NURC: CELEBRATING 50 YEARS OF INTERNATIONAL PARTNERSHIPS IN OCEAN RESEARCH AND OPERATIONS

Project 20 Low-Frequency Active Sonar

The Successful Union of Oceanographic and Systems R&D Disciplines at the NATO Undersea Research Centre and Elsewhere

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This paper documents and illustrates how the original SACLANTCEN/NURC (Supreme Allied Command Atlantic Undersea Research Centre/NATO Undersea Research Centre) project initially known as the Active Adjunct Project, or Project 20, naturally led not only to increased cooperation and interaction among individuals, programs, and the systems and oceanographic research divisions and support groups within the Centre itself, but also, in a broader way, served as a catalyst for improved and increased international cooperation and collaboration. Over the past 50 years, these interactions contributed to new understandings and breakthroughs in ocean research. Evidence of the continuing success and emphasis can be seen in the name change from the original NATO SACLANT Anti-Submarine Warfare (ASW) Research Centre to NATO SACLANT Undersea Research Centre and, eventually, to the present and geographically broader NATO Undersea Research Centre (NURC).

When author Tompkins first started working at the Centre in 1979, a director and deputy director headed an organization made up of Systems and Undersea scientific research divisions—with most of their scientific and engineering personnel coming from the different NATO nations on a rotating basis—and several technical support divisions covering computers, electronics, mechanics, and research ships.

The Active Adjunct concept was basically a low-frequency active sonar system that employed a passive towed sonar array as the receiver in conjunction with a high-power, low- to mid-frequency (100–800 Hz) transmit sound source (towed or otherwise). The use of these larger receiving arrays, in contrast to conventional (and mostly hull-mounted) active sonars, was necessitated by the use of the much lower-frequency active sonar transmit waveforms employed by the Active Adjunct Project for the detection, localization, tracking, and classification of submarines. In contrast, most known NATO tactical active sonar systems for ASW operated at frequencies above several kilohertz and mostly used either bow- or hull-mounted arrays of elements for transmission and reception. For example, the US AN/SQS-26 bow-mounted surface ship transmit/receive active sonar array system used some of the lowest known frequencies at that time (approximately 2.5–4.0 kHz).

The need for new sonar systems with improved detection, tracking, and localization performance against submarines was driven by decreases in passive sonar performance against threat submarines that had become quieter through modern silencing applications, the use of hull coatings for both reduced radiated noise and active sonar echo strengths (at least at frequencies above 1000 Hz or so), and the proliferation of diesel-electric submarines that were inherently quiet when operating on battery.

Active Adjunct - 1979
SACLANT Undersea Research Centre

- Concern over threat submarine quieting and battery operation
- Adm Jackson approves active adjunct R&D at SACLANTCEN
- Director Basil Lythall's encourages new ideas
- Optimum frequency of Hastrup, Akal, Kuperman, and Jensen (Centre Scientists, JASA, pg 813, Vol. 78, March 1983)

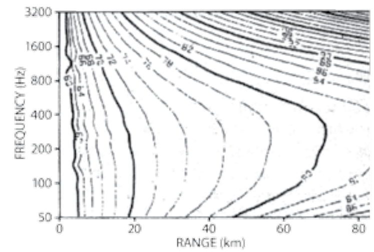

Figure 1. Factors leading to the development of the Low frequency Active Sonar Adjunct Project and model predictions of propagation loss (in decibels) for a Mediterranean Sea summer environment showing strong preferential frequency dependence (approximately 100–800 Hz).

The idea for such a new sonar system configuration and a proposal to initiate it at the Centre can be credited to then Deputy Director Stan Lemon. Prior to his arrival at the Centre, Lemon was particularly well known for his innovative and successful towed array systems development, design, and demonstration efforts in the United States going back to the mid-1960s and earlier.

Another contributing and encouraging factor for pursuit of this concept came from a series of Mediterranean sound propagation loss measurements (supported by various computer model predictions) conducted by Centre oceanography division scientists including Ole Hastrup, Tuncay Akal, Bill Kuperman, and Finn Jensen (Figure 1). These data show that for intermediate source and receiver depths in a summer environment, there is a preferred frequency region, ranging from about 100–800 Hz where propagation loss is significantly less than for any other exploitable regime. This is particularly important for active-sonar applications where two-way propagation loss from source-target-receiver is involved.

In 1981, author Tompkins presented a formal proposal to the Scientific Committee of National Representatives (SCNR) that had technical oversight of the Centre's programs and provided advice and recommendations to the NATO command for which the Centre worked at that time (SACLANT). The committee accepted this proposal and established a new Centre project—the Active Adjunct Project.

As is often the case, this project was structured around existing Centre resources that included a Prakla-Seismos towed array of 64 passive receiving elements spaced one meter apart and a towed sound source on loan from the United States consisting of flextensional transducers operating at a center frequency of 350 Hz. The general approach for this project was to conduct a series of controlled, low-frequency, active sonar systems research investigations from the Centre's research vessel *Maria Paolina G.* under a variety of environmental conditions, using existing Centre hardware complemented by existing and future oceanographic research data, at-sea investigations, and computer modeling. Figures 2, 3, and 4 show NURC and US personnel at sea conducting joint experiments as well as executing towed array repairs, and preparations in the Centre's towed-array lab prior to testing.

To experimentally examine the Active Sonar Adjunct concept feasibility, the plan naturally focused on those primary parameters essential to concept performance and included measurements of low-frequency submarine target strength, reverberation, noise, signal coherence, and propagation loss for those oceanographic environments of interest and concern to NATO and its member nations. We knew from the beginning that the project would

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Figure 2. View of R/V *Maria Paolina G.* main lab during joint sea trials with the United States in about 1980.

Figure 3. NURC preparing towed active sonar receiving array for joint experiments undertaken around 1980 with the United States.

Figure 4. Another view of R/V *Maria Paolina G.* main lab during the 1980 sea trials with the United States.

have to rely heavily on support—and cooperation—from individual nations in critical areas, such as in the use of submarine services and hardware, and, similarly, on the Centre's own oceanographic research division.

The Centre conducted a series of some seven sea trials in the Mediterranean through 1984 in different seasonal and deep- and shallow-water environments. Four of those experiments specifically involved the support of submarines from different NATO nations specifically for target-strength measurements and detection experiments at the unusually low active-sonar frequencies involved. In general, project scientists found that good (long) detection ranges were achieved in a variety of environments and that results agreed well with predictions made using the Centre's oceanographic models and databases. They were encouraged to find that coherent signal processing gains generally increased with increasing transmit pulse lengths and that the spatial coherence across the entire receiving array aperture was always high (near theoretical projection).

Cooperation and involvement with individual NATO nations had already begun during these experiments using, for example, submarine services from France and Italy for at-sea testing and measurements.

In addition to these initially favorable and very encouraging results, it also was discovered that, using CW, linear, and, later, hyperbolic FM pulses and explosive sources, beam aspect target strength values were in good agreement and in the expected range from 15–25 dB at beam aspect, but that off-beam aspect target strength values at frequencies below approximately 700 Hz were much lower in amplitude.

Some other significant and important instances of cooperation between the Centre and the individual nations of France, United Kingdom, and Holland began around this time. They involved the exchange of target strength information for both numerical model predictions and physical-scale model measurements. The mutual benefits of such exchanges were obvious and appreciated by all parties, and subsequently led to increased efforts of cooperation and mutual—and third-party—benefit.

Throughout the project, it was obvious—and of concern—that perhaps the most difficult environmental or oceanographic effect to predict, model, or even understand was reverberation backscattering from the seafloor and subbottom features, including seamounts and smaller-scale, unidentified phenomena. Although model predictions and experimental results confirmed that surface reverberation normally occurs only at short ranges and no volume reverberation was observed at all early on, we repeatedly observed that reverberation associated with backscattering from rough seafloor features even at low grazing angles and from unidentified bathymetric features in apparently "clean" areas were major sources of system interference and, therefore, performance limitations.

Figure 5 shows some examples of reverberation interference in the Strait of Sicily during a cooperative US Naval Research Laboratory/SACLANTCEN project where we observed strong bathymetry reverberation from coastlines, seamounts, sharp-gradient areas, and oil rigs with some correlation to known features from existing databases—but not always. In addition, strong bottom reverberation clutter from supposedly "clean" regions was observed where no features were evident in subsequent side-scan and fathometer surveys, although some possible contributors were subsequently identified in seismic profile data. These large and widely distributed regions of strong and unanticipated reverberation clutter highlighted the possible need for cooperative, in situ mapping in areas crucial to NATO and individual nations, as well as scientific investigation into their cause. In fact, similar areas of unanticipated reverberation interference were encountered in subsequent US/Centre experiments in these straits and off the east coast of Spain.

In subsequent years, a series of joint, cooperative sea trials and experiments involving French towed-array ships and a French submarine in the Gulf of Lyon included mono- and bistatic operations. These were followed in the 1980s and into the 1990s by experiments in the southwestern approaches to the English Channel, in and outside the Mediterranean, in the North Sea (with the Federal Republic of Germany), in the Vestfjord off the coast of Norway (with Norway), and later, within the Mediterranean (with the Netherlands and with Germany). These joint experimental efforts were primarily in support of systems-development programs within the nations mentioned and also fostered subsequent joint cooperative programs between some of the individual nations themselves.

In 1994, author Tompkins, Centre oceanographic and systems research personnel, and representatives from Federal Republic of Germany, United Kingdom, and several US research and development laboratories attended a Shallow Water Active Sonar Surveillance Workshop hosted by the Centre. Those attending agreed on various undersea systems and environmental aspects requiring further research, identified several new areas of collaboration, and formulated more detailed plans in already established areas of cooperation.

After more than two and a half decades since its inception, the Active Adjunct Project has led not just to increased cooperation and interaction among individuals and programs of the Oceanographic and Systems research divisions and the support groups within the Centre itself, but also, in a broader way, it also has served as a catalyst for improved and increased international cooperation and collaboration among NATO nations. This successful interaction is a result of the Centre's unique assets and capabilities, including dedicated research ships, computer models and databases, and personnel trained and experienced in the areas of oceanographic and undersea systems research, which all complement or supplement those of any individual nation. It is also a result of the important fact that, fundamentally, undersea systems like sonars cannot be properly designed and used without full consideration of the science of the environment in which they must operate—in this case, oceanography. This is, of course, a lesson applicable to almost any scientific discipline.

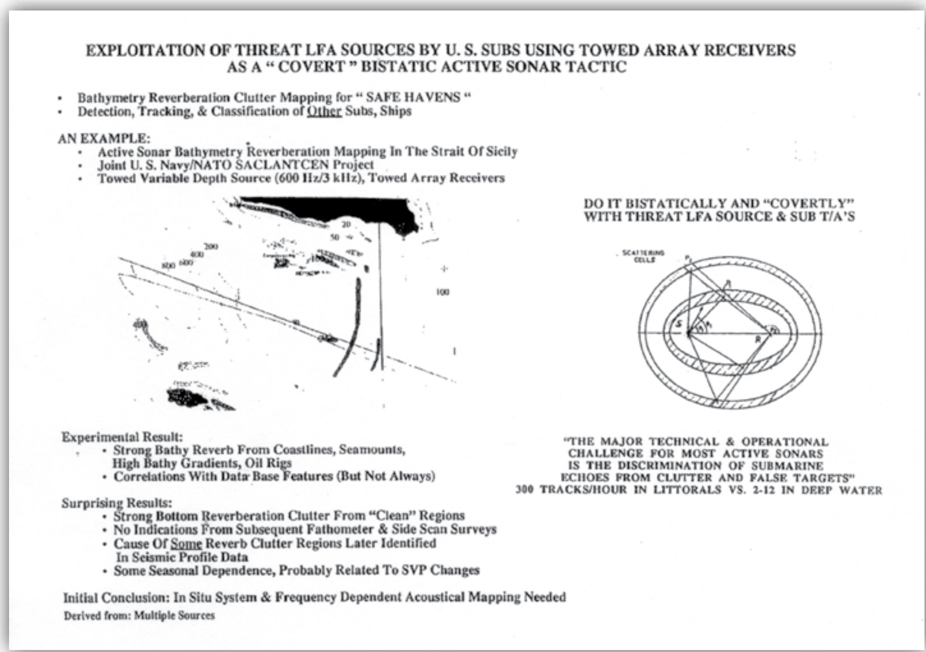

Figure 5. Actual example of unexpected bottom reverberation clutter as measured in the Strait of Sicily during a joint US/NATO Undersea Research Centre cooperative experiment.