Ocean Explorer autonomous underwater vehicle after an experiment.

As early as 1988 Centre scientists and engineers were exploring the potential of autonomous underwater vehicles, a concept made possible through advances in artificial intelligence and the decreasing size and cost of computers. In 1999, the Centre secured funding for its first autonomous underwater vehicle, embarking on a new era of research. In 2002, the Ocean Explorer autonomous underwater vehicle was procured from Florida Atlantic University. The Ocean Explorer vehicle gathers information on

Above: 2016. The Ocean Explorer vehicle operates near the NRV *Alliance* during an experiment.

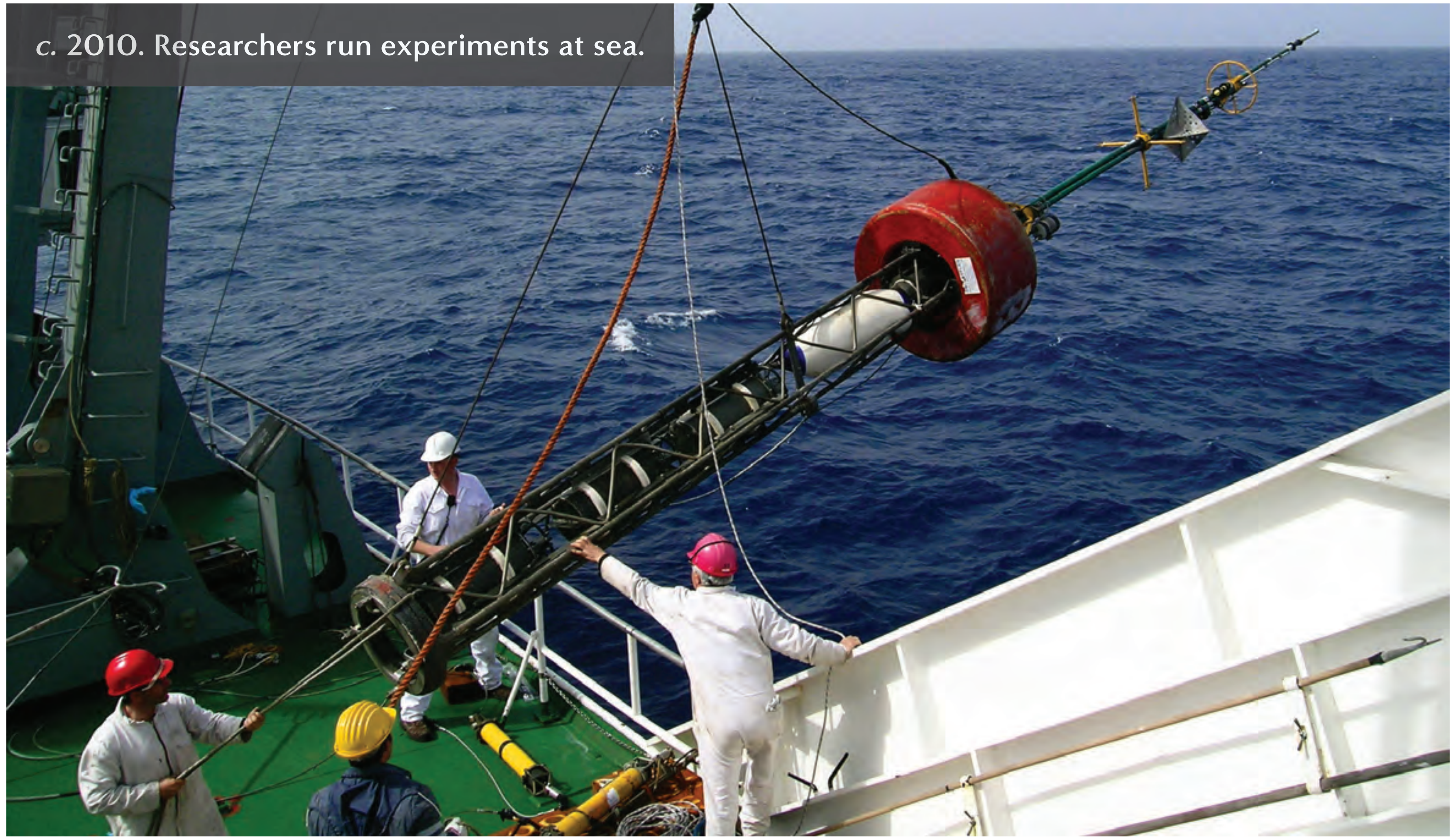
the presence of objects of interest in the underwater environment. In the first tests in the early 2000s, the vehicle performed closely spaced tracks over target positions in order to acquire video and sonar images of the objects. Now, having undergone significant modifications at the Centre, the Ocean Explorer vehicle can adapt to dynamic underwater conditions and is used in a range of programmes, including antisubmarine warfare.

In February 2003, the process of designing the requirements for the Centre's first autonomous underwater vehicle dedicated to naval mine countermeasures began. In 2006, the Minehunting Unmanned Underwater Vehicle for Shallow Water Covert Littoral Expeditions (MUSCLE) ran its first sea trials. This autonomous vehicle, typically equipped with navigation, communication and computation equipment, also carries a synthetic aperture sonar, one of the most advanced systems of that period. The Centre developed programmes around minehunting sonar performance models and the improvement of synthetic aperture sonar with increased detection range and maximum platform speeds. Centre researchers took part in several NATO and national exercises. These activities marked the first stage towards the development of systems based on several networked unmanned underwater vehicles equipped with sonar non-acoustic sensors and data fusion capabilities in order to improve the deployability, speed and effectiveness of naval mine countermeasures operations.

Right: *c.* 2008. A MUSCLE vehicle lifted on to the NRV *Alliance*.

In 2007, Maritime Situational Awareness was added to the Centre's portfolio of research programmes. The objective was to develop tools to detect abnormal movements of ships by exploiting Automatic Information System (AIS) data from ships and fusing it with data from other sensors such as satellite imagery. A Maritime Data Simulator was developed to help in the optimization of surveillance assets needed to cover a specific area.

Left Page: 2007. Tomas Folegot, Domenico Galletti and Andrea Cavanna test a monitoring system made from thermistor chains to measure the water temperature profile.
Photo by: Andrea Cavanna.
Right Page, Top: 2008. Centre staff launching the MUSCLE vehicle.
Below: *c.* 2000s. Researcher listening for acoustic signatures on the NRV *Alliance* during a sea trail.



c. 2010. Researchers run experiments at sea.

Meanwhile, advances in submarine technology continued, leading to the proliferation of stealthier, long-endurance and highly manoeuvrable submarines. The Centre maintained its focus on its original mandate of antisubmarine warfare by improving target detection, tracking, classification, and reducing false alarm rates caused by clutter. One of the techniques the Centre pioneered was multistatic sonar; by using multiple sonar receivers and sources simultaneously, the probability of detection of a submarine and the coverage area were greatly increased compared to conventional sonar. The Cooperative Antisubmarine Warfare programme, started in 2009, successfully demonstrated multistatic sonar capabilities in multiple NATO exercises, paving the way to the use of underwater autonomous vehicles as a key part of a multistatic sonar system.

2002. The Hellenic Navy submarine HS *Triton* with the NRV *Alliance* during the Broadband Adaptive Sonar Experiment. This antisubmarine warfare trial, conducted over the Malta Plateau in November 2002, was the first to fully utilize the recently acquired broadband active sonar capability and the newly commissioned CRV *Leonardo.*

Toward the Future:
2010 and Beyond

At the November 2010 Lisbon Summit, NATO Heads of State and Government endorsed a new strategy of continual reform to maximize efficiency. One result of the strategy was the establishment in 2012 of the NATO Science and Technology Organization (STO) with the mission to position the Alliance's science and technology investments in areas that most benefit defence and security.

The Centre became a NATO body within the STO and transitioned from being common funded by the 29 Allied Nations to a new customer-funded model. As a result of these changes and in recognition of the importance of the Centre's role in at-sea experimentation and demonstration, the name of the Centre was changed to the Centre for Maritime Research and Experimentation (CMRE). The refreshed mission of the Centre is organizing and conducting maritime scientific research, technology development, and experimentation to deliver innovative and field-tested science and technology solutions to address the maritime defence and security needs of the Alliance.

Right: 2019. Marco Padi on one of the Centre's Rigid Hull Inflatable Boats (RHIB) completing mine countermeasures experiments with the Centre's 21-inch Bluefin underwater autonomous vehicles.

CMRE has established closer ties with the operational community. The Centre has a unique capability to support a range of areas through the introduction of prototypes (hardware and software), analyst support, and at-sea demonstration during maritime exercises.

In 2017, the Centre worked with Allied Maritime Command to introduce Maritime Unmanned Systems (MUS) into antisubmarine warfare exercises.

Left Page, Top: 2017. The TCG *Dolunay* carries out a series of trials with the NRV *Alliance* during the Antisubmarine Warfare Operational Deployment of Concepts (ASW-ODC) exercise.
Below Left: 2017. CMRE staff deploy a gateway buoy during Dynamic Monarch 2017.
Below Right: 2017. CMRE staff deploy underwater acoustic equipment during Dynamic Monarch 2017.
Right Page: 2018. CMRE staff and a Portuguese Naval officer stand onboard the NRP *Arpao* during the execution of the Recognized Environmental Picture Atlantic 2018 exercise.

2018. CMRE staff launch the Deployable Multistatic Sonar System source buoy during a sea trial.

Above: 2019. CMRE Modelling and Simulation team.

CMRE is a recognized centre of world-class expertise in maritime unmanned systems, autonomy, big data and deep-learning. The Centre continues to conduct cutting-edge maritime experimentation and demonstration in extremely challenging ocean conditions from the

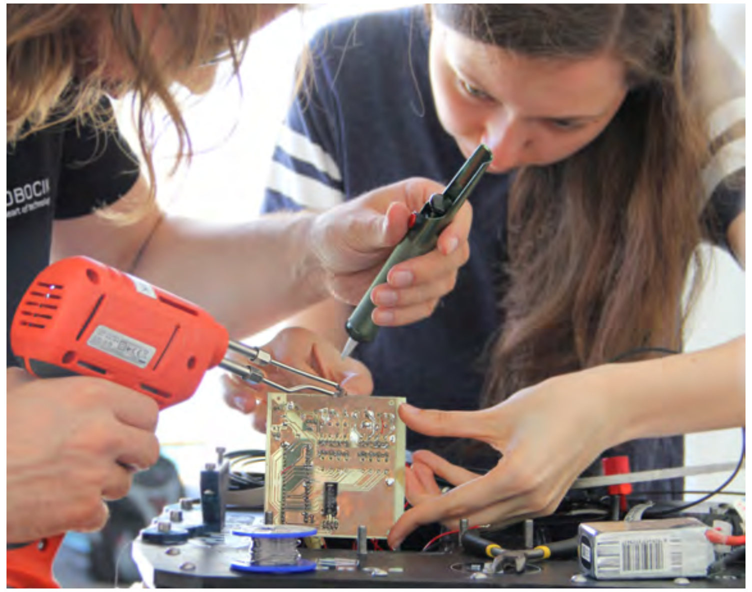
Above: 2019. CMRE Modelling and Simulation team.

Mediterranean Sea to the Arctic Ocean. It provides an outstanding at-sea research environment where internationally recognized scientists and engineers from NATO Nations share their knowledge while delivering results more economically than would be possible by individual nations.

2019. CMRE staff at work.

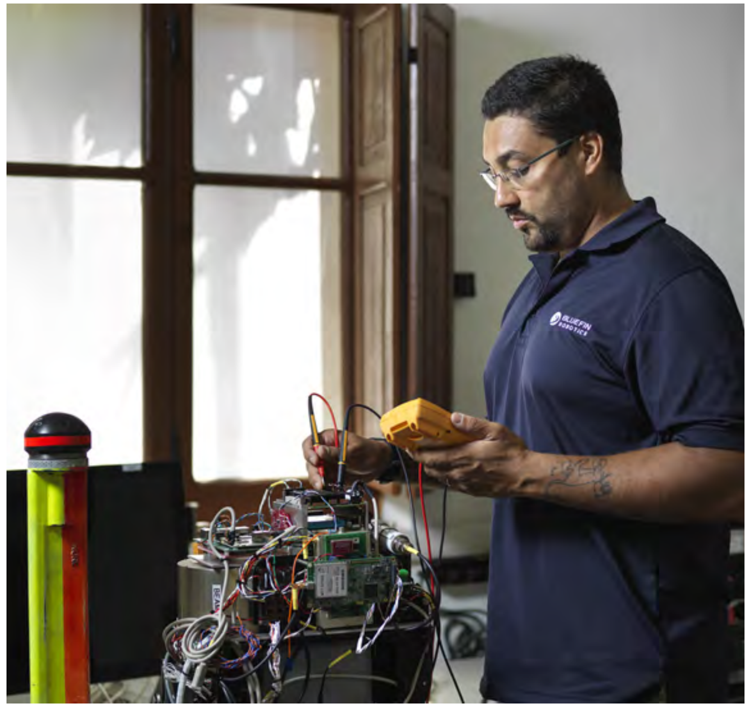
Above: 2019. CMRE Director Dr Catherine Warner, Italian Naval officers and staff with local high school students onboard the CRV *Leonardo*.

Outreach to local and international science and engineering students is part of CMRE's programme. In 2010, the Centre began hosting the Student Autonomous Challenge-Europe (SAUC-E). This robotics tournament that has become the leading student autonomous underwater vehicle competition in Europe, brings the researchers of tomorrow to CMRE. In 2019, CMRE welcomed local high school students to study underwater acoustics onboard the CRV *Leonardo*.



Right: 2019. European Robotics League Tournament hosted by CMRE.

The Centre remains at the forefront of international efforts to develop and demonstrate maritime unmanned and autonomous systems to enhance warfighting capability. These systems will create fundamental shifts in the conduct of naval operations. The Centre´s research is essential for the realization of future maritime forces that will be a hybrid of manned and unmanned systems. CMRE´s contribution focuses on developing and testing concepts at sea and establishing interoperability among technologies, mitigating the risk of the introduction of unmanned systems to the maritime operational community. The Centre´s contribution is exemplified through the JANUS underwater communication protocol that specifies a modulation and coding scheme for underwater acoustic communications, which was developed at the Centre and recently adopted as a NATO standard.



Right: 2019. Engineers at work at CMRE.

2018. An engineering trial with autonomous underwater vehicles onboard the CRV *Leonardo* in the Ligurian Sea.

2018. NRV *Alliance* in the High North.

2019. The Italian Navy has operated the NRV *Alliance* since 2016.

2017. NRV *Alliance* participated in the NATO antisubmarine warfare exercise Dynamic Mongoose held between Norway and Iceland.

At its 60th anniversary, the Centre for Maritime Research and Experimentation has established itself as a maritime collaboration hub within NATO to accelerate the development and introduction of new technologies while ensuring interoperability. As Nations commence the journey to unmanned autonomous maritime solutions, CMRE will be instrumental in ensuring a smooth transition to these new capabilities. Today the Centre is at the forefront of new research areas in autonomy and big data analytics, and their maritime applications. As new science emerges in artificial intelligence and autonomy, the Centre will continue to fulfil its mission to organize and conduct scientific research and technology development and deliver innovative and field-tested S&T solutions in the maritime domain to address the defence and security needs of the Alliance, supporting NATO´s goal of maintaining a technological edge.

Left: 2018. Standing NATO Mine Countermeasures Group 2 staff, HMS *Enterprise* crew and CMRE scientists during Italian Minex 18.

October 2019

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NATO
OTAN
S&T
organization
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