WTEC Panel Report on

Research Submersibles And Undersea Technologies

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TABLE OF CONTENTS

2. Sensors and Instrumentation

Algis N. Kalvaitis

3. Energy, Propulsion, and Hydrodynamics

Don Walsh

4. Manned Submersibles

Brad Mooney

5. Unmanned Systems

Claude P. Brancart

6. Applications of Acoustic Technology

Richard Blidberg

7. Systems Engineering and Integration

Larry L. Gentry

8. Navigation, Communication, Automation and Control

Michael J. Lee

APPENDICES

B. Russian Site Reports

- Intershelf (Moscow)
- Intershelf (J.P. Kenny Intershelf)
- Intershelf (St. Petersburg)
- Kharax Company Ltd.
- KOPRON
- Krylov Shipbuilding Research Institute
- RRC Kurchatov Institute
- Lazurit Central Design Bureau
- Malachite
- Oceanpribor
- P.P. Shirshov Institute of Oceanology (May 17,'93)
- P.P. Shirshov Institute of Oceanology (May 20,'93)
- Central Design Bureau for Marine Engineering (RUBIN)
- Scientific Research Institute of Computer Complexes (NIIVK)
- St. Petersburg State University of Ocean Technology

C. Ukrainian Site Reports

- E.O. Paton Electric Welding Institute
- Institute of Geological Sciences
- Institute of Hydromechanics
- Mariecoprom
- Marine Hydrophysical Institute

D. French Site Reports

- IFREMER
- INRIA
- LIFIA

E. United Kingdom Site Reports

- Institute of Oceanographic Sciences - Deacon Laboratory
- Marconi Underwater Systems
- Reson System (UK)
- Slingsby Engineering Ltd.
- Marine Technology Directorate (MTD)
- Camera Alive Ltd.
- Heriot-Watt University
- Mobil North Sea Ltd.
- Tritech International Ltd.
- Marconi UDI

F. Finnish Site Reports

- Rauma Oceanics Ltd.

G. **Glossary**

WTEC Welcome Page

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EXECUTIVE SUMMARY

BACKGROUND

The World Technology Evaluation Center (WTEC) panel on Research Submersibles and Undersea Technologies was formed to review the state of the art in this broad field within the countries of the former Soviet Union (FSU), particularly Russia and Ukraine, and in selected Western European countries. The panel visited leading companies, academic research programs, and government laboratories in Finland, France, Russia, Ukraine and the United Kingdom. Because of the large geographic area and the breadth and technical complexity of the subject, the study could not be comprehensive. However, by carefully selecting the sites to be visited -- based upon the substantial prior knowledge of many committee members -- it was possible to acquire a meaningful evaluation. The end of the Cold War and the resulting efforts to commercialize some military technology, plus the increased utilization of sophisticated equipment in the exploration for and production of oil and gas in the North Sea, had led the sponsors of this study to the belief that a review of subsea technology in this geographical area would be productive. This was verified by the panel's findings.

Because much less was known a priori about the technologies in Russia and the Ukraine, there were more new findings in those countries than in the Western European nations visited. Some general conclusions will be drawn based upon the panel's overall experiences, and these will be followed by more specific conclusions in each of the study's subject areas.

There is a pronounced emphasis in the United Kingdom on the development of advanced sensors and affordable autonomous and remotely operated vehicles. These vehicles are being developed for use in both the research community and the offshore industry.

Research and development is being conducted in the United Kingdom and in France on developing very great endurance (hundreds of kilometers to full ocean width) for autonomous vehicles.

Europe is making substantial progress in cooperative and coordinated research in subsea technology, including the development of standards. No such cooperative research and development is underway in the United States, which may have a significant impact on future competitiveness.

The economic stimulus for subsea technology development in Western Europe appears to be largely to support fisheries management and offshore oil and gas production.

All of the countries visited and all of the agencies interviewed see shrinking horizons for research and development and for economic opportunities in this field.

Russia and Ukraine have developed a highly educated and experienced manpower pool, skilled in almost all phases of subsea technology, that is substantially underutilized at this time. Russia and Ukraine possess impressive, and in some cases unique, facilities for physical testing. These assets are also underutilized and offer opportunities at very low cost for Western nations.

Researchers in Russia and Ukraine have extremely limited computing facilities compared to Western engineers in this field. As a result, researchers there take a strong theoretical or analytical approach to most problems, which appears to be very valuable. It has also resulted in an ability to write extremely efficient computer code to facilitate numerical analyses and signal processing on limited computer platforms. Given the ready availability of large platforms in the West and the greater difficulties in maintaining tightly coded programs, it is not clear that this capability represents a technological asset to the rest of the world.

Russia and Ukraine possess extensive fleets of seagoing research vessels capable of long voyages and possessing state-of-the-art facilities for conducting oceanographic investigations. With the exception of those vessels under contract to Western nations, these vessels are largely inactive at this time.

Russia and Ukraine have a philosophy of including human presence in nearly all subsea geophysical and oceanographic investigations. They have produced an impressive variety of manned research submersibles, again largely unused at this time. The beginning of research on autonomous vehicles in Russia means that country has, in effect, largely skipped the development of conventional cable-controlled remotely operated vehicles.

The panel principally visited government entities in Russia. In a few cases, it was possible to visit newly formed commercial companies associated with such centers. It became apparent that large numbers of companies with shared personnel and objectives have been established surrounding many of the important "mother" research and development facilities, and that these companies form sources of technology and commercial capability that were not adequately assessed by the panel.

Many of the panel's observations can be assumed to represent only the general state of the art in the research and development laboratories in that country. That is, there are almost certainly more advanced technical investigations and facilities that the panel was not able to visit.

SPECIFIC CONCLUSIONS

Sensors and Instrumentation

Deep ocean submersibles, such as the Mirs (Russia) and Nautile (France), continue to be effective platforms for undersea work and research because of their extensive sensor, instrumentation, and manipulative capability. Some scientists consider the Mir submersibles, built by Rauma in Finland, to be the best equipped and most capable research tools for deep sea (6,000 m) research.

Although Russia and Ukraine have developed limited remote sensing capability for ocean studies using Lidar and acoustic Doppler current profilers, these designs are not unique and are within the current international state of practice.

The countries of the FSU are marketing oceanographic instruments (such as conductivity, temperature, and depth, or CTDs, and current meters). Their data quality is unknown, and intercalibrations should be conducted to determine measurement capabilities. Other factors, such as reliability, maintainability, and service must also be addressed. Prices are currently quite low, but this may be a short-term situation that will eventually change to correlate more closely to Western prices.

Several European countries outside of the FSU are actively developing research-type remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs). The European Economic Community is supporting as major programs unmanned platforms for undersea and oceanographic research using enhanced sensors and samplers. This is in marked contrast to the United States, where there is no major focused thrust for developing scientific AUVs.

Energy, Hydrodynamics, and Propulsion

Energy. The WTEC teams did not see any particularly new concepts in energy systems at any of the sites visited. However, at the same time, panelists were impressed with the variety of sources being used, or designed for use, in underwater vehicles. The spectrum of systems in use in the FSU range from small, simplified nuclear reactors to conventional lead-acid batteries (used in the numerous manned submersibles in the FSU). In Europe, the panel found fuel cells, semi-fuel cells, Rankine Cycle engines, Sterling Cycle engines, and hydrazine gas generators all presently at sea onboard various vehicle platforms.

In Russia, the most impressive directions were nuclear power systems (first developed for military submarines) and fuel cells (first developed for the space program). While the fuel cells were of conventional design, several had been built and many hours had been logged in spaceflight conditions.

In Europe there was a clear developmental trend towards high energy density energy sources such as the Rankine, Sterling, and Hydrazine-powered engines. The semi-fuel cells, such as Alupower's aluminum oxygen battery, offer long-duration power supplies that can make AUVs true underwater satellites. As in Russia, there was very little research and development work evident in storage battery technologies. Most designers were using advanced concept batteries from the automotive and aerospace sectors.

Hydrodynamics. Design of both relatively slow-speed manned submersibles and remotely operated vehicles is less dependent on hydrodynamic considerations than are high speed vehicles. For military submarines and torpedoes, speed is a virtue. For long-duration autonomous unmanned vehicles, onboard energy conservation is critical to permit prolonged mission times.

As might be expected, the former Soviet Union has an extensive family of organizations and institutions concerned with hydrodynamics. Having the largest and most diverse submarine force in the world required a major technical support base. While this was evident to the WTEC teams, unfortunately, not much of this work has direct relevance to deep submergence technologies, the primary subject under investigation.

Propulsion. Efficient conversion of energy to propulsive force/thrust is critically important to manned submersibles, remotely operated vehicles, and autonomous unmanned vehicles. Here energy conservation and the resulting tradeoffs are key concerns of the designer. However, with the exception of the work being done with the Autosub project in England, the panelists did not see much research and development work in this area. At several of the sites in Russia, there was some mention made of work they were doing in propulsion for high speed submarines, but no documentation was provided.

On a much larger application scale, the Russians are doing work in magneto-hydrodynamic propulsion (MHD), and in the Ukraine there is ongoing work on mechanical emulation of fish swimming motions. But in both cases it is difficult to see how these mega-technologies can be applied to deep submersible vehicles.

Manned Submersibles

There is great interest among ocean engineers and ocean researchers in the former Soviet Union in manned submersibles and tourist submarines. Previous interest in manned submersibles in the United Kingdom has been replaced by remotely operated vehicles and a growing effort in autonomous underwater vehicles. IFREMER, in France, continues to support the notion of placing man in situ using Nautile.

The WTEC group was surprised by the variety and number of manned submersibles built in the FSU, in operation now, and planned for the future. Several visited activities, mostly those that have been either involved in manned submersibles or military submarines in the past, now have tourist submarine plans on their drawing boards. (Computer-aided design is essentially unavailable.)

The existing manned submersibles are fundamental, low cost, uncomplicated, reliable, tested, and available. Ocean researchers are enthusiastic users who are quite satisfied with the capabilities of these tools. The ability to use and fabricate titanium in undersea vehicles in Russia and Ukraine is advanced. The acceptability of Russian Registry Certification by Western insurance companies needs to be examined carefully before contracting for use of manned submersibles built in the FSU.

Academically, industrially and operationally, the existing manned submersible base in Russia and Ukraine is truly impressive and has great potential.

Unmanned Submersibles

Great Britain and France. Slingsby Engineering Ltd. (SEL), located north of London, is the major large ROV supplier in Great Britain. The company's only competition is Perry Tritech, a Florida-based company owned by a French company (Coflexip) and International Submarine Engineering (ISE) of Port Coquitlan, B.C., Canada. SEL identifies the customer needs and designs the hardware accordingly, as is the case with its MRV ROV. Where needed, SEL continues to improve the components. SEL will remain a small organization because the customer market is small and because more user/service companies are fabricating their own special purpose ROVs.

The Mobil-FSSL project is a typical example of a major oil company starting with a large working ROV (the SEL MRV) and adding specialty tools to undertake major underwater tasks. This trend will continue.

Great Britain has a respectable position in scientific unmanned systems. The Deacon Laboratory Autosub project is very ambitious but must wait at least five more years to see final results. The Marconi ODAS vehicle, based on torpedo technology, could have a major impact on the scientific community because of its low cost.

The observed trend is for universities to take a narrower view of technology development because of funding constraints. Also there is a cooperative culture for technology development, not just within Great Britain, but within the European Community. A prime example of this is the European Community Marine Science and Technology (MAST) research programs. A new MAST program aimed at furthering autonomous underwater vehicles is the Advanced Research for Unmanned Autonomous Underwater Vehicles. The contributors to this program are Deacon Laboratory and DRA from Great Britain, IFREMER, ECA, and INRIA from France, the National Technical University of Athens, Greece, and Institute Hidrogr fico in Portugal. There may be something to learn from this type of cooperative technology development, especially in a tight money environment.

Former Soviet Union. Russia's present position relative to the Western world is difficult to establish. The country's low-cost ROVs are dated technology. However, the operating techniques of Russia's 6,000 m ROV systems have much to offer. There is nothing technologically exciting about their unmanned systems, primarily because the nation's efforts have been concentrated on manned systems.

The observed trend is for members of universities and governmental agencies to form private ventures in an effort to generate needed funds. There are many ventures formed to develop tourist submarines. This is disappointing because the world market for tourist submarines is already nearly saturated. Another trend is for foreign firms to form teaming agreements with individuals and facilities to conduct business on a world-wide basis. The Intershelf company of Russia demonstrates this trend. Russia must overcome the credibility and logistic support gap before it can compete in the world markets for underwater unmanned systems.

Acoustic Applications

In Western Europe the technology developments are very similar to those efforts in the United States. Some of Western Europe's sonar imaging systems are more interesting than similar units manufactured in the United States due to price and performance issues. In the FSU the situation is different. The following observations relate mostly to what was seen in Russia and Ukraine.

Understanding of Basic Theory. The researchers participating in the discussions were very clearly aware of the basic principles of the technology with which they were involved. Possibly the limitation of computer capability and the need for efficient problem solving has forced this need for in-depth basic understanding. This is clearly different in the United States, where computer capability and the cost of people can force development to proceed along lines where an engineering solution is more important than reaching a total understanding of all aspects of a problem.

Application Ideas. There were several interesting discussions about new applications under consideration by researchers in Russia and Ukraine. Some of these ideas appeared to be novel, and had not been considered in the United States, at least in circles represented by members of the WTEC team. It may well be that the new freedom to determine research directions has allowed researchers to consider novel applications of technology. It may also be that having to compete in a world marketplace demands new and novel products and ideas.

Implementation Software and Hardware. As alluded to above, there is general agreement among the panel that research in Russia and Ukraine has been undertaken in an environment with limited computer hardware capability. This limitation has most probably been the reason for the direction of software development there. The emphasis has been on efficient algorithms and highly capable microprogramming.

Maturity of Applications. There have been many applications of technology that are both interesting and novel. It must be understood, however, that the actual maturity of those applications is not clear. Many of the technological concepts discussed were in their conceptual stages only. With limited financial resources, it is unclear just how many of those applications will come to fruition.

Infrastructure. The changes in the FSU have had a strong impact on the technology infrastructure. Communications among various groups is unclear. Also, the method for moving from concept to final prototype was controlled very completely in the past, and the resources needed to accomplish a development effort were planned and in place. It seems that this is no longer the case and it will be a while before such an infrastructure evolves in this new environment.

Several factors affecting technology development in Russia and Ukraine were apparent during the visits and discussions. Although not necessarily related to technology development, the following factors are among those that are important to the process used to develop technology:

- Publishing in professional journals
- Acquiring better computer hardware
- Establishing better communication channels
- Better understanding of how to do business with the West
- Better understanding of technology outside of the FSU

There were applications of acoustic technology that were both exciting to consider and important to advancing the state of the art in this field. Due to limited time, it was not possible to truly understand the technical accomplishments of the technologists, yet their ideas were intriguing and their concepts novel. More should be done to fully understand many of these efforts.

As mentioned previously, one of the questions that constantly surfaced was how far specific applications had been taken. It was not clear at times whether a concept being discussed had yet moved to hardware or prototype development stages, whether it had been evaluated in a real world setting, or whether it had already become available as a product.

Sometimes it was also unclear what the future held for specific applications that were discussed. With limited resources and a very dynamic environment, the future of an idea is uncertain. Many of the applications discussed could well be moved into viable products readily sought after in the world marketplace. Whether they will reach that goal is not clear.

It was recognized by many members of the WTEC team that solutions to technological problems had been implemented on computer hardware of limited capability. Emphasis was placed on efficient algorithms and clearly understanding the principles of the problem. Many can remember how their first efforts at applying microcomputers to instrumentation forced the use of machine languages and complex interface programming. This is not unlike what seems to be the norm in Russia and Ukraine today. The benefit of this has been to develop unique solutions to complex programming problems.

There is a genuine desire for cooperation and collaboration. On one hand this is obvious since funding and equipment are lacking. More importantly, however, is the perception that technologists in Russia and Ukraine truly believe that cooperation and collaboration will bring new insights and further advance their technological interests. The individuals involved in the visits were very talented technical people. Much would be gained by the synergism resulting from true cooperation.

The current environment in the FSU is allowing technologists the freedom to choose their own research directions. In addition, many technologists are starting small businesses to privatize their talents and products. This has not been possible in the past since funding and resources were directed at specific projects planned outside of the various institutions. It is clear that this new freedom will allow researchers to consider directions that were not available in the past.

The WTEC team agreed unanimously that the time available for the visits did not allow for in-depth discussions. This was probably inevitable for this first series of visits, but should be corrected during future visits. There is much to learn concerning acoustic applications in Russia and Ukraine. Learning is always a slow process that follows a less than straight path. Future visits should allow time for technical discussions with the actual professionals involved in moving applications from concept to reality.

System Engineering

Europe. Underwater vehicles and marine technologies are very important to the European countries visited. This is evidenced by government-funded programs, such as the Marine Technology Directorate (MTD) program, sponsored by the United Kingdom's Science and Engineering Research Council (SERC) and France's IFREMER program. Also, a European-wide focus is offered by the Marine Science and Technology program. European marine technology and underwater vehicle (UV) activities are well planned and focused, and funding, though never enough, is adequate. The bottom line is that the Europeans are making good progress in developing AUVs, and are moving toward some very useful national and regional objectives in ocean research. Good work is also in progress toward development of ROVs for the offshore oil industry.

The organizations involved in UV development and marine research are well equipped for research, engineering, and overall system integration. The computer equipment and test facilities are modern and as capable as any in the United States.

Former Soviet Union. Labor and materials are still cheap in Russia and Ukraine, and the availability of micro-electronics is limited. This has led in the past to an emphasis on manned UVs rather than unmanned units. Manned UVs are easier to integrate and maintain, and use low-cost labor to good effect. This trend will probably continue into the near future, until the industrial sector begins to mature and costs drive it toward unmanned systems. In the West, the high cost of labor and the risk of litigation and insurance penalties have driven scientists toward unmanned solutions. However, the same cost of labor has made sophistication and high technology expensive. The United States has improved performance and minimized man-dependency, but in some cases has violated the basic rules: "keep it simple" and "sufficient is good enough." The United States is too often enamored of the whiz-bang solution rather than the simplest one.

Fundamental science in Russia and Ukraine is impressive and based on sound theory. Due to lack of computational capabilities, there has been a focus on empirical validation rather than in-depth analysis. This will continue during the process of economic, political, and defense conversion.

FSU scientists and engineers have been very creative in applied research, and have many accomplishments that equal or exceed those of the West. Some examples include manned submersibles, acoustic tomography, nonacoustic ASW, high-speed underwater projectiles, and materials development for the marine environment.

Engineering in Russia and Ukraine is generally behind that of the West in sophistication, but not necessarily in results. Some engineering and integration achievements there include the following:

- Numerous and very good research test facilities
- Short development spans based on a theory of build it, field it, and then improve it
- Avoidance of the analysis paralysis that slows progress in the West
- Lack of preoccupation with aesthetics; systems are built stout to last and simple for easy maintenance

Navigation, Communication, Automation, and Control

There is limited technology in the former Soviet Union in the areas of automation in underwater vehicle technology. The control technology is based primarily on manual operation. Navigation and communication systems in the former Soviet Union use technologies that are currently available worldwide. There are a large number of well-trained engineers and scientists in the FSU who are underutilized because of the current funding situation. There are several very nice design, test, and fabrication facilities in the former Soviet Union. Russia and Ukraine would like to make these facilities available in some form to be used in the world market. The engineers said that access to computers, computer-aided design and simulation software, and more reliable electronics, would make them more effective.

France is the leader in the field of underwater vehicle technology. French programs in the integration of local sensor data for navigation and control have the potential of opening up new capabilities for underwater vehicles.

The United Kingdom is leading a European Community effort in developing long- range underwater vehicles. This program is pushing the limits in underwater vehicle technology in automation, navigation, and control.

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