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This publication is an official publication of the Office of Naval Research European Office. It describes research that is being conducted in Europe and the Middle East.

Commanding Officer ..... CAPT John M. Evans, USN
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Survey of European Surface Current Radar Systems

by LCDR Larry Jendro, USN, the Liaison Officer for Oceanography and Environmental Systems at the Office of Naval Research European Office. LCDR Jendro was an active duty naval officer from the US Navy's oceanography community, assigned to the Office of Naval Research European Office.

KEYWORDS: CODAR; Bragg scattering; LSEET; spatial resolution; beamforming

INTRODUCTION

Radar instruments, which may provide the key to unlock the secrets of coastal ocean dynamics, have followed different paths of development in Europe and in the United States. In Europe, three independent and unique approaches to the utilization of radar surface current sensing technology have expanded the field of instruments available to oceanographers. This has occurred at a time of rapidly increasing government interest in and funding for coastal investigations.

This interest is fueled, in part, by increased concern about pollution, environmental protection, and global climate change. The United States Navy also has a strong interest in improving the environmental quality of harbors and in understanding the complexities of the coastal, shallow-water environment to support naval tactics in areas of military interest.

An additional stimulus is the need to develop new scientific tools for studying these difficult regions. Specifically, the development and validation of new satellite ocean-observation instruments and numerical coastal-ocean models require detailed information about surface circulation over relatively large coastal areas. The European developments in surface current radar systems reported here may provide oceanographers with increased capabilities to pursue investigations of great public importance.

Surface current radar systems are not new. They have been used in coastal oceanographic research in the U.S. for almost twenty years. Since 1976, development of surface current radar systems in the U.S. has concentrated on compact, transportable coastal ocean dynamics application radar (CODAR) systems using a direction-finding method of bearing resolution.[1] This approach has resulted in very advanced systems that have increased range and drastically reduced size and power requirements.

The paths of development in Europe have been different and have produced several unique surface current radar systems. The independent development of these European Systems has increased the range of instruments available to scientists and opened new areas to investigation by and proposed new uses for surface current radars.

The Office of Naval Research European Office (ONR Europe) has investigated three surface current radar systems from the United Kingdom (U.K.), France, and Germany. These systems include the Ocean Surface Current Radar (OSCR) originally developed at Rutherford-Appleton Laboratory in the U.K.; the LSEET VHF (very-high-frequency) system from the Laboratoire de Sondages Electromagnetiques de l'Environnement Terrestre (LSEET), Toulon, France; and a ship-borne HF (high-frequency) CODAR system developed by the Institute of Oceanography at the University of Hamburg, Federal Republic of Germany.

The following article contains a general review of the principles of operation of surface current sensing radar. Three European systems are described in terms of specifications, capabilities, physical equipment, and recent utilization. Finally, the capabilities and utilization of the three systems are compared.

PRINCIPLES OF OPERATION

High-frequency (HF) and, recently, very-high-frequency (VHF) ocean surface current radar systems have been designed to operate on the principle of first-order Bragg scattering from ocean waves. First-order Bragg scattering[2] produces a spectral peak in the radar returns from ocean waves whose wavelength is 1/2 the wavelength of the transmitted signal. The technique of using first-order Bragg scattering from ocean waves for determining surface currents was developed in the early 1970s.

Ocean surface waves provide the radar targets that are used for determining surface currents (Fig. 1). A Doppler-shifted spectral peak is produced by the radar reflection from ocean waves. All movement of the waves (some motions caused by wave action and some by ocean current) produce Doppler shifts in the frequency of a returned radar signal. The result is a return echo spectrum containing two main peaks, which can be identified with both advancing and receding surface gravity wave echoes.

Surface gravity waves have a characteristic group speed related to their wavelength, and the wavelength of waves "seen" by Bragg scattering is determined by the radar frequency. The contribution of wave action to the Doppler shift of the radar return can be computed from the radar frequency and subtracted out. The remaining Doppler offset of the return from the transmitted frequency, after this correction for wave motion, is due to current in the line-of-sight

$$\Delta f = 2V_{cr}/\text{wavelength}.$$

The radial current so determined by an HF system is the mean surface current in the line of sight to a depth of about 1/2 meter.

Developing vector currents requires that two systems be simultaneously observing the same area of ocean. The temporal variability inherent in a "storm-tossed sea" requires a scheme of time-averaging over each area in which surface current is determined (for HF systems, averaging time spans of about 20 minutes are used).

BASIC SYSTEM OPERATION

Two-dimensional surface current vectors are computed by simultaneously using two spatially separated systems to generate radial currents, over the same area, along two lines of sight, and combining the results (Fig. 2).

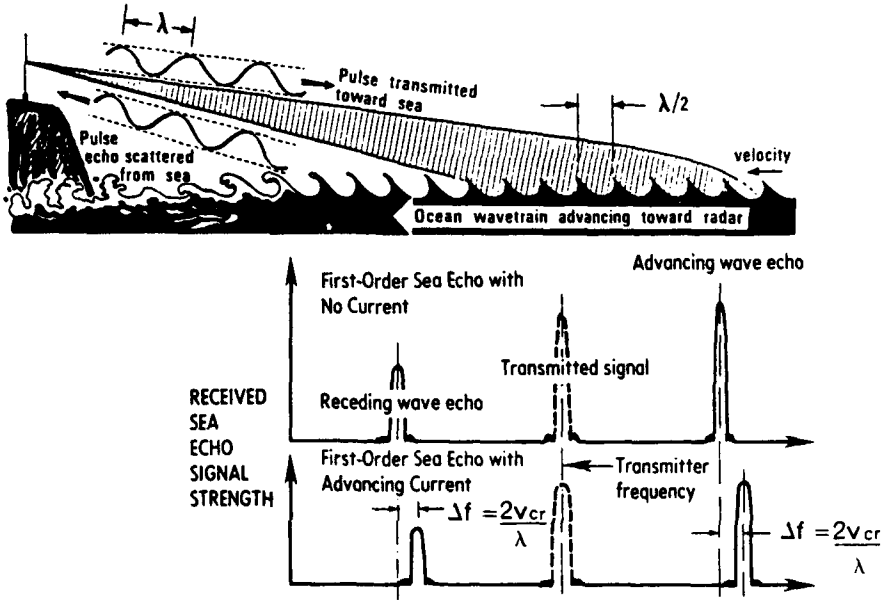

Fig. 1 — Principles of first-order HF Bragg scatter from the sea, and resulting signal echo spectra without and with an underlying current. (Barrick, D.E., M.W. Evans, and B.L. Weber, *Science*, 1977)

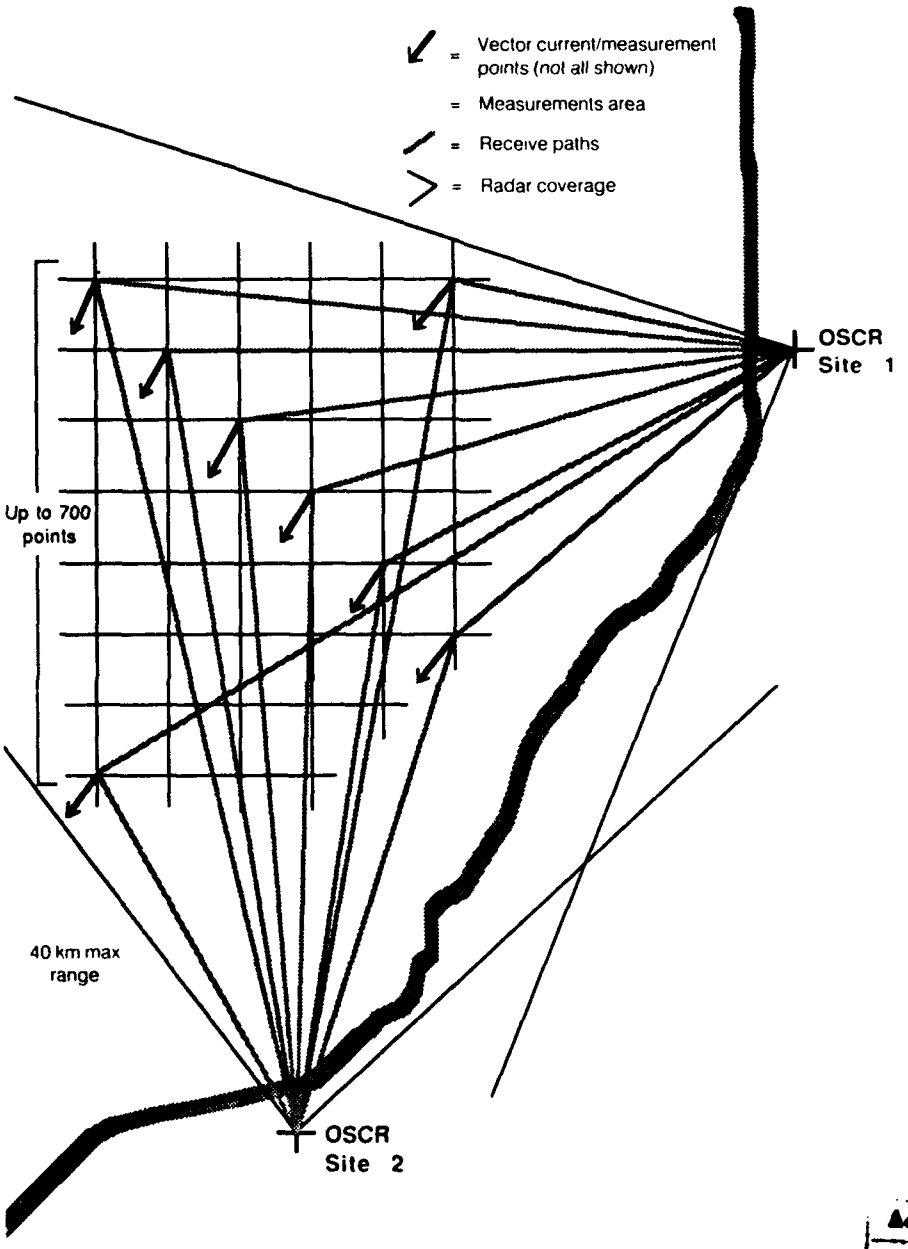

Fig. 2 — Overlapping coverage of two surface current radar sites and the development of two-dimensional current vectors. (Courtesy of Proudman Oceanographic Laboratory)

To resolve spatial variation in the surface currents, small areas of the examined field must be processed separately. Thus, the direction, extent, and duration over which the received beams are to be processed must be carefully controlled. This is supported by transmitter and receiver antenna arrays and control systems together with beamforming or direction-finding software processing systems (Fig. 3).

BASIC SYSTEM DESCRIPTION

Basic systems consist of a transmitter, an omnidirectional transmitting antenna, a receiving antenna array (generally 8 to 16 dipole antennas in a line, normal to the signal path for the narrow beamforming and 4 receiving antennas arranged in a square for the direction-finding system), and a receiver. The system also contains a computer and control circuitry to control the transmitter, form beams at the receiver, step through the cell areas covered, compute the currents from frequency differences, and collate and store data.

The output from a single system is a measurement of radial surface current in the direction of the signal path, on a small square of ocean surface. Obtaining a two-directional current vector requires that two spatially separated systems be monitoring the same area simultaneously.

DIRECTION-FINDING VS BEAMFORMING SURFACE CURRENT RADARS

Two methods are used to isolate the scattering path in bearing: beamforming and direction-finding. In beamforming, a narrow beam is created by using an antenna aperture many wavelengths long. This is done by a linear array of vertically polarizing elements called a phased array. A beam can be made to point up to ± 45 degrees from broadside by either hardware switching or software combining after reception. Angular resolution depends on beamwidth, which in turn depends on wavelength divided by array length. For example, a 16-element 85-meter-long array at 25 MHz produces a beam that is about 10 degrees wide at broadside, and increases to 14 degrees at ± 45 degrees. About 6 or 7 independent beams can be formed between ± 45 degrees.[3]

Direction-finding (DF) methods use much more compact antenna systems to locate the scatterer in bearing. One method is to compare the phase at a given Doppler frequency from two separated antenna elements. Bearing accuracy with DF depends on signal-to-noise ratio (SNR); a 15 dB SNR can produce a bearing accuracy of 2.5 degrees.

HF current-sensing systems that use DF principles have become known as CODARs (coastal ocean dynamics applications radar). Continuing improvements in both types of systems have reduced the size and power requirements of the equipment. In the U.S., development of HF surface current radar systems since the mid 1970s has followed the DF approach.

CODAR has generally been used to indicate HF Doppler radar systems used to measure dynamic properties of the ocean surface. More recently CODAR has been defined to refer only to systems using direction-finding techniques. "CODAR systems are differentiated from other types of phased-array HF radars in that the former employ compact antennas combined with direction-finding methods, while the latter form and scan narrow beams to locate the echo's bearing."[1]

In the systems described below, the OSCR system and the LSEET VHF system use the narrow beamforming method of azimuthal scanning; the shipboard HF CODAR system uses the DF method.

EUROPEAN SYSTEMS

The three ocean surface current radar systems described below have been developed at European laboratories. Each variant addresses some limitation of the basic system. For example, azimuthal resolution is improved with the beamforming system of the OSCR systems. It is further improved by the higher frequency VHF used in LSEET and OSCR II systems. The difficulty of locating two optimally positioned systems is partially overcome by placing at least one system on a ship (as was done in the shipboard CODAR system).

OCEAN SURFACE CURRENT RADAR

Ocean Surface Current Radar (OSCR) was developed at the Rutherford-Appleton Laboratory

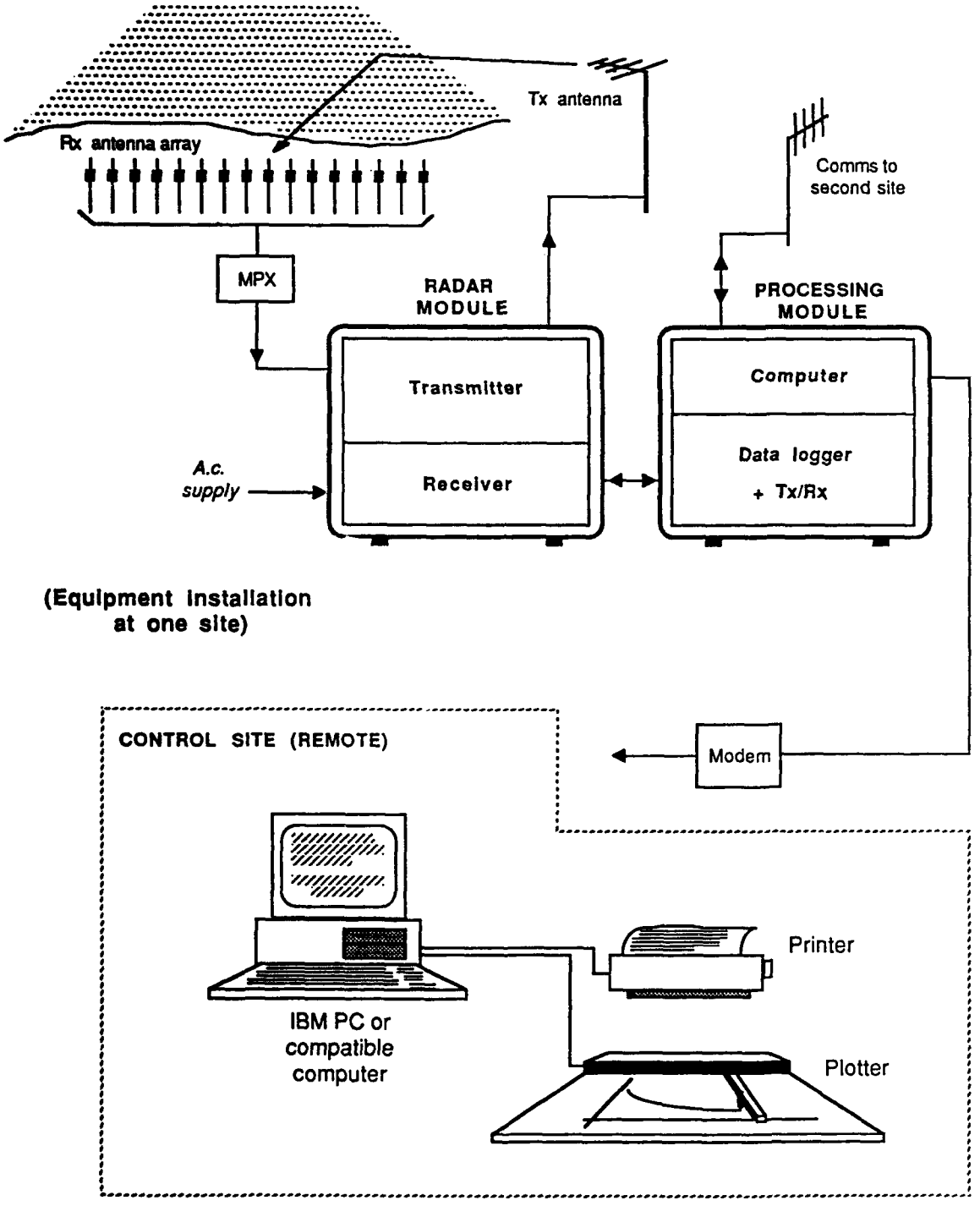

Fig. 3 — Typical equipment used to support narrowbeam surface current radar site. (Courtesy of Proudman Oceanographic Laboratory)

and is currently commercially produced by MAREX, Cowes, Isle of Wight, England. The most advanced version available is OSCR II, which has HF and VHF versions; Table 1 lists OSCR II specifications.

The OSCR is the only one of the three systems investigated that has been commercially developed. It has been used very extensively around the U.K. and Europe for scientific studies and engineering applications. For example, OSCR II has been used for

- siting long sea sewage outfalls,
- studying the Irish Sea,
- wave studies,
- estuary pollution research,
- barrage studies, and
- studying ocean fronts and nearshore ocean currents.

In the fall of 1991, OSCR was used at Cape Hatteras and Miami Beach by the University of Miami. At Cape Hatteras the HF version was used in a major experiment sponsored by the Office of Naval Research. The new high-resolution VHF (50 MHz) version of OSCR was evaluated at Miami, Florida. Initial review of data collection indicates that both the HF and VHF systems, when evaluated in terms of the consistency of the data as a function of space and time, were correctly observing currents.[4]

LSEET VHF SYSTEM

A (French) system being used by the Laboratoire de Sondages Electromagnetiques de l'Environnement Terrestre (LSEET) at the Université de Toulon is similar the OSCR HF system but is designed for the higher frequency of 47.8 MHz. Table 2 lists LSEET characteristics. It has an array of 16 vertical monopole antennas arranged along a total distance of 60 meters. These antennas are connected to form a broadside beam of 3.5 degrees. The higher frequency reduces the depth of the mean current evaluated to about 25 cm.

To date the system has been used only in experiments to look at a single azimuth. However some accumulated data have been processed, after the fact, to form beams. Only one system has been operated by itself, and it is capable only of describing radial components of surface currents.

This French system has been successfully used in three experiments, one with the radar on the north shore directed southward across the Etang de Berre, another with the radar on a 500-meter cliff directed out into the Mediterranean, and the most recent at the mouth of the Rhone River in the south of France.

These experiments revealed interesting capabilities of VHF surface current sensing. The use of VHF increases the intrinsic accuracy of current measurement to about 1 cm/s and provides better spatial resolution of current and sea state measurements.[5] A disadvantage of VHF is the reduction in range resulting from the greater attenuation of ground waves in the VHF frequency range. Increasing antenna altitude appeared to consistently increase range, all other parameters being the same.

Significant effects of water surface conductivity on LSEET returns have been noted in a recent experiment over a Rhone River plume in the Mediterranean. This demonstrated the potential for using surface current radar to track river plume fronts and raises the possibility of using VHF radar as a surface conductivity sensor.

Recent developments have included numerical beamforming to obtain azimuthal diversity. Future directions include constructing a second unit to provide vector currents and data processing on a PC computer.

GERMAN SHIPBOARD CODAR

The German shipboard system was developed at the Institute of Oceanography, University of Hamburg, Federal Republic of Germany. The principle of operation is the same as the land-based system described above, with differences necessitated by shipboard operation. An omnidirectional transmitting antenna is used and the receiving antenna array has four elements arranged in a square; the angle of arrival of the signal is determined by the phase differences between the antennas. Table 3 lists specifications for the German Shipboard CODAR.

Operating a surface current radar system at sea presents problems not encountered with the

Table 1. OSCR II System Specifications*

	HF Version	VHF Version
Frequency	0 - 30 MHz	40 - 50 MHz
Radar type	Pulse Doppler	Pulse Doppler
Bandwidth (-3dB)	125 / 63 kHz	500 / 250 kHz
Range resolution	1 / 2 km	250 / 500 m
Transmit peak RF power	1 kW ERP	100 W ERP
Transmit peak PA power	500 W	50 W
Transmit mean power	21 W	2 W
Transmit antenna	4-element YAGI 6 dB forward gain 16 dB front/back ratio	same as HF
Receive antenna	1/4-wave whip × 16	1/4-wave whip × 32
Azimuth coverage	90 degrees	90 degrees
Azimuth resolution	8 - 11 degrees	4 - 5.5 degrees
Radar footprint	1.0 × 1.9 km 2.0 × 3.8 km	250 × 528 m 500 × 1058 m
Maximum unambiguous radar range	22 / 44 km	11 / 22 km
Transmit time	293.6 seconds	same as HF
Doppler spectrum width	± 1.5259 Hz	same as HF
Doppler spectrum averaging	2 × 896 point spectra with 25 percent overlap	same as HF
Tape format	QIC 24 using DC600A cartridge	same as HF
Control terminal communications	V22 auto dial/answer	same as HF
UHF communications	458 MHz	same as HF

OSCR II System Capabilities (both HF and VHF)

Maximum number of measurement cells	700
Operational range (depends on sky and propagation conditions)	15 to 30 km
Measurement cycle repeat (user configurable)	Every 20 minutes
Accuracy:	
Radial current	2 cm/s
Vector current	4 cm/s
Vector direction error maximum	5 degrees
Maximum online data storage:	
Radial current	30 days at 700 cells
Vector current	30 days at 700 cells
Capacity increase (days) with decreasing cells	(e.g.) 60 days at 350 cells

*OSCR's most recent equipment development is the option (with some equipment changes) to use VHF to 50 MHz, providing finer resolution and greater accuracy.

Table 2. LSEET VHF Characteristics

Frequency	47.8 MHz
Antennas (receive and transmit)	Array of 16 monopoles
Peak power	30 kW maximum
Pulse length (PL)	1, 2, 4, or 8 μs
Repetition rate (IPP)	50, 100, 200, or 400 μs
Doppler spectra	256 points
Typical Specifications:	
Receive antennas	16 monopoles along 75 m
Beamwidth	3 dB beamwidth: 3 degrees
Power	Peak power: 2.7 kW
PL	4 μs (resolution cell: 600 m)
IPP	250 μs
	45 resolution cells along the radar beam
Range	1 to 30 km
Dwell time	6 minutes
Precision	4 cm/s

Table 3. German Shipboard CODAR Specifications

Frequency	29.85 MHz
Type	Pulsed CW
Power	4 kW
Antennas:	
Transmit	Omnidirectional whip
Receive	4 vertical, arranged in a square
Range resolution	1.2 km
Effective range	35 km
Grid resolution	3-km radius

land-based systems. Radial current velocity ambiguity is a problem because the antennas are surrounded by reflecting waves. Ambiguity resolution is achieved by shielding one side of the antenna with the ship's superstructure, thereby basically limiting transmission to a 180-degree semicircle. Keeping the ship moving in a direction perpendicular to the area being sampled, at a speed faster than the expected current, allows forward/aft ambiguity resolution.

The ship's motion requires that measured current velocities be corrected for with ship's speed. This is done by integrating a global positioning system (GPS) with the CODAR. Since the ship's velocity is not constant over the 18-minute sampling time, the time series is divided into 15 overlapping parts, for which radial current velocities are computed and corrected by the actual ship's drift as determined by GPS.

The effects of pitch and roll of the ship are minimized to acceptable levels by limiting the elevation of the antenna. These effects average out in cases in which the angular displacement (maximum 3 m) is small compared to the HF wavelength of 10 m.

The accuracy of the shipboard system, adversely affected by the motion of the ship and dependent on the accuracy of the GPS system, was estimated to be 10 cm/s.

This shipboard system was first used successfully during the Norwegian Continental Shelf Experiment (NORCSEX),[6] which combined land- and sea-based CODAR systems. The ability of the CODAR system to map horizonal variability in surface currents was noted in this experiment; its results compared very well with ocean frontal positions determined from airborne radar imagery.

SUMMARY COMPARISON OF SYSTEMS INVESTIGATED

Table 4 compares the specifications of the three systems. Increased resolution of the beamforming systems and greater increases with increasing frequency are clearly noted; also noticeable is the trade-off of range and bearing resolution for the reduced array length when the CODAR system, using the direction-finding method of angular resolution, is compared with the other narrow beamforming systems.

In June 1985, a special international meeting of the IEEE Ocean Engineering Society ("HF Radar for Ocean Surface Observations") met in Vancouver, Canada. During a Special Panel discussion at the end of the two-day meeting, leaders in the field published a Panel Discussion Summary that included generic accuracies for CODAR and narrowbeam coastal radars. These accuracies (Table 5) are applied to the systems investigated, based on CODAR or narrowbeam design.

CONCLUSIONS

The development of ocean surface current radar systems in Europe has taken significantly different directions from the development of

Table 4. System Comparisons

System:	OSCR HF	Shipboard CODAR	LSEET	OSCR VHF
Type	Commercial	Research	Research	Commercial
Frequency	20-30 MHz	29.85 MHz	47.8 MHz	40-50 MHz
Antennas:				
Transmit	4 YAGI	Vertical whip	16 monopulse	4 YAGI
Receive	16 1/4-wave whips	4 square	16 monopulse	32 1/4-wave whips
Type	Pulse Doppler	Pulse Doppler	Pulse Doppler	Pulse Doppler
Range	1/2 km	3 km	750 m	250/500 m
Azimuth	8-11 degrees	3 km	3 degrees	4 - 5.5 degrees

Table 5. Generic Accuracies

	OSCR HF	Shipboard CODAR	LSEET	OSCR VHF
Current speed (cm/s)	1-3	2-4	1-3	1-3
Current direction (degrees)	10-15	5-12	10-15	5-12

similar instruments in the U.S. This diversity has resulted in an increased range of capabilities of instruments and an increased area over which these instruments can be used. It has also demonstrated the potential for the use of these instruments in other types of measurements.

The commercial development to the OSCR II system by MAREX, Isle of Wight, England, has provided U.S. researchers with an alternative to CODAR DF systems. Initial analysis of data from recent experiments by U.S. researchers in Florida and North Carolina has demonstrated the successful operation of OSCR II in both HF and VHF configurations.

The shipboard system from the University of Hamburg has overcome many obstacles to provide the ability to use a surface current radar system in geographically difficult areas and has opened the possibility of surface current surveys in the open ocean. The French LSEET VHF system demonstrates advantages of increased frequency and the ability to track water mass fronts and has shown the possibility for use in remote surface conductivity monitoring.

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Cooperative Marine Science Program for the Black Sea

by Dr. David Aubrey, Dr. A. Bologa, and Dr. Ü. Ünlüata. All authors are members of the Executive Committee of the Steering Committee of the Cooperative Marine Science Program for the Black Sea. Dr. David Aubrey is a Senior Scientist at the Woods Hole Oceanographic Institution and is the Chairman of the Executive Committee in the Black Sea Program. Dr. A. Bologa is the Director of the Marine Hydrographic Institute in Sevastopol, Ukraine; Dr. U. Ünlüata is Director of the Institute of Marine Sciences of the Middle East Technical University of Erdemli, Turkey.

KEYWORDS: anoxic; Black Sea; pollution; thermocline; cooperation

SUMMARY

Since April, 1991, a cooperative marine science program has been developing to investigate the science and environmental problems of the Black Sea. This program has incorporated strong participation from all riparian countries of the Black Sea as well as from the United States. Major accomplishments of this program include a successful five-ship cruise to the Black Sea (HYDROBLACK '91), comprising nearly 300 hydrographic stations and 100 biogeochemical stations. This experiment was the first basin-wide quasi-synoptic cruise throughout the Black Sea and represents the first cooperative marine science effort among all the Black Sea countries.

An international workshop was held in Varna, Bulgaria, during September-October 1991. This week-long workshop presented the state of knowledge of the Black Sea as it exists within each country, as well as a series of interdisciplinary topics coauthored by scientists from all Black Sea states. The workshop also defined major science and management goals for the Black Sea for the next decade, as a framework for future cooperation. In addition, a Steering Committee was established to conduct the Cooperative Marine Science Program for the Black Sea during the upcoming decade. Responsibilities of this Steering Committee are:

- coordinating national marine science programs for the Black Sea,
- fund-raising in the international arena to offer new opportunities to improve the scientific capabilities of these countries, and
- planning and implementing interdisciplinary cruises for coordinated science activities.

The recent dissolution of the Soviet Union (into the Commonwealth of Independent States) and the opening of eastern Europe brings with it significant scientific opportunities within regional seas such as the Black Sea. Previously difficult to work within, with restricted access or data sharing, these areas have now opened dramatically. The science opportunities made possible by these events are unprecedented, providing a realization of global science. The enthusiasm of the scientists in these countries is contagious, and can accelerate the pace of the science for Eastern Europe as well as Western participants. The availability and low cost of ships in these regions, at least to date, provide other opportunities for less-expensive science.

INTRODUCTION

The recent opening of eastern Europe has rekindled interest in research within marginal seas controlled by these countries. The Black Sea, specifically, is of intrinsic scientific interest because it is the largest anoxic marine basin in the world and serves as a useful analogue to conditions in photo-oceans of the Mesozoic period. Moreover, the severe pollution of this nearly enclosed basin provides a useful prototype for severely affected marginal seas the world over.

The Woods Hole Oceanographic Institution has a long history of research in the Black Sea. Although previous, cruises have included use of United States ships in the Black Sea, access has been limited, particularly during the past 20 years.

For instance, the 1988 cruise of the R/V *Knorr* into the Black Sea was restricted to Turkish waters, covering less than 40 percent of this basin. New opportunities for collaborative research have opened and are described here briefly.

Although the present discussion addresses the Black Sea in particular, the program is illustrative of the types of programs that may be conducted within many marginal seas of the former Soviet Union. SPASMO, a Western Europe-Soviet marine science investigation, is a program in the arctic Sea of Laptev where similar cooperation is taking place. Thus, the Black Sea program can be thought of as a new and useful mechanism for coordinating, conducting, and funding science in the international arena.

To illustrate the program, we briefly discuss HYDROBLACK '91 and the Varna Workshop. Remembering that the first planning meeting for these events was held in April, 1991, in Sofia, Bulgaria, the progress is exemplary. This illustrates the enthusiasm of the riparian countries for cooperation and collaboration. The Sofia meeting was followed by a June, 1991, meeting in Constantza, Romania, and then by a July, 1991, meeting in Erdemli, Turkey. The meetings were conducted by an hoc group of scientists from all countries bordering the Black Sea, as well as from the Woods Hole Oceanographic Institution. Copies of reports of these meetings are available from D. Aubrey (see Appendix).

HYDROBLACK '91

This extensive hydrographic cruise of the Black Sea served two purposes: to obtain high-quality scientific data of unprecedented coverage throughout the Black Sea, and to see how well these countries could work together, given long histories of military, political, cultural, economic, and social differences. The scientific objective of HYDROBLACK '91 was to establish a definitive phenomenology to understand, quantify, and model the fundamental physical processes and their interactions with biological and chemical processes. This experiment was to form the basis for further studies on questions such as transport and dispersion of material; productivity; efficient utilization, exploration and exploitation of marine resources; management of the environment; and control of pollution. The following are some specific problems that must be addressed to achieve this objective:

- intercomparison of the main forcing mechanisms (the wind versus thermohaline forcing, source/sink flow through straits and their spatial as well as seasonal, annual, interannual variabilities, and budgets);
- the roles played by the topography and the irregular coastline;
- the process of convection associated with the cold intermediate water formation and its subsequent sinking, spreading, and mixing characteristics;
- identification of major features of circulation, its energetics, and basic space and time scales of its variability;
- analysis of available historical data sets and satellite imagery;
- determination of the dissolved oxygen and hydrogen sulfide levels and the oxic/anoxic interface;
- implication of the circulation for the distribution of biological and chemical properties;
- determination of important sources and sinks of nutrients and the role of eddies in nutrient transport and primary productivity;
- determination of horizontal and vertical material fluxes within the sea and their variability;
- investigation of the primary biogeochemical processes of the euphoric and aphotic zones of the water column; and
- impact of eddies and other features of circulations on fisheries through recruitment and/or production.

This cruise provided hydrographic and biochemical measurements. It also gathered remotely

sensed data to place these measurements in context, as well as to provide links to numerical modeling results for comparing modeling techniques and assumptions.

In April, 1991, a decision was made to conduct this multiship operation in the Black Sea. In June, 1991, a draft cruise plan was presented by U. Ünlüata of Middle East Technical University in Erdemli, Turkey, for review by the Steering Committee. Finally, in July, 1991, a cruise meeting was held in Erdemli, Turkey, to firm up details of the program. The cruise plan included components characteristic of most international efforts, specifying not only scientific goals, objectives, and methods, but also communications protocol, publication policies, etc.

Five ships participated in HYDROBLACK '91 (Table 1). These ships all provided data from several different brands of conductivity, temperature, and depth sensors (CTDs). To the greatest extent possible, they used similar procedures, as outlined in the HYDROBLACK '91 cruise plan.

HYDROBLACK '91 completed nearly 300 hydrographic stations (Fig. 1), using ships from three different Black Sea riparian countries. For the first time, two Ukrainian vessels (*Kolesnikov* and *Parshin*), two Turkish ships (*Bilim* and *Piri Reis*), and one Bulgarian vessel (*Akademik*) participated, occupying stations quasi-synoptically over the entire Black Sea during a period of three weeks. Station spacing was approximately 20 nmi.

Following the cruise, the data were exchanged by all parties, on board the R/V *Kolesnikov* in Varna harbor, Bulgaria, in early October. At this time the Office of Naval Research European Office supported a postcruise wrap-up and analysis planning workshop. From 1-15 December, 1991, an Intercalibration Workshop was held at the Woods Hole Oceanographic Institution, with participants from all Black Sea countries except Romania (visa problems). A report describing the intercalibration exercise has been published.[1]

The intercalibration of the hydrophysical data was a labor-intensive exercise because of the various CTDs used. However, the results were of high quality. As an example, the dynamic topography calculated at the 5 dB level relative to the 900 dB level (Fig. 2) shows considerable structure characteristic of the Black Sea: two central cyclonic basin-scale gyres, with intense anticyclonic eddies around the margin of the Black Sea. These anticyclonic features are quasi-permanent. They result from interactions of the rim current with topography and bathymetry, and probably from baroclinic instabilities. A temperature section from the Danube Delta to the southeast shows more characteristic Black Sea features (Fig. 3). The surface mixed layer is warm (exceeding 22 °C), floored by a strong thermocline. Beneath the thermocline is the cold intermediate layer (CIL: defined generally by water cooler than 7.5 °C), with an increase in temperature below that level.

In February, 1992, the cruise participants met in Sevastopol, Ukraine, to present and intercalibrate the other measurements from HYDROBLACK '91, including oxygen, hydrogen sulfide, nutrients, and Secchi disk depth. The data are being used for interdisciplinary investigations of the biogeochemical cycling within the Black Sea.

In summary, HYDROBLACK '91 was successful from both a logistical and a scientific viewpoint, demonstrating the capabilities and interest of the Black Sea countries for collaboration. Future work will include an expanded scientific program of investigation, including data collection, modeling, and interdisciplinary work. Now that the program has been initiated successfully, broader collaboration is encouraged.

Table 1 — HYDROBLACK '91 Ship and CTD Inventory

Vessel	Country	CTD	Dates	Number of Stations
R/V *Akademik*	Bulgaria	Sea Bird SBE-9	2-12 Sept 91	53
R/V *Bilim*	Turkey	Sea Bird SBE-9	5-23 Sept 91	104
R/V *Prof. Kolesnikov*	Ukraine	Istok V	9-29 Sept 91	94
R/V *Parshin*	Ukraine	Hydrozond	8-12 Sept 91	40
R/V *Piri Reis*	Turkey	Sea Bird SBE-9	7-17 Sept 91	16
			Total	307

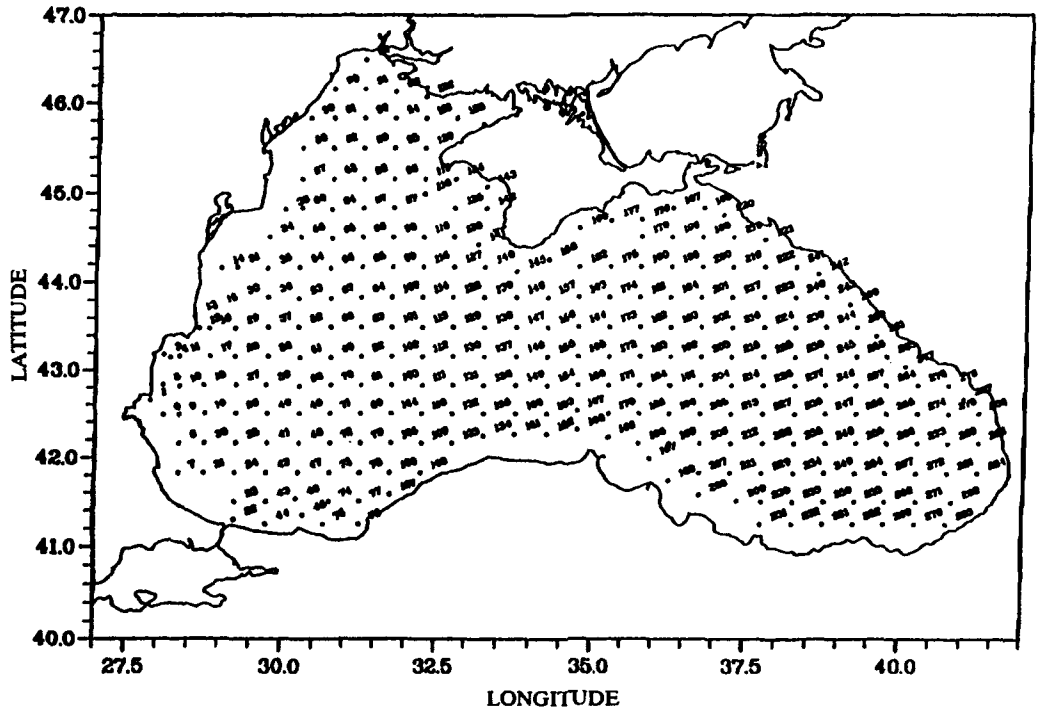

Fig. 1 — HYDROBLACK '91 station locations

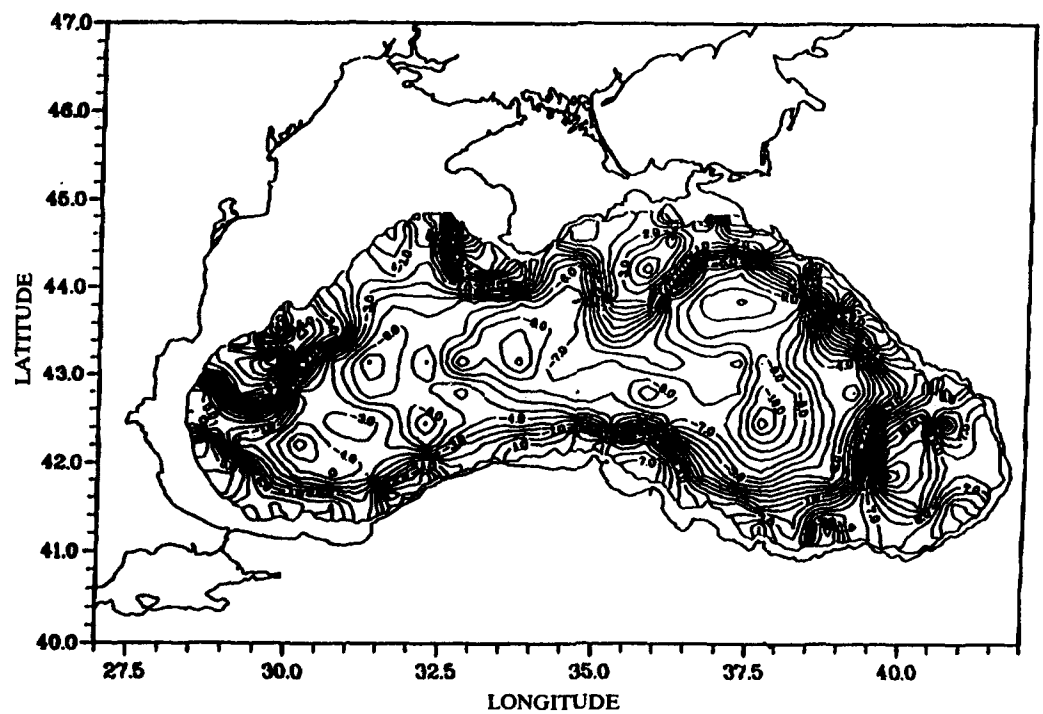

Fig. 2 — Dynamic topography, in centimeters, at the 5-decibar level relative to the 900-decibar level

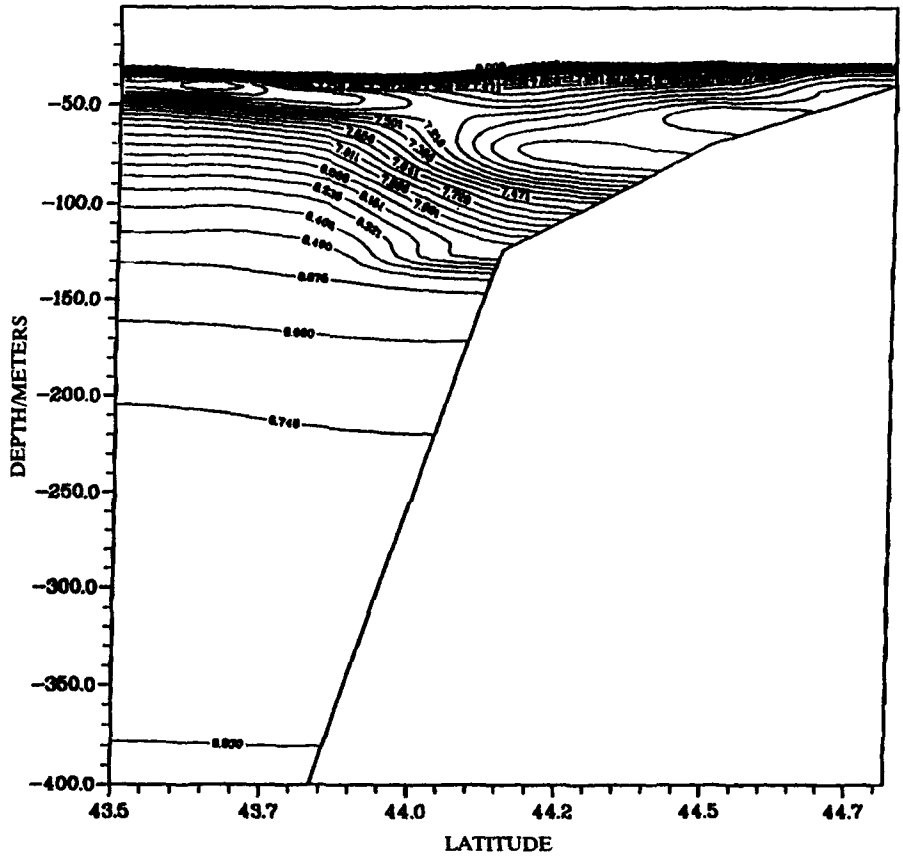

Fig. 3 — Cross section of temperature from the Danube Delta to the southeast, showing the strong stratification and presence of the Cold Intermediate Layer

INTERNATIONAL WORKSHOP ON THE BLACK SEA, VARNA, BULGARIA

At the first planning meeting of April, 1991, in Sofia, Bulgaria, the interim Steering Committee agreed to host an international Workshop on the Black Sea. The intent was to limit the participants of the workshop to make for more effective scientific interaction during the working sessions. The Workshop was held at Varna, hosted jointly by the Bulgarian Academy of Sciences, Institute of Oceanology, and the Coastal Research Center of the Woods Hole Oceanographic Institution.

The workshop had several goals:

- review and assess what data exist on the environmental and scientific issues of the western Black Sea shelf;
- reestablish collaboration of the marine scientific community within Eastern Europe, as well as with external scientists; and
- derive a holistic multiyear research plan (Action Plan), consisting of both natural and social science components addressing the environmental issues of the rivers, deltas, and shelf of the Black Sea.

The meeting was a success, although so much interest was expressed that participants arrived without invitation and unannounced, thwarting our original attempt to limit participation. By limiting the working group sessions, however, some significant advances were made.

The results of the workshop are being presented in two volumes. The first is a summary of the workshop, including copies of the country profile

reports, working group summaries, and recommendations (Action Plan) for the future. The second is a larger volume that includes the interdisciplinary scientific papers that were presented during the meeting. (Further information is available from D. Aubrey, Woods Hole Oceanographic Institution.)

A nongovernment organization was proposed and accepted, and named the Cooperative Marine Science Program for the Black Sea. Terms of reference were defined and adopted:

- Implement the recommendations of the Workshop on the Black Sea,
- Coordinate marine science activities, as appropriate, among the Black Sea countries,
- Improve communication among scientists in these countries,
- Provide the highest quality science, published in refereed literature, to provide decision makers with a solid scientific framework for management, policy, regulatory, and legal issues regarding the Black Sea,
- Serve a fund-raising function for the member nations, and
- Serve as a nongovernment body to communicate with the involved governments, national, and international programs (including United Nations Environmental Programs (UNEP)), as well as the Convention for the Protection of the Black Sea) and local programs on the Black Sea.

In addition to the scientific components, a permanent Steering Committee was established. A five-member Executive Committee was formed from the Steering Committee to coordinate the overall program (see Appendix). Additional members to the Steering Committee will likely be added from Western Europe and the international agencies.

The Steering Committee's primary functions are to serve as initiator, facilitator, and coordinator of Black Sea science, addressing oceanographic and environmental issues of critical concern to these countries. Although government participation in this Steering Committee is limited, close contact with the ministries and governments is attempted.

Methods used for implementing the above terms of reference include:

- Establishing subgroups for carrying out specific goals related to the Marine Science Program,
- Hosting workshops with the subgroups to achieve specific for those subgroups,
- Encouraging cooperative marine science projects, such as those outlined in the Working Group reports, by coordination and where possible by fund-raising,
- Hosting Black Sea meetings to encourage rapid and free dissemination of recent results, and close interaction with management, legal, and policy interests,
- Publishing, where appropriate, scientific articles and books on the Black Sea,
- Encouraging or implementing a monitoring, database management, and geographic information system (GIS) for the Black Sea riparian countries,
- Strengthening ties with private, national, or international science bodies.

CONCLUSIONS

A nongovernmental Cooperative Marine Science Program for the Black Sea has been established. The Woods Hole Oceanographic Institution will maintain a significant role in this research effort, as it has already in the formation of the program.

The success of this program depends on a number of factors, including funding, continuing interest of the governments, and economies of the member countries. It appears, however, that the enthusiasm and openness in these emerging countries will help assure a successful science program that will enable improved management of this environmentally degraded resource.

U.S. efforts should be expanded, with increased participation by more U.S. universities, as well as by government agencies (the Environmental Protection Agency, the National Oceanographic and Atmospheric Administration, and the U.S. Geological Survey, for example). The U.S. government will be able to help in the future by channeling appropriate funding for the program (for science, training, facilities improvement, personnel exchange, and the like), by easing problems with visas for visitors, and by essential agency participation and coordination.

REFERENCE

1. D.G. Aubrey, T. Oguz, E. Denirev, V. Ivanov, T. McSherry, V. Diaconu, and E. Nikolaenko, "HYDROBLACK 91: Report of the CTD intercalibration Workshop," Woods Hole Oceanographic Institution, WHOI 92-10/CRC92-01, CoMSBlack-92-005 (1992).

Appendix

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European Geophysical Society Conference: Report on Sessions Related to Marine Meteorology and Oceanography

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KEYWORDS: Global Ocean Observing System; high-resolution model capabilities; ocean-atmosphere interface; Surface Density Depression Pool; forecasting

INTRODUCTION

The excellent research being conducted in Europe in marine atmospheric boundary layer dynamics, air-sea interaction, satellite oceanography, large-scale ocean flows, polar ocean circulation, and ocean modeling was described at the 17th Assembly of the European Geophysical Society (EGS). This meeting was held at the University of Edinburgh, Edinburgh, Scotland, during the period 6-10 April 1992.

As with American Geophysical Union annual meetings, regular and special sessions were held on a wide range of topics in geophysics. Other topics of interest to us included shelf and coastal seas, benthic boundary layer, orographic effects in meteorology, nonlinear processes in geophysics, Lagrangian diffusion and dynamics, and coherent structures in turbulence. In addition, other sessions of less interest to us were held on hydrological sciences, natural hazards, solid earth geophysics, solar-terrestrial, and planetary and solar system sciences.

Major contributions were made by scientists from the United Kingdom (U.K.), Germany, France, and Russia, with only a smaller number from the remaining European countries and the U.S. There were about 2000 participants from more than 50 countries, with presentations from almost 30 countries. Most papers were given 12-15 minutes for presentation with a small amount of additional time for wrapup, questions, and change of speakers, although some invited talks were longer. There was the usual emphasis by the authors on presentations rather than posters, although the latter generated many more chances for interaction, and provided some lively and interesting discussions.

Because of the large number of topics and concurrent sessions within each topical area, this report represents the authors' participation. It focuses on air-sea interaction, satellite oceanography, marine atmospheric boundary layer dynamics, oceanic processes and large-scale flows, ocean modeling, and circulation in polar oceans. This report begins with a summary of the Society Lecture; selected highlights follow from some of the special sessions.

SOCIETY LECTURE: FORECASTING THE OCEAN

Dr. John D. Woods, the Head of the Marine and Atmospheric Sciences Directorate of the U.K.'s Natural Environment Research Council (NERC), delivered the Society Lecture on the opening day of the five-day conference. The theme for the presentation was ocean model development and forecast capabilities over the next decade. Dr. Woods argued that three prerequisites are necessary for ocean forecasting: scientific understanding, computer resources, and high-resolution global databases. Given that teraflop computers will be available during the mid-1990s and that the planned Global Ocean Observing System (GOOS) will provide the required data, ocean model development will rapidly evolve toward a high-resolution (10 km or better) capability before year 2000.

Such high-resolution model capabilities will enable dynamical-chemical-biological studies to be conducted on issues such as coastal water quality, cross-shelf transport, atmosphere-ocean interaction,

and eddy-eddy interaction. By the end of the century, the plan is for large-scale models to be built with high enough resolution to capture local biological feedbacks that are interactive with ocean chemistry and dynamics.

Dr. Woods indicated that the European Committee for Ocean and Polar Sciences is proposing the development of a "European Centre for Research on Ocean Forecasting." This center is planned to be a lead international organization in the development of modeling and forecasting capabilities for the oceanic environment. We feel that this is a very enthusiastic projection, and look forward to further information on this topic from NERC in the near future.

SESSION HIGHLIGHTS

Dynamics and Bio-Geochemistry of the Ocean-Atmosphere Interface

This session extended over two days and 46 papers were scheduled. However, primarily because of the large number of no-shows from the Commonwealth of Independent States, only 36 papers were presented. The session began with a series of papers on upper-ocean dynamics and their surface and satellite signatures. By using SeaSoar data, K.J. Richards (University of Southampton) showed that subsurface profiles in strong eddies have little correlation with the surface.

On the other hand, however, he found strong correlation between chlorophyll and the partial pressure of carbon dioxide. This suggests strong correlation with satellite remote sensing data in the blue-green band. It was suggested that air-sea gas exchange and ocean chemistry may be strongly linked to surface remote-sensing signatures and that operational codes may be explored.

Allen et al. (Rennell Center, U.K.) followed this presentation with a discussion of strong upper-ocean mixing near frontal zones. This mixing results from baroclinic instabilities, strong horizontal advection, and shear; data were obtained near the Iceland Faeroes Front. Later in the session, Mironov (Institute of Limnology, St. Petersburg) argued that there is a strong diurnal signal to entrainment intensity in the upper ocean. Mironov's model for mixing was presented and was reported to have been successfully tested against lake and ocean observations.

To examine local processes involved in upper-ocean mixing, Soloviev et al (Shirshov Institute, Moscow) reported on the dynamics of the Surface Density Depression Pool (DDP). DDPs arise as the result of anomalous wind bursts, solar heating variability due to partly cloudy conditions, and/or to local precipitation. The DDPs are located in the near-surface layer of the ocean and have unusually high downward entrainment rates that result in strong vertical mass and heat fluxes.

Soloviev argued that the dynamics of evolving DDPs can be tackled by use of the Korteweg-deVries-Burgers equation, which can simulate short-period internal gravity waves and the subsequent instabilities leading to flux bursts. The work was highly theoretical, and it was reported again in a very similar form at the Liege Colloquium on Ocean Hydrodynamics two months later.

Two papers reported on ocean surface interfacial dynamics resulting from biota interactions and/or oil slicks. Lapshin (State Oceanographic Institute, Moscow) described a model that illustrates the strong influence of biotic surface-active substances on mass and heat transfer. Lapshin's model considers evaporation, gravity/capillary breaking rates, turbulence and diffusion, and concentrating effects due to Marangony waves; it predicts fluxes of heat, salt, carbon dioxide, and other gases. The model is very theoretical and is yet to be fully tested with field measurements.

Kazmin (Shirshov Institute, Moscow) tackled the same problem, but he used scaling arguments for fluxes, which eases the problem of validation against field data. Kazmin reported that his model is able to predict highly variable heat flux (and therefore also convection) that result from inhomogeneities in oil slicks.

There were two papers from the Institut de Mecanique Statique de la Turbulence (IMST) Wave Facility in Marseilles, France. Caulliez (IMST) reported that over the windspeed range of 2-14 m/s, the high-frequency tail of the wave spectrum followed a -7/3 power law against frequency. For the mid windspeed range, they also found that the energy level in the capillary range was proportional to the friction velocity cubed.

Giovanengelli (IMST) examined the intricate processes associated with momentum flux to wind waves. He reported several key results:

- there is a linear coupling between air pressure fluctuations and wave slope at the frequency of the dominant wave;
- 75% of the wind stress could be attributed to form drag over the dominant wave; and
- the probability for air flow separation strongly depends on wave age.

The IMST results are highly relevant to Office of Naval Research (ONR) and other efforts to model air-sea fluxes and their dependence on wave parameters. Although the results reported were highly interesting, it is our opinion that the technology and results from the IMST team are ready for use in the field where a wider range of fetch and wave conditions could be encountered.

A series of papers on aerosol and gas exchange over the sea were presented. Mestayer et al (Ecole Centrale de Nantes, France) described the atmospheric turbulence dynamics associated with submicron aerosol deposition over the sea resulting from advected continental aerosol, and he described a bin model to predict the downward fluxes. De Leeuw (TNO Physics and Electronics Laboratory, The Hague, Netherlands) and Woolf (University of Southampton, U.K.) each described the importance of bubbles in gas and aerosol flux upward from the ocean surface. Both presentations were theoretical. They presented plans for developing upper-ocean parameterizations involving waves and bubbles that could be incorporated into operational aerosol prediction systems to upgrade their performance.

In collaboration with 13 authors, Michael Shulz (University of Hamburg, Germany) described an atmospheric experiment (North Sea Experiment) that was conducted in 1991. It included measurements of the anthropogenic aerosol and its modification during advection over the North Sea. Two ships were involved, each equipped to measure aerosol size spectra, meteorological conditions, and nitrogen compounds and their fluxes. The experiment involved scientists from Denmark, Germany, the Netherlands, and the U.K. Harrison (University of Birmingham, U.K.) and Bange (Max Planck Institut, Mainz) gave preliminary reports of nitrogen measurements.

Discussions during the conference, however, indicated that there were discrepancies in preliminary intercomparisons that need to be reconciled during ongoing analyses.

The North Sea Experiment conducted in 1991 was one of the first multinational efforts to integrate air-sea fluxes of momentum, heat, moisture, aerosol, and gas in coastal regions that blended atmospheric turbulence and air pollution research. It is a prototype program from which the community needs to build.

Use of Satellite Data in Meteorology and Oceanography

This session listed 63 abstracts, but only 50 were presented. Many presentations focused on the use of satellite sensors to map specific features and/or tackled issues outside the marine sciences. This section highlights papers that reported on marine-relevant issues and touched on new concepts in air-sea interaction, marine variability, and the atmospheric boundary layer.

Four presentations were made on the topic of measuring relative humidity over the ocean by using remote sensing techniques. Hlevaty (Czech Hydrological Institute, Prague) described a method for estimating the relative humidity statistical pattern on a regional scale by using variations in texture and temperatures in Channels 1-4 of the NOAA daytime imagery. Data showed good agreement when tuned to a particular region, but its global applicability still needs to be evaluated. To support studies of the global water cycle, Husson et al (Laboratoire de Meteorologie Dynamique, France) identified a practical approach for using existing satellite sensors (e.g., SSM/I, TOVS) to infer the distribution and transport of water vapor.

Geernaert (Office of Naval Research, Arlington, Virginia) described the role of humidity flux in atmospheric stratification and radar cross-section retrieval. He suggested that the humidity flux may be more important than the air-sea temperature difference in removing the atmospheric stability bias in satellite calibration/evaluation (cal/val) campaigns over the tropical oceans. Geernaert's presentation was based on theoretical calculations

and scatterometer retrieval simulations. Filiberti (Environmental Physics Research Center, France) reported on techniques to assimilate tropospheric mean column humidity into a meteorological forecast model, a step toward realistic assessment of modeled hydrometer distributions in forecasted storm regions.

Satellite imagery to study small-scale variability and structure dominated a series of papers. Two papers were presented by the Oceanography Group, University of Lisbon. Oliveira (Lisbon) reported on a cal/val experiment to evaluate sea-surface temperature algorithms by using satellite, aircraft, and a surface ship. Oliveira found that, while the aircraft and satellite agreed within statistical limits, the ship data were generally biased low. The explanation was that the low wind conditions encountered were probably associated with a strong temperature gradient in the ocean-surface sublayer. This gradient is normally very small during higher windspeeds.

Sousa (Lisbon) described the use of existing remote-sensing sensors to map and study the coastal current off Portugal. It was reported that at the peak of the upwelling season, filaments of cool, phytoplankton-rich upwelled water, with widths of tens of kilometers, are seen on thermal and color satellite images. This upwelled water can extend offshore for hundreds of kilometers, sometimes terminating as dipole eddies. A statistical study of the infrared imagery showed that such filaments reappear each year at nearly the same places, suggesting topographic steering by ridges and canyons. Sousa suggested dynamical instability mechanisms for the formation and decay of the features and speculated that their role in cross-shelf and vertical fluxes is very important.

E. Perez Martell (Marine Sciences Faculty, Las Palmas, Spain) reported on the intensification of the Canary Current during an anomalous southwest drift of surface waters in the region. The speaker showed strong correlations between surface temperature patterns and the formation and evolution of this current.

Guymer (Rennell Centre, U.K.) showed multisensor imagery of temperature, wind, and current fields in the Tyrrhenian Sea, with the objective understanding eddy dynamics. Because the scatterometer is a key sensor for use in Guymer's study and the scatterometer is currently inoperable on the ERS-1, plans were presented for an integrated research program once the scatterometer is brought back online as a useful sensor.

Oceanic Processes and Large-Scale Flows

This session was convened by A. Colin de Verdiere (Laboratoire de Physique des Oceans, Brest, France) and G. Siedler (Institut fur Meereskunde, Kiel, Federal Republic of Germany). Nelson Hogg (Woods Hole Oceanographic Institution, Massachusetts) presented the only U.S.-authored paper, on the topic of the Gulf Stream and its recirculations. This paper included results of the recent SYNOP (Synoptic Ocean Prediction experiment) observational program. The paper was an invited paper, and this provided time for weaving the new experimental results into the framework of our understanding concerning the driving mechanisms for the recirculation zones flanking the Gulf Stream.

Peter Saunders (Institute of Oceanographic Sciences, U.K.) gave an invited talk on measurements of the overflow water in the Charlie-Gibbs Fracture Zone. An array of current meters was used in conjunction with CTD casts to monitor the flux of cold overflow water entering the Iceland Basin, principally through the Faeroe Bank Channel. A finding of high variability was not too surprising. However, a strong freshening of the water compared with previous decades clearly supported the conclusion that the production of bottom water in the East Greenland and Norwegian Seas has changed on this time scale.

Two papers were given by Kevin Speer (Laboratoire de Physique des Oceans, Brest, France). These presented the first measurements of the Antarctic Bottom Water flow through the Romanche and Chain Fracture Zones and the Hunter Channel and provided a nice contrast to the North Atlantic results of Saunders and others.

Raymond Pollard (James Rennell Centre, U.K.) gave an invited talk on his methodology for obtaining high-resolution density and velocity measurements by using their highly developed SeaSoar and ADCP instruments. The data are processed in a complicated technique to derive estimates of the upwelling (and downwelling) of water in the zones of high horizontal gradients in eddies and fronts. This is important because the

vertical velocities associated with these motions cannot be measured directly. The method looks promising for relatively linear features, but it is only in the developmental stage for the complicated 3-D features more typically found in frontal zones.

John Gould (Institute of Oceanographic Sciences, U.K.) presented the results of his CTD and ADCP data collected during CONVEX-91, a 3-D survey of the large-scale structure of the ocean between the British Isles and Greenland. The data provide a comprehensive picture of the water masses and circulation; they show the core of the Labrador Sea water in the Irminger Basin to be significantly colder than a decade earlier.

Several papers by Russians provided some insight into their view of "lenses" of anomalous water that now are known to exist in many parts of the ocean. Soloviev's view of anomalous lenses of near-surface water was discussed previously, while G.I. Shapiro (Shirshov Institute, Moscow) gave two talks on aspects of lenses found deep in the main thermocline. Data from CTD surveys of lenses of Mediterranean water in the North Atlantic and of Red Sea water in the Indian Ocean were presented. The emphasis was on the generation and decay mechanisms of these large oceanic features.

We learned that the Shirshov Institute also has an experimental facility to study laboratory models of features of this general type. We had a chance to discuss this with Shapiro and with A.G. Zatsepin, who heads the experimental laboratory. There are numerous papers and a monograph on this subject, all in Russian, whose existence were unknown to us. Surprisingly, two other papers on this subject was not presented. The abstracts were on a self similarity theory and on observations of lenses of South Atlantic Central Water in the Cape Verde Frontal Zone.

Ocean Modelling Workshop

This session focused on numerical models of ocean circulation, with both eddy-resolving and non-eddy-resolving types of models. It was dominated by the British, French, and Germans. The session was not the most focused on this topic in recent years; it included papers on exploration of model types, sensitivity studies of parameter values, data assimilation, and display of model results. We felt that in too many cases, the results of the studies were not conclusive.

One highlight was a combination of talks associated with the U.K. Fine Resolution Antarctic Model (FRAM) by S.R. Thompson (Institute of Oceanographic Sciences, U.K.) and Kelvin Richards (University Southampton, U.K.). Thompson gave a good introductory talk on the model, which is a NERC Community Research Project in which many institutions have collaborated in the development and operation. It is an eddy-resolving model of the circulation in the Southern Ocean. It has been integrated for more than twenty model years and has been used for many studies, both for model physics and for predictions for use during the upcoming World Ocean Circulation Experiment (WOCE). It has successfully assimilated all available hydrographic data (as expressed in the Levitus data set), providing dynamical analyses of the density and velocity fields.

The most interesting part to us is the plethora of current jets that are predicted to occur over the numerous topographic features in the form of midocean ridges and passages in the region of the Circumpolar Current. David Webb of the Institute of Oceanographic Sciences, U.K., has been the coordinator of this work and was instrumental in producing an atlas of the mean density, temperature, salinity, and velocity fields.

On the negative side, we think that the spatial resolution of FRAM is only marginal, so that the mesoscale eddies are too large, too similar in size, and they follow paths that are too regular. The eddies do not appear to carry a large enough fraction of the stress on the Circumpolar Current. They decay faster than we would expect, and the cold deep water flows are weaker than observational data would lead us to believe is the case in the real world. Richards' talk on model physics in general and FRAM in particular summarized interesting results of an analysis of the importance of bottom topography in the stress balance in the transport field. The specific dynamical feature that the topography apparently provides is a field of Rossby lee waves that are a control mechanism on the transport rate.

Another highlight of this session was an invited lecture by M. Ghil (Laboratoire de Meteorologie Dynamique, Ecole Normale Superieure, France. This lecture was based on the relative

maturity of 4-D data assimilation technology in meteorological prediction systems. He reviewed known techniques in terms of sequential estimation and optimal control theory as the framework for assimilating irregular and inaccurate data into evolutionary dynamical models of the ocean. The specific techniques he mentioned include direct insertion, successive corrections, nudging, optimal interpolation, the Kalman filter, and the adjoint method. He also gave interesting examples of application of the methods to tropical and mid-latitude models, both meso- and basin-scale, and showed several short film loops of process studies.

Circulation in Polar Oceans

This session was chaired by J.C. Gascard (Universite Pierre et Marie Curie, Paris, France) and D. Olbers (Institut fur Meereskunde, Kiel, Federal Republic of Germany). It included 45 scheduled talks by scientists from a large number of European organizations on the general topic of circulation in the polar oceans, both northern and southern. The talks included a good mix of observations, model development, and model results.

Several interesting talks were given on estimates of Arctic circulation, using tracer observations made during the ODEN-91 cruise across the Nansen and Amundsen Basins and into the Makarov Basin by L.G. Anderson and R. Lindegren (Univ. Goteborg, Sweden), B. Rudels (Institut fur Meereskunde, Univ. Hamburg, Federal Republic of Germany), and E.P. Jones (Bedford Institute of Oceanography, Canada). Profiler and bottle stations were made at 59 stations for oxygen, nutrients, chlorofluorocarbons, and radioactive elements.

Rudels made interesting comments on the importance of the Atlantic Water crossing the Barents Sea in mixing and cooling the Atlantic Water that enters the Arctic through the Fram Strait and subsequently turns eastward. J.C. Gascard gave a very good summary talk on the mid-depth circulation in the Greenland Sea and into the Arctic through Fram Strait, as deduced from sofar float measurements made since 1988. Additional modeling studies were presented by scientists from many institutes; in combination with the Modeling Session, we counted more than ten different models being developed for the northern and southern seas.

OVERALL COMMENTS

The European Geophysical Society Conference has a tradition of collecting the best research in marine meteorology, atmospheric chemistry and air pollution, nonlinear processes, and remote sensing. The Europeans have strengths in boundary layer meteorology and marine air chemistry, and they have been successfully launched integrated programs that blend the disciplines. The North Sea Experiment described by Michael Shulz (University of Hamburg) is an excellent example of a multinational, multidisciplinary project with potentially high payoff.

The session on Satellite Meteorology and Oceanography was deeply qualitative and suffered from the lack of scatterometer observations to support existing research efforts. Based on the presentations, most of the efforts were on using satellite data in either data assimilation studies attached to forecast systems or as supplements to in situ observations for studying coastal ocean dynamics. The Portuguese effort was particularly impressive at using satellite signatures to understand the dynamics responsible for coastal currents and temperature patterns.

The sessions on oceanography were very informative in documenting just how far the Europeans have come in the last decade in planning and running their own oceanographic programs. Although many of the talks were from programs that included a large U.S. constituency, many more of them were from programs that were almost entirely European, either scientists working within their own countries' programs or a coalition of scientists from several European countries. Most of this research is equal in quality to the best in the U.S.

Unfortunately, like most large conferences, there were too many extremely interesting concurrent sessions. For example, several colleagues mentioned that many papers presented in the Nonlinear Dynamics Session were very interesting and relevant to the boundary layer sciences. Although both of us are interested in this field, we had interesting concurrent sessions, and neither of us were able to attend. This is an unfortunate characteristic

of large conferences such as this one. On the other hand, the EGS Assembly represents a myriad of scientific topics woven through the numerous sessions and workshops, so a week's investment of time is most rewarding.

A number of Russian scientists were at the meeting as the result of the availability of travel grants from EGS. There were so many scientists from the Shirshov Institute in Moscow that the *Academik Keldysh*, one of the very large research vessels operated by that Institute, was used for transport and hotel accommodations for some of the scientists at the meeting. The cost of the voyage was partially defrayed by EGS by paying dockage and pilotage fees. The presence of these Russian scientists was strongly felt at the sessions on turbulence and nonlinear dynamics, but their presentations in the more general oceanography sessions were not particularly strong, and many scheduled talks were canceled. For the most part, cancellations were due to the inability of the scientists to attend the meeting, but there were a surprising number that were not presented, even though at least one author on the abstract was present in Edinburgh.

As with many national or international gatherings, the meeting was an opportunity to hold smaller, (sometimes) unscheduled meetings with colleagues from different countries. One such meeting was hosted by Raymond Pollard (Rennell Centre for Ocean Circulation, U.K.), with the title "North Atlantic Gyre Dynamics Experiment". The title led us to expect a discussion of an observational program, either in progress or being planned for the future. The title turned out to be misleading. An introductory talk was given by John Woods of NERC, and he set the goal of determining if there were support within the oceanographic research community for a large European program for research on ocean prediction in the next decade.

This was a clear attempt to obtain feedback from the topic he addressed in his Society Lecture several days earlier. We feel that this is a very interesting idea; ocean prediction clearly is a central need of all climate research programs, but specific plans for an international ocean prediction program have not yet been put in place. The opportunity apparently is an expression from the European Committee on Ocean and Polar Science that it will entertain proposals for "Grand Challenges," which are defined to be projects with goals so difficult as to require international cooperation and long-term commitment. The leading candidates for such Grand Challenges that were mentioned are a European Program on Ice Coring in Antarctica, a deep ocean coring program perhaps led by IFREMER in France, some unreferenced program in the Arctic (perhaps the Finnish Initiative) and, finally, an ocean program on forecasting and/or contribution to the planned Global Ocean Observing System.

Following Dr. Woods' presentation on this opportunity, there was a long, energetic discussion between leading scientists and administrators of the many European oceanographic institutes represented at the meeting, with the expected comments about timeliness, affordability, and commitment. John Gould (Institute of Oceanographic Sciences, U.K.) also gave a short presentation on the World Ocean Circulation Experiment Core Project 3, the Gyre Dynamics Experiment, and how he thought it fit into the general discussion. Raymond Pollard will act as a central point of information on this topic. He will collate written information submitted to him concerning the idea, and distribute it to all interested parties. Dr. Pollard can be reached at:

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Finally, abstracts of all papers and posters presented at the 17th Assembly of the EGS are available as a supplement to Volume 10 of *Annales Geophysicae*. The 18th Assembly will be held in Wiesbaden, Germany, on 3-7 May 1993.

Biology

Aspects of Cell Biology Research

by Dr. Constance Oliver, Scientific Officer, Systems Biology, Office of Naval Research, Arlington, Virginia

KEYWORDS: hypoxia; respiration; metabolism; anoxia; acidosis

INTRODUCTION

Many organisms undergo long periods of reduced oxygen (hypoxia or anoxia) as a normal part of their life cycle. For other organisms, hypoxia and anoxia are experienced only during periods of stress or trauma. Many different mechanisms have evolved to manage hypoxia. Recent travels by the author have highlighted the many pathways that scientists are following in trying to understand these cellular defense strategies to hypoxia.

SYMPOSIUM ON CELLULAR DEFENSE STRATEGIES TO HYPOXIA

The Symposium on Cellular Defense Strategies to Hypoxia, under the auspices of the International Union of Biochemistry, was held in Noordwijkerhout, The Netherlands, 31 July - 2 August 1991. It was attended by approximately 80 scientists, largely from Europe, with a few representatives from Canada and the United States. The meeting was divided into four subject areas, advantageous metabolic pathways, models for metabolic suppression, membrane function, and recovery and intervention.

Advantageous Metabolic Pathways

Organisms have devised a wide range of strategies to deal with conditions of hypoxia and anoxia. A diversity exists in the metabolic pathways used under conditions of lowered oxygen. The topic of metabolic pathways was further subdivided into bio-energetical advantages, efficiency advantages, and pH advantages. The subject of bio-energetical advantages consisted of four presentations dealing with organisms ranging from single-celled yeast to invertebrate erythrocytes.

A. Scheffers from Delft University of Technology discussed maintenance of redox balances during anaerobic metabolism of sugars by yeast. How yeast metabolize sugars is affected by the nature of the sugar, its concentration, the type of yeast, and the availability of oxygen. Yeast can alter its use of glucose to produce biomass or energy depending on its environment. Under anaerobic conditions, yeast mitochondria may play an anabolic role in order to produce energy for the cells.

F. Menegus of the Instituto Biosintesi Vegetali, Milano, Italy, compared the metabolism of rice and wheat under hypoxic conditions. Plants such as rice are able to live in oxygen-poor soil because their systems have the ability to adapt to hypoxic conditions. In anaerobic conditions, rice utilizes almost pure alcoholic fermentation with virtually no lactate production, while wheat uses lactate and alcohol fermentation. Avoiding lactate fermentation appears to be important in developing tolerance to hypoxia in plants.

On the other hand, parasitic helminths transform into predominately lactate-producing organisms under aerobic conditions. A. G. M. Tielens, Utrecht University, detailed the transition from aerobic to anaerobic metabolism during the life cycle of parasitic helminths. For most of their life, helminths are free living and respire aerobically. However, in the adult stages inside the intermediate or final host, they have predominately anaerobic energy metabolism. However, among the helminths at least two distinct mechanism for anaerobic transition occur. The liver fluke, Fasciola hepatica, switches gradually from aerobic to anaerobic metabolism. As the parasite grows, oxygen diffusion is limited and only the outer layer of cells

can respire aerobically. In Fasciola the switch to anaerobic metabolism is controlled by the size of the organism. In Schistosoma manosoni, the switch to anaerobic metabolism occurs rapidly as the organism penetrates the skin; it is triggered, not by low oxygen but by high glucose levels that increase the glycolytic flux. The transition from aerobic to anaerobic metabolism occurs at the end of the helminths' life cycle, and once the transition is made, they never return to aerobic metabolism.

The final presentation in this section by A. de Zwaan from Delta Institute of Hydrobiological Research, The Netherlands, dealt with respiration in erythrocytes of the blood clam Scapharca inaequivalvis. Invertebrates store more oxygen per unit volume of erythrocytes than mammals and can support aerobic respiration approximately 12 times as long as man. Anaerobic respiration is activated a much lower pO_2 than in other clams lacking blood cells. Under anaerobic conditions, the mitochondrial respiratory chain is utilized, with glucose, not glycogen, serving as the energy source; the cells are able to maintain high ATP levels at very low oxygen tensions. The next area of discussion was efficiency advantages.

Erich Gnaiger from the University of Innsbruk began the session with an overview. Anaerobic metabolism utilizing glycolysis to lactate is characterized by high energy production but low efficiency. However under anoxic conditions, glycolysis to succinate, propionate, and acetate occurs with high efficiency but low metabolic power. In fact that efficiency is lowered during periods of high ATP demand (such as in a working muscle) can be explained by the fact that at maximum efficiency, the energy flux and metabolic power are shut down. Therefore, maximum power and maximum efficiency are mutually exclusive.

Dr. Gnaiger's talk was followed by C. van Hardeveld, Free University, Amsterdam, discussing the role of thyroid hormone in the regulation of energy efficiency of muscle contraction. T_3 stimulates both the resting metabolic rate of muscle and the energy turnover during contraction, but it does not induce a comparable increase in force. The alterations in metabolic rate may be due to an increase in the amount of fast myosin heavy chain induced by T_3. The increased energy requirement produced by T_3 is, to a large extent, compensated for by an increased capacity for mitochondrial respiration.

P. W. Hochachka, University of British Columbia, then described how humans can adapt their metabolic efficiencies under hypoxic conditions. Comparing Andean indians to lowlanders, to individuals who were trained as marathon runners and to those who were power trained (professional hockey players), he found that the Andean indians had adapted to chronically low O_2 availability in three ways. They maximized the moles of ATP obtained per mole of substrate metabolized, maximized the moles of ATP obtained per mole of O_2 consumed, and maximized the work achieved per mole of ATP utilized. Although the Andean natives were able to work longer before reaching the point of fatigue, marathon runners showed similar efficiencies in utilizing energy, while there was no difference between power-trained and sedentary individuals.

The last topic covered in this segment of the program was pH advantages. H. O. Portner, Universitat Dusseldorf, began the session with a talk on acid-base and metabolic homeostasis during anaerobiosis. pH in animals is controlled by many factors, such as phosphagen byproducts, buffer substances, the amount of H^+ ions present, the release of protenated end products, metabolic rate, and ion exchange. The rate and efficiency of proton equivalent ion exchange may depend on changes in metabolic rate during anaerobiosis and subsequent recovery. Movement of undissociated end products also contributes to pH maintenance. The rate of transport is determined by concentration gradients, pH gradients, and cellular permeability to lactic acid.

The presentation by Aren van Waarde, University of Leiden, focused on the unique metabolic adaptation of goldfish to anoxia. Unlike most organisms that produce lactic acid as an end product in response to reduced oxygen tension, goldfish and crucian carp produce and excrete ethanol. In response to lowered oxygen levels, the goldfish produces lactic acid as a result of anaerobic metabolism. The increase in lactic acid results in a drop in intracellular pH that leads to the activation of enzymes necessary for ethanol production. Thus lactic acid is metabolized and does not accumulate in the tissues.

A. Malan, Universite Louis Pasteur, Strasbourg, France, discussed pH_i regulation and metabolic depression in mammalian cells. Metabolic depression is assumed to occur in mammals under two physiological conditions, hibernation and diving. During hibernation, intracellular pH is reduced in most body compartments, but not in the heart and liver. The resulting acidosis has an inhibitory role on energy expenditure by inhibiting the formation of ion channels that allow for the alkalinization of the cells. Alkalinization is prerequisite of a thermogenic response.

S. C. Hand, University of Colorado, examined the effect of pH_i on the synthesis of cytochrome oxidase during anoxia in brine shrimp Artemia embryos. Under either aerobic or anaerobic conditions, synthesis of cytochrome oxidase is blocked as the cells acidify. The synthesis of both mitochondrially and nuclearly encoded subunits is affected equally. Evidence suggests that the block occurs at the translational rather than at the transcriptional level.

The regulation of intracellular pH in hypoxic plant tissues was the subject of the talk by J. K. M. Roberts, University of California, Riverside. At the onset of hypoxia, plant cells experience a mild acidosis. This acidosis is necessary to activate the metabolic pathway leading to ethanol rather than lactate production. Cytoplasmic protons may also be transported to the large acidic vacuole that occupies the interior of most plant cells. Therefore, plants control hypoxia-induced acidosis both by a shift in their metabolic end products and by removing protons from the cytoplasm.

The final presentation of this session by J. J. Lemasters, University of North Carolina, Chapel Hill, dealt with acidotic protection of liver and heart cells during ischemia and a "pH paradox" following reperfusion. During both ischemia and reperfusion, lethal cell injury can be prevented or delayed by acidosis (pH < 7.0) while neutral or alkaline pH accelerates cell death. In models of ischemia and reperfusion, it is the rapid return to normal pH, rather than reoxygenation, that results in cell death. ATP depletion or ion deregulation during cell injury may lead to the activation of hydrolytic enzymes such as phospholipase, proteases and endonucleases whose activity is inhibited at acid pH. Maintaining the cell at an acidic pH following reoxygenation may allow for recovery with minimum cell injury and death.

Models for Metabolic Suppression

Many animals respond to oxygen deprivation by suppressing their metabolic pathways. This subject area was divided into two topics, comparative studies and mammalian tissues. K. B. Storey, Carleton University, Ottawa, led off this session with a lecture on molecular mechanisms of metabolic arrest in mollusks. Marine mollusks use metabolic arrest as a key part of anaerobiosis; terrestrial gastropods exhibit metabolic rate depression during aerobic estivation. In marine mollusks, coordinated control of glycolytic rate depression during anoxia is achieved by reversible phosphorylation of several of the key enzymes in the metabolic pathway. This produces less active enzyme forms during the aerobic-anoxic transition.

The effects of hypoxia on energy metabolism, metabolic rate, and brain cell structures in insects was then discussed by G. Wegener, Johannes Gutenberg Universitat, Saarstrasse, Germany. Upon anoxia, adult insect become paralyzed within seconds. Unlike mammals, however, they have the ability to recover from prolonged periods of anoxia, such as 12 to 24 hours in 100% nitrogen. During such anoxia, insects are in a state of depressed metabolism. Glycoiysis is blocked, and few anaerobic products are formed. Prolonged anoxia leads to ultrastructural damage in brain tissue, but the changes are reversible and nerve cells seem to recover completely from anoxic injury.

The next presentation by G. van den Thillart, University of Leiden, The Netherlands, covered the role of metabolic acidosis in the buffering of ATP by phosphagen stores in fish. In anoxic muscle of three different species of fish, phosphocreatine hydrolysis and anaerobic glycolysis appear to be functionally coupled. This coupling disappears with reoxygenation. There seems to be a natural balance between the consumption of H^+ by phosphocreatine hydrolysis and the production of H^+ by anaerobic glycolysis. M. Rosenthal, University of Miami, Miami, Florida, examined the metabolic adaptations that promote tolerance to anoxia in the brain of the freshwater turtle Pseudemys scripta. The key to anoxic tolerance is

maintenance of essential high-energy intermediates such as ATP. Also, decreased energy demand from depression of electrical activity and changes in membrane physiology, which decrease reliance on ion transport, are essential for anoxic tolerance.

G. E. Nilsson, Uppsala University, Sweden, presented evidence that GABA (gamma-aminobutyric acid) is a mediator of metabolic depression in crucian carp and that metabolic depression can be modulated pharmacologically.

The second part of this session dealt with metabolic suppression in mammalian tissues. W.N. Stainsby, University of Florida, opened the session by describing the metabolism-perfusion relationship. In skeletal muscle, reducing blood flow reduces Vo_2 by an unknown mechanism and produces a down regulation of the contraction process and metabolism. Since flow elevation reverses this process, flow-related down regulation must occur under normoxic spontaneous flow conditions near Vo_2 max.

The role of amino acids in stabilizing intracellular structure during ATP depletion during hypoxia or metabolic inhibition was the subject of the talk by M. A. Venkatachalam, University of Texas, San Antonio. Kidney proximal tubule cells transport and concentrate glycine to much higher levels than is present in blood. When depleted of ATP by hypoxia or metabolic inhibition, the cells undergo structural disintegration. Extracellular exposure to six amino acids, glycine being the most effective, was able to prevent this disintegration. Forty other amino acids and their analogs were ineffective. It is suggested that glycine plays a critical role in maintaining cell structure and integrity.

The regulation of oxygen uptake in periportal and pericentral regions of the liver was described by R. G. Thurman, University of North Carolina, Chapel Hill. There is no difference in the ability of hepatocytes from different regions of the liver to take up oxygen. However, the liver does possess an oxygen sensor. Evidence suggests that Kuppfer cells may function as such a sensor, and that hypoxic damage to the liver may be the result of activation of the Kuppfer cells.

J. A. Hoerter, Universite Paris-Sud, gave the last talk in this group. In the mammalian heart, integrity of the energy transfer function of creatine kinase rather than ATP content appears important in maintaining contractile function. The intracellular compartmentalization of creatine kinase isozymes may play a key role in this function of energy transfer.

Recovery and Intervention

C. D. Moyes, University of British Columbia, led off this session by describing the recovery metabolism of fish white muscle following burst exercise. Compared to recovery in mammals, in fish the conversion of lactate to glycogen is extremely slow. The conversion occurs in situ rather than in the liver, and the mitochondrial content of the muscle may be an important determinant of the rate of recovery in white muscle.

W. M. M. J. Bovee, Dealt University of Technology, provided a description of the use of nuclear magnetic resonance (NMR) to study hyperammonemia in hepatic encephalopathy in vivo in the rat. NMR provides a noninvasive method to perform chemical analysis on localized regions of the body such as measuring metabolite levels in brain. The neuropsychiatric syndrome seen in patients with impaired liver function may be due to increased levels of ammonia in the blood.

Hypoxic damage to fibroblasts incubated with erythrocytes was presented by J.M. Rifkind, National Institutes of Health. Deoxygenation of hemoglobin will cause an increase in its binding to band 3 of the erythrocyte membrane. Under hypoxic conditions, hemoglobin can autoxidize with the formation of superoxide from hemoglobin bound to the erythrocyte membrane. The superoxide may then leak out of the cell through anion channels. During hypoxia, if the erythrocytes are in intimate contact with other cells (such as fibroblasts or endothelial cells) there is damage to these cells.

Membrane Function

C. J. Doll, University of British Columbia, discussed the possibility that turtles (Chrysemys picta) utilize "channel arrest" (the reduction in ion leakage across the plasma membrane) as a mechanism to cope with anoxia. Intracellular recordings of membrane changes of turtle cortical

slices indicates that neurons are not using "channel arrest," but rather survival is largely dependent on glycolytic energy production.

Martin Brand, University of Cambridge, then described how control analysis theory can be used in complex metabolic systems to discover how control is distributed and the site of action of effectors. If a system is isolated from outside influences, it can be broken into a series of blocks; the input and metabolic output of each block can be measured to determine which are the controlling steps and to assess the effects of agonists or antagonists.

An overall impression of the meeting was given by P. Lutz, Florida Atlantic University, Boca Raton. Organisms use a variety of metabolic strategies to deal with the problems of hypoxia and anoxia. While lower organisms and mammals may have developed differing mechanisms to deal with these problems, much can be learned by taking a comparative approach to studying hypoxia and anoxia.

Summary

The Symposium on Cellular Defense Strategies to Hypoxia was highly successful. The meeting brought together leading scientists who provided a detailed accounting of the various mechanisms organisms use to cope with hypoxia. It was clear from the meeting that many different strategies have developed to protect an organisms from hypoxia. These strategies range from alterations in metabolic pathways to changes in membrane ion channels. The results most relevant to the Office of Naval Research (ONR) are those dealing with the effects of hypoxia on mammals. Peter Hochachka, University of British Columbia, reported that humans can alter their metabolic efficiencies to adapt to the hypoxic conditions at high altitudes. C. van Hardeveld, Free University, Amsterdam, indicated that thyroid hormones may play a role in the energy efficiency of muscle contraction.

A number of investigators discussed the role of acidosis during hypoxia, and John Lemasters, University of North Carolina, Chapel Hill (an ONR grantee), provided evidence that maintaining an acidotic intracellular pH during recovery from hypoxia prevents cell death. This finding has profound implications in the treatment of hypoxia resulting from trauma. The symposium also demonstrated the value of using a comparative approach to studying the value of using a comparative approach to studying the effects of hypoxia. While it is clear that different organisms may respond differently to hypoxia, it may be possible to exploit the mechanisms used by hypoxia-tolerant organisms to increase tolerance in humans. Tissue damage following trauma-induced hypoxia is a major concern in combat casualty care.

CELL BIOLOGY DEPARTMENT, UTRECHT UNIVERSITY, THE NETHERLANDS

The primary focus of the Cell Biology Department is the intracellular sorting and compartmentalization of proteins and lipids. The members of the department have used the endosomal-lysosomal system as a model for their studies. Current research by Dr. Ger Strous indicates that, unlike many other lysosomal enzymes that rely on mannose-6-phosphate receptors for sorting and delivery, cathepsin D may be sorted by another, as yet unidentified, receptor system.

Electron microscopic immunocytochemical studies indicate that the high and low molecular weight forms of the mannose-6-phosphate receptor have different intracellular distributions. The small molecular-weight receptor is primarily associated with small endosomal vesicles. The differences in their intracellular distribution may give clues as to the functions of the two forms of the mannose-6-phosphate receptor. New methods of labeling lipids have allowed Dr. Gerrit van Meer to initiate studies on the synthesis and transport of lipids. Lipids are synthesized in the endoplasmic reticulum and presumably are transported through the Golgi apparatus for further processing and modification. Current research is aimed at elucidating the complex pathways used to transport and sort intracellular proteins and lipids.

CELL BIOLOGY AND HISTOLOGY DEPARTMENT, DEPARTMENT OF RADIOBIOLOGY, UNIVERSITY OF GRONINGEN, THE NETHERLANDS

The research emphasis of the Radiobiology Department, headed by A.W.T. Konings, is on

injury to cells and tissues after therapeutic irradiation. Following exposure to therapeutic doses of X-irradiation, there may be damage to surrounding normal tissue. The function of the salivary glands may be compromised as a result of head and neck irradiation. Likewise after X-ray treatment of bones, marrow function is depressed. The Department of Radiobiology is currently establishing in vitro systems to examine the effects of X-irradiation on salivary glands and bone marrow stem cells. Following irradiation of the salivary glands, certain proto-oncogenes, c-fos, c-jun, and c-abl, are know to be activated. The time course of activation varies with the oncogene. The role these oncogenes play in radiation damage is under investigation by Birgit Peter. The in vitro systems are also being used to assess the effects of various radiation levels and dose rates on cellular injury.

Chemistry

Industrial Advances Stimulate Interest in Organometallic Compounds

by Harold E. Guard, Scientific Officer for Organic and Organometallic Chemistry, Office of Naval Research, Arlington, Virginia

KEYWORDS: industrial advances; organoarsenicals; environment; organotins; biogeochemistry

INTRODUCTION

Interest in the environmental fate and effects of organometals and in organometal therapeutic agents is increasing. In 1986 the Office of Naval Research European Office sponsored the Fifth International Conference on the Organometallic and Coordination Chemistry of Germanium, Tin, and Lead. Because of exploding world-wide interest in the environment, a separate conference that focused on environmental and biological aspects of organometal chemistry was discussed.

The result was the First International Conference on Environmental and Biological Aspects of Main-Group Organometals, held in Padova, Italy, 15-19 September 1991. The conference was sponsored in part by the Università di Padova, Regione del Veneto, and the Italian Chemical Society. Professor Giuseppe Tagliavini, Department of Chemistry, Università di Padova, Italy, organized, hosted, and chaired the meeting, with Prof. V.G. Kumar Das, Department of Chemistry, University of Malaysia, Kuala Lumpur, Malaysia as cochair.

Each conference session was opened with an invited plenary lecture introducing the session topic. Plenary lectures covered

- Biogeochemistry of arsenic
- Interactions of organotins with biological systems
- Biological activity of organosilicon and germanium compounds
- Mechanisms of methylmercury cytotoxicity
- Computer modeling of transport and fate of pollutants.

These lectures were followed by selected scientific papers; a poster session was also held. More than 60 scientists attended from laboratories and universities across the world representing Australia, Belgium, Canada, Peoples Republic of China (PRC), France, the Federal Republic of Germany, Italy, Israel, Latvia, the U.K., the U.S., and the former U.S.S.R.

Industrial advances have stimulated interest in the environmental and biological aspects of organo-

metallic compounds. These industrial advances have led to increased environmental insult by main-group metals and organometallic compounds, the discovery of natural pathways for methylation of metals, and the discovery of beneficial biological effects of the germanium- and tin-containing organometals. Three basic themes emerged during this conference:

- Understanding the environmental biogeochemistry of main group organometals
- Organometals as potential therapeutic agents
- Organometals as pesticides and herbicides.

Research described showed that our understanding of accumulation and toxicity is moving beyond the concepts of bioaccumulation factors and 5-day bioassays. For biomonitoring and environmental assessment, kinetically controlled processes must be considered. Also, chemical speciation of both metals and organometals is prerequisite to understanding environmental impacts.

BIOGEOCHEMISTRY AND THE ENVIRONMENTAL IMPACTS OF ORGANOARSENIC COMPOUNDS

Professor William Cullen, University of British Columbia, Vancouver, opened the conference with an excellent plenary lecture describing the speciation of arsenic in aqueous environments and the role of biological methylation of arsenic. Chemical speciation of arsenic remains a problem, with 20 percent of arsenic in the terrestrial environment unspeciated and 30 percent in gastropods. Speciation of arsenic is critically important because it is intimately interwoven with its toxicity and the biological strategies for detoxification.

Professor Cullen described some results of his research that, if borne out in generality, will revolutionize thinking on bioaccumulation and the use of biomonitors. He has pioneered with liposomes as models for biological membranes in quantitating biological mobility of arsenic. Through this work, he has discovered that the rate of arsenic diffusion out of a liposome can vary by a factor of 10 for chemical species exhibiting similar equilibrium bioconcentration factors.

Furthermore, he suggests that accumulation may be kinetically controlled by membrane transport phenomena and not always by equilibrium partitioning. This finding and his suggestion attack the very heart of the equilibrium assumption on which is based the use of mollusks as integrating biomonitors of environmental levels of metals and xenobiotics.

The role of organoarsenicals (especially arsenobetaine, $(CH_3)_3As^+CH_2COO^-$, the most abundant organoarsenic species in marine organisms) received considerable attention. Doctor Kevin Francisconi, Western Australian Marine Research Laboratories, North Beach, presented a detailed discussion of possible biochemical pathways leading to arsenic-containing ribosides and ultimately to arsenobetaine. Arsenobetaine has very low toxicity and probably results from detoxification strategies.

Professor Shigeru Maeda, Kagoshima University, has found that foodchain transport of organoarsenic compounds occurs with nearly a 10-fold decrease in tissue burdens in each trophic level. No food chain bioconcentration was found here. Finally, in studies of arsenic in marine organisms, Dr. Toshikazu Kaize, Kanagawa Prefecture Public Health Laboratories, Yokohama, Japan, reported that little inorganic arsenic (the most toxic forms) was found in tissues of marine organisms. However, total arsenic levels as high as 126 μg/g were found in some fish tissues.

INTERACTIONS OF ORGANOTINS WITH BIOLOGICAL SYSTEMS

The U.S. Navy has played a key role in developments in the environmental arena by its support for research into the environmental chemistry and ecological impacts of the tributyltin compounds. The Navy's interest stems from the potential use of tributyltin-containing paints as antibiofouling coatings on naval vessels. Previous research sponsored by the U.S. Navy led the field and stimulated the expansion of environmental concerns regarding the use of tributyltin compounds.

Although the U.S. Navy has decided not to use organotin-containing paints, these paints remain the state of the art for antifouling coatings used by international commercial fleets. Consequently,

much interest in organotins remains in the international research community.

With organotins, the theme of the rate-limiting nature of membrane transport of organometallics was continued in the plenary lecture, "Interactions of Organotins with Biological Systems," by Prof. Renato Barbieri, Università di Palermo, Italy. In a review of the state of knowledge of organotin toxicity, he discussed interactions of tributyltins with human erythrocytes.

This work builds on contributions from the Office of Naval Research (ONR) grantee, Prof. M.T. Tosteson, University of Puerto Rico, and Navy scientists, Drs. T. Porvosnik and B. Grey, while at the Navy Toxicological Detachment, Wright-Patterson Air Force Base, Ohio. In his own research based on the use of Mössbauer spectroscopy, Prof. Barbieri presented evidence for the importance of five-coordinate organotin species in biological membranes.

While organotins tend to be four-coordinate in nonpolar organic solvents, in environmental and biological systems, higher coordination (especially the five-coordinate trigonal bipyramid) is the rule. Even six-coordinate organotin structures may be important in interactions with DNA.

In studies with model constituents of marine biofilms, the uronic acids, I reported the observation of chelate formation invoking five-coordinate tin. In addition, I reported a unique trialkyltin-catalyzed equilibration of galacturonic acid. This is the first report describing the catalysis of reactions of sugar derivatives by an organometal species found as a contaminant in the marine environment.

A very important, if somewhat understated, finding emerged from the poster session. Dr. J. Weike Tas, Environmental Toxicology Section, Research Institute of Toxicology, University of Utrecht, the Netherlands, presented results of toxicity studies of tributyltin compounds with both continuous and pulsed exposure regimes. In all exposures, all dead fish contained approximately the same lethal body burdens of tributyltins.

This result, taken together with previous observations that the organotins are "slow-acting" toxic compounds, casts doubt on the value of the standard 5-day bioassay for developing environmentally sound regulations for organotin compounds. In these experiments, the toxicity was more closely related to accumulation level than to water concentration or exposure regime. To relate accumulation level to water concentration or dosage, knowledge of the uptake and depuration kinetics is required.

MINAMATA DISEASE AND THE ENVIRONMENTAL CHEMISTRY OF METHYLMERCURY

The classic case of the importance of methylation of metals in the marine environment is the methylation of mercury and the devastating health effects of methylmercury on humans seen in Minamata disease in Japan. Professor E.J. Massaro, Duke University, Durham, North Carolina, reviewed methylmercury poisoning. He emphasized its pathology and symptomology. Proceeding to his own research, he described an elegant technique for the rapid assessment of effects of organometals and toxic compounds in general based on the use of flow cytometry.

This technique characterizes effects on growing mammalian leukemia cells by measuring both growth and viability of individual cells. As an example of the power of this technique, he presented results refuting the previously held hypothesis that methylmercury blocks microtubule formation during cell replication. Instead, methylmercury appears to block DNA synthesis.

The bioaccumulation of methylmercury still attracts the attention of biologists, as evidenced by the paper of Prof. V. Minganti, Università di Genova, Italy. He discussed the accumulation of mercury and methylmercury by cephalopods. Both the accumulation of total mercury and its speciation are dependent on the tissue type in these organisms.

ORGANOMETALS AS THERAPEUTIC AGENTS

A major research program is under way in Belgium to discover organotin antitumor agents based on a hypothetical analogy to the antitumor agent cis-platin, a platinum organometallic compound. Professor Marcel Gielen, Vrije Universitiet Brussels, presented an update on the results of this program in in-vitro testing of organotin compounds for activity against a mammary tumor cell

line and a colon carcinoma. In these studies, the most effective organotins were 10-20 times more active than the cis-platin reference. These compounds would be expected to exhibit a considerably lower cytotoxicity to kidney tissue than would platinum compounds. Therefore, there is hope for an improved chemotherapeutic agent for certain tumor types.

This conference had the honor of having the first international presentation by a scientist from the Republic of Latvia. In a plenary lecture, Dr. E. Lukevics, Latvian Academy of Sciences, Riga, described the biological properties of organosilicon and organogermanium compounds. The judicious substitution of silicon and germanium for carbon, nitrogen, sulfur, or oxygen in analogues of known pharmaceuticals, can result in improved delivery, enhanced activity, or reduced toxicity.

Silicon-containing prodrugs that hydrolyze to the therapeutic agent are known. In some cases, the inclusion of germanium reduced toxicity while maintaining the specific activity. The field of silicon and germanium drug analogues is empirical at this time. Trends have been observed, but no predictive capability exists based on the generalization of these trends. Much of the available data needs to be reinterpreted based on molar toxicities rather than on values based on weight. Nevertheless, these ideas offer possibilities for controlling delivery rate as well as balancing activity and toxicity in new therapeutic agents.

ORGANOMETAL PESTICIDES AND HERBICIDES

Scientists from Malaysia, PRC, and Canada, highlighted their interest in developing new organotin compounds for use as pesticides and herbicides. Environmental and human health concerns, together with licensing roadblocks, have all but eliminated organotin pesticide use in the U.S. Nevertheless, there remains both a need for and interest in organotin pesticides and herbicides for food crop protection in the Far East.

Professor V.G. Kumar Das, University of Malaysia, discussed his synthesis of many organotin carboxylates, structure-activity relationships relating to acute and sublethal effects, and their synergistic effects with biological agents. His work refutes the often-quoted paradigm that in trialkyltin compounds, R_3SnX, the nature of the fourth group, X, does not affect the toxicity.

Professor Kumar Das has extensive data that show significant effects of the nature of X and the substituents on the X group. Also, Prof. Q.-L. Xie, Nankai University, Tianjin, PRC, presented data showing both the importance of the R-group and the X-group in ascaricidal activity of organotin compounds. Again, the importance of speciation arises. If X is hydrolyzed readily or upon delivery, then the nature of X is not important for toxicity. However, if the original R_3SnX remains intact, then the nature of X exerts an important control over observed toxicity.

In studies relating to synergistic effects of organotins with biological agents, Prof. Kumar Das hypothesizes that the organotin compounds have a role in preventing the development of resistant organisms that occurs after the application of biological agents alone.

Professor Ivor Wharf, Dawson College, Westmount, Quebec, presented his research results assessing the role of steric and electronic factors governing fungicidal activity of triorganotin acetates and hydroxides. Both steric and electronic effects are important factors in determining biological activity. These results are interpreted in terms of organotin binding to a hydrophobic site containing one or two ligands that bind the organotin in trigonal bipyramidal configuration. This is another example of the biological importance of five-coordinate tin.

SUMMARY

To quote Prof. Peter Craig, Leicester Polytechnic, Leicester, U.K., "Main-group organometallic chemistry has moved from synthesis and catalysis to the detailed study of effects and the role of organometallic compounds in environmental and biological systems." The conference focus reflected this change in emphasis.

As an outcome on this conference, it is clear that the field of biogeochemistry of metals is rapidly moving toward organometals as important transport species with inordinate biological effects. Speciation is of paramount importance. Indications

are that transport kinetics are more important than previously believed.

The Second International Conference on Environmental and Biological Aspects of Main-Group Organometals is tentatively scheduled for 1994 in France. Dr. Oliver F.X. Donard, Université de Bordeaux, Talence, France, will chair this conference.

ABSTRACTS AND PROCEEDINGS

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A special issue of *Applied Organometallic Chemistry* devoted to selected and reviewed papers from the conference is planned for publication in 1992 by John Wiley & Sons in England. For a free copy, contact

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Engineering

Robotics in Theory, Robotics in Practice: 1992 IEEE Robotics and Automation Conference

by Daniel E. Whitney, currently serving as the Liaison Scientist for Manufacturing at the Office of Naval Research European Office. Dr. Whitney is on leave from the Charles Stark Draper Laboratory, Inc., Cambridge, Massachusetts.

KEYWORDS: robotics; combinatorics; artificial intelligence; micromachine; actuators

BACKGROUND

The 1992 IEEE Robotics and Automation Conference brought together more than 950 participants who heard more than 450 papers. Participation from Europe was especially strong, since this was the first year the conference has been held outside of the United States.

The meeting was held against the backdrop of NASA's efforts to retrieve the INTELSAT. The counterpoint is particularly ironic since the conference presented a great deal of theory that has as-yet seen little or no application; all the while the best robotics technology available in space was unable to retrieve the satellite.

Robotics today has two branches, one dealing with prepared environments (industrial) and the other dealing with unstructured and unpredictable environments (underwater, catastrophes, and space). It was once thought that a great deal of sensing and perception would be needed, even for industrial robots but this has turned out to not be true.

Industrial robotics is burgeoning in many countries, especially Japan, exactly because time and circumstances are available in which to prepare the robot, its task, and its environment, then to practice the task and perfect it, so that it can be repeated successfully many times. Sensing is rarely used to cover slight unpredictability, but this is sufficient; planning and preparation are the watchwords of manufacturing.

Robotics researchers have had to turn to the unstructured environment to justify much of the

sensing and dexterity work they have done over the last decade. Yet this environment has eluded them. It is important to note that the Shuttle's difficulties in retrieving satellites are due in large part to the inability to prepare the task environment. The issue is not lack of time to practice but rather the lack of documentation of appropriate grasping surfaces or lack of such surfaces on satellites. Regardless of how the task is done, improvisation is necessary from the start.

The fact that human astronauts had to perform the rescue lowered the morale of many of the conference's participants, especially those who hoped NASA would increase funding on robotics. The keynote speaker, Prof. Jacques Blamont of the Academy of Sciences of France, argued on Tuesday (two days before the satellite was recovered) that the progress of computer hardware and the difficulty of maintaining people in space would eventually drive them out, to be replaced by automation and robotics. "Man is there to smile and vomit," he said.

Obviously, man can do much more, but the question remains whether robotics will replace him or not. We cannot go on asking astronauts to risk their lives so that the Olympics can be broadcast. Yet conference participants did not agree with Prof. Blamont that the mere power curve of computing hardware was a convincing argument. Software does not follow as easily, and many problems are mechanical and cannot be fixed by software updates.

The issue is one of many that the robotics community has to grapple with. In many areas, theory has run years or decades ahead of applications. In other areas, either the lack of applicable technology is painfully obvious, or quite reasonable success can be achieved with much lower technology. This means that one be willing to be "unrobotic" and prepare an environment that guarantees task success.

CONFERENCE SESSIONS

I attended two workshops and several technical sessions that bring out these points. The workshops were Assembly Planning (in which I participated as a coauthor) and High Precision Sensors/Actuators and Systems. Other sessions included Constrained Motion Control, Mechanical Design of Robots, Fine Manipulation, Force Control, a panel on Large Scale National R&D Projects, Robots and Manufacturing (I was co-chair), and Neural Networks.

Assembly Planning

This is a relatively recent branch of robotics, dealing with fairly high level planning of task sequences rather than detailed planning of gross hand trajectories or fine insertion motions. It was interesting to hear the honorary workshop chairman, Prof. George Bekey of the University of Southern California, state in his introduction that "Assembly planning is planning and therefore part of Artificial Intelligence."

It was interesting because the field originated in the efforts of researchers whose motivation was design of mechanical products and the factory equipment that would assemble them. The majority of the workshop speakers represented this view and said so explicitly. That is, assembly planning to them is part of product design and concurrent engineering. At the same time, artificial intelligence (AI) methods and researchers have been strong contributors to the field.

The talks reflected the product design tilt. They emphasized linking assembly planning to CAD models of parts and to the economics and technical challenges of laying out factory floors and choosing appropriate equipment (not always robots!) to accomplish the planned assembly.

The central challenge of this field is determining the thousands of possible assembly sequences and finding the desirable one from among the possible ones. It is challenging because the problem is combinatoric in principle, and yet the worst combinatoric limits are never reached because of factors that are not understood. Another challenge is to find efficient representations and datastructures for the knowledge that is required so that efficient automatic or semiautomatic procedures can be used to find the possible sequences.

Two philosophies for representing the knowledge were discussed at the workshop, but the profound differences between them were not evident to the participants until late in the day. These philosophies are (1) geometric, and (2) logical or constraint-based.

The geometric representation is essentially a CAD model. The geometric constraints that permit some sequences of assembly and prevent others are found by computationally manipulating the geometry and searching for interferences. The logical representation assumes that the parts were designed by someone who has the opportunity to encode with the geometry most of the information that is relevant to assembly (such as the direction in which parts must approach—screws go into holes along the holes' axes, for example).

Such information is there in the design and thus does not have to be discovered by the assembly planning algorithm. This approach is called Feature-based Design (FBD); it has a 10-year history of research, mostly in supporting the fabrication of parts. Using FBD to support assembly planning is about three years old. It is the subject of a large new ESPRIT program that will be described in a separate report.

The status of assembly planning, as evidenced by the papers, is as follows:

- The combinatorics have been brought under control; products with 30 parts or more can be handled with relative ease. It is generally agreed that subassemblies with more than 30 parts are rare, and larger assemblies are usually broken into smaller subassemblies for other reasons. Some approaches require a person to provide intricate geometric reasoning; others simplify the allowed geometry so that this is not necessary. Very soon this distinction between approaches will disappear, since it is easy for users to provide the missing information. Permitting this approach makes the methods applicable to practically every mechanical product imaginable.

- Several criteria and search methods for finding desirable sequences have emerged and have practical relevance: lowest cost, fewest machines, fewest reorientations of the product during assembly, and so on.

- Successful links between planning algorithms and CAD models have been demonstrated.

- Good user interfaces exist, making it easy for users to tackle what used to be impossible problems. In fact, the problem usually was not even recognized by product and process designers. No one gave much thought to finding good assembly sequences systematically until Concurrent Engineering came along and showed that this was an important design step.

- The frontier of unsolved problems includes factoring in tolerancing, dealing with products with flexible parts, and making a stronger link between feasible sequences and desirable factory floor layouts. Several researchers indicated that they were working on these problems.

PRESENTATIONS AND BRIEF SUMMARIES

"Lega: A Computer-aided Generator of Assembly Plans," by J. Henrioud and A. Bourjault, Universite de Franche Comte, Besancon, France

Bourjault launched this field with his Ph.D. thesis in 1984. It contains the basic ideas of modeling the product's interconnections with a logical graph called the liaison diagram, and finding the allowed sequences through a dialog with the designer. The original method required too many questions, and many researchers, including Henrioud, have directed their efforts toward making the interaction more efficient. These authors firmly place their work in the domain of product and process design for industry. Recent advances include being able to simplify the search by permitting the designer to define groups of parts to lump temporarily (all share the same approach direction or tool, for example). Other researchers (De Fazio and Whitney, Lee, cited below) have done similar things.

"Computer Aids for Finding and Evaluating Assembly Sequences: What Is Now Done and What Are Some Gaps in Current Application," by T.L. De Fazio and D. E. Whitney, Charles Stark Draper Laboratory, Inc., Cambridge, Massachusetts

De Fazio and Whitney were the first to see the need for more efficient user interaction while seeking assembly constraints, and they developed two classes of algorithms. The most recent is called "onion skin;" it requires the user only to identify parts that can be removed from the outside of the assembly. The process is strongly aided by the use of assembly features obtained during the design process (or merely typed in by the user during concept design). The required information consists of part names, a connection list, and a direction of mating or separation for each part pair.

This work has extended to providing users with filters for finding sequences that obey certain industrially useful constraints or that optimize cost, number of reorientations, etc. Output sequences have been connected to assembly system design algorithms. Unsolved problems include linking "facility constraints" into assembly system design: some operations must be done at certain places on the factory floor where space, ventilation, or other resources are located; part supply lines must not interfere with the line, etc. It is similar to circuit board layout.

Another area in need of work concerns creating assembly plans that meet quality or strategy requirements. Quality requirements include the need to intersperse in-process test and rework; some sequences are better for this than others. Strategy includes planning for seasonal variations or permitting many models of the same product to be made in unpredictable proportions. Preliminary work has been done in both areas. Tolerances are also starting to be attacked.

"Task Decomposition and Planning in an Assembly Workcell Using AND/OR Nets," by A.C. Sanderson, L.S. Homem-de-Mello, and T. Cao, Rensselaer Polytechnic Institute (Homem-de-Mello is at JPL)

Homem-de-Mello did a seminal Ph.D. thesis on assembly planning in 1989 in which he proved the equivalence of several different datastructures and constraint representations for assembly plans. This presentation summarized that work and follow-on—all again placed firmly in the context of industrial product design. The algorithms for finding feasible sequences are similar to those described in the other presentations. The new work includes pruning unwanted sequences by forming groups like those suggested by Henrioud.

More interesting is the conversion of a selected assembly plan into a Petri net so that a robot action plan can be obtained. This is the subject of Cao's Ph.D. research, in progress. The talk included a video of a two-arm robot system with vision and force sensing planning and executing the assembly of some strutlike parts of a miniature space station. The demonstration obviously included work by many others besides Cao. It required coordinating many degrees of freedom and sensors, plus scheduling a complex multiprocessor control system.

Other new or planned work includes representing tolerances in the assembly data and adjusting the sequence or the robot's plan to take tolerances into account.

"Assembly Research at Sandia Laboratories," by David Strip, presented by Randy Brost

Sandia is attempting to find ways to automate low-volume production of complex mechanical assemblies, such as are found in the triggering mechanisms of nuclear weapons. Cleanliness and care are very important, but the volume is so low that people have a hard time learning the right methods before all assemblies have been built. On the other hand, conventional robotics usually requires higher volume than the Department of Energy (DOE) has in order to be economically attractive.*

Strip identified some difficulties of teaching and of designing fixtures, and created an assembly planner that can do both. The planner works only on a very restricted class of objects, however, and he has not extended it beyond these limits since the original work about two years ago. However, it is the only assembly planner that includes fixture design in the process. It operates on simple CAD descriptions of the parts and is rule-based. The plan is automatically converted into robot commands, and the demonstration includes the robot carrying out the plan.

*Actually, the economics are complex and a good case can often be made for low volume automation in precisely this environment. The argument is based on the percentage of successful assemblies that can be obtained, and the cost of failed ones. Automation usually has higher yield.

"Backward Assembly Planning with DFA Analysis," by Sukhan Lee, University of Southern California

Lee's approach is similar to Homem-de-Mello's, and they have collaborated for two years. (They also organized the workshop and recently published a book of papers on the topic, which contains reports by all the presenters here plus others (*Computer-aided Mechanical Assembly Planning*, Kluwer Academic Publishers, New York, 1991).) Lee's main contribution has been to identify the need to break large assemblies into subassemblies to reduce the combinatoric load. While this is often done routinely in industry, Lee has been seeking automatic methods. These include ones similar to Henrioud's, such as defining common directions or tools.

Also on Lee's list are common operations that do not accomplish assembly, such as testing and painting. Several of his methods are heuristic and are difficult to understand. This is true of other papers in this field, when the need to include desirable functions exceeds the ability to represent them quantitatively. The needs of real designers are still beyond the abilities of algorithms here, and this is why several researchers have fallen back on simply querying the designer at key points in the process.

"An Integrated Assembly System," by C.S.G. Lee and Y. F. Huang, Purdue University

This paper also places assembly planning in the industrial context. The work was done in conjunction with Purdue's Engineering Research Center, which already has facilities for "quick turnaround" CAD/CAM of single parts. Lee's work adds assembly to this capability. An important component of the work is the attempt to include facility capabilities such as the constraints of tools and fixtures. Another is the wish to provide designers with direct feedback on assembly problems and suggestions for redesigns. This last is one of the most difficult goals to achieve in this field, and the wish has again run ahead of the ability to deliver.

The approach has been largely implemented by asking the user to comment, with very simple rules being used by the computer to point out areas where problems exist. The group discussion after this paper indicated that people doubt whether serious redesign suggestions can be expected from computer-based methods because of the need to be creative and to understand many unstated design constraints and detailed engineering knowledge.

"Methods of Knowledge Representation for Assembly Planning," by Jan Wolter, Texas A&M University

This was a useful paper because it summarized most of the existing methods for representing geometric assembly constraints and the resulting plans. It also carefully compared the assumptions and limitations of each method. There are more similarities than differences, so the result was to show where the field is and what problems remain. For example, all methods are limited to one approach direction at a time and to no temporary positions for parts during assembly. Only one method permits three or more disjoint part sets to be mated during one operation (Wilson, see below). He has proven that the main types of constraint used by different methods are in fact equivalent.

Several minipresentations for which there are no papers followed these presentations:

- Carlos Ramos, Oporto University, Portugal, described a five-agent software system that plans and executes assembly. Tasks are described symbolically, and the user provides some of the geometric reasoning.

- Randy Wilson, Stanford University, described his recent research in which he developed what is probably the most efficient algorithm for finding the set of feasible sequences. He works with CAD models and finds separation constraints by finding contact planes between parts and determining separation directions. The sets of allowed directions are then reduced to their intersection, which determines how the part can separate from its neighbors. As in other methods discussed today that take a similar approach, the fact that a part is trapped is easily discovered once the set of escape directions is known. Wilson then exploits this knowledge very efficiently to produce the final result. However, Wilson assumes no design information is available, in contrast to the feature-based design approach. Thus his method has to recreate a

lot of information that is not exclusive to assembly planning. The combination of the efficiency of the rest of his algorithm with the FBD approach would create a dynamite method.

• Luiz Homem-de-Mello of JPL described his recent work planning the assembly of the space station. This structure is regular and has regular substructures. Homem-de-Mello showed that he could represent these structures in a hierarchical graph in which all the geometric constraints were encoded as symbols of different shapes. The search for allowed assembly operations is very much simplified and resembles the FBD approach in many ways. It also places the two knowledge representation philosophies (geometry vs logic) in the starkest contrast and shows the power of the latter most strongly of all the papers presented.

• Louis Whitcomb of Yale described his recently completed Ph.D. research in which he uses potential functions and dynamic equations of motion to generate assembly plans. Parts repel each other and are attracted to their final desired locations in the assembly by suitably constructed potentials. He has implemented this only for spherical objects. He showed a video of these parts literally dancing into their final positions. The potential field method has also been used for robot motion planning and real-time robot obstacle avoidance.

WORKSHOP ON MICROSENSORS AND ACTUATORS

This all-day workshop was in an area unfamiliar to me, and I came to learn. My impression of micromachines is that the field is in the exciting discovery period in which the possibilities are just starting to be discovered. The limitations are not being considered, and no one can predict whether really useful techniques and devices will emerge. In some cases, better alternatives exist. An example is "cell sorting," a possible application cited by several speakers.

The micromachine approach is a scale-down of a macromachine approach, as if cells were little boxes at the biological post office. At the post office one would identify each box and mechanically push it in the right direction. The micromachine people envision little micropushers. However, cell sorters are starting to be developed that work on fluid flow principles, using valves or gates to switch the flow and direct cells in different directions. Since cell sorting is likely to be a high-volume job, a flow approach makes sense. Micromachine valves for switching the flow were discussed.

Another clue that the micromachiners are still in the discovery mode is that they are generating new capabilities in isolation from possible classes of applications. In particular, they have not analyzed applications to obtain design requirements on their machines. When I asked what force the actuators could produce I was told "enough to support their weight." When I asked what forces were needed for target tasks, there was no answer.

Construction of these devices has advanced to the point where they are getting complex— often consisting of a half dozen or more individual parts that must be "assembled." Assembly takes two forms. One is well known and consists of various semiconductor processing steps that add or remove material in a complex sequence. The other is new; it involves making parts in the plane and folding them up to make 3D structures, rather like setting up a flagpole or stepping a mast.

The point is that design of such structures and their assembly processes requires a lot of skill, experience, and 3D geometric reasoning. I determined (from asking both U.S. and German speakers) that there are as yet no design tools to aid this process. (One paper described using CAD to visualize how the folded-up structures might fit together.) Here is an important research need, one that the assembly planning community might contribute to.

PAPERS, AUTHORS, AND SUMMARIES

"New Microactuators," by Prof. T. Fukuda, Nagoya University.

He described several electrostatic devices made by layering methods. An example is a parallel jaw gripper. It is made from a monolith by semiconductor processes. The moving jaws are suspended by slender leaf springs that permit relative jaw motion in one lateral and two angular directions. The different directions are obtained by turning on and off different combinations of segments on the

face of the actuator. He can get motions as large as 0.18 degrees and 50 microns. The devices must operate in a vacuum because squeeze film damping would bring their motions practically to a halt. He uses capacitive sensors to close control loops around the jaws to obtain controlled motions. For some reason, however, he has not designed the devices with actuation symmetry (push-pull arrangement that eliminates most nonlinearities). The result is that his controller is complex and results are only fair.

He has extended the principle to a complete 6 degree of freedom actuator by combining three of the simpler ones. His most interesting device was an "optical actuator." It is made from material that changes length when UV is shone on it. The principle is one of polarization, not heating, although other speakers used the latter. Fukuda has built little untethered walking horses and showed a video of one stubbing its way along. These are the first micro autonomous vehicles. Right now the motion is very slow.

"Microstructures and Microactuators for Submillimeter Robots," by Ron Fearing of the University of California, Berkeley.

Fearing has constructed 3D devices by folding them up from 2D shapes. Folding is done either manually (and painfully), or somewhat destructively by blowing fluid over the flat structures. Many do not survive, but he will undoubtedly improve on this. Folding takes place around hinge joints that are made by a selective plating and etching process. Some hinges are made with square pins to provide a bistable design: the parts want to snap upright once they are pushed up a little from the flat orientation.

Among the structures he has built are multipart hot-wire anemometers, complete with built-in signal amplifiers. These fold up in several directions and have to interlink in the process. Tab-slot assembly is used, which is done manually with microprobes under a microscope. It's incredible! The structures have integral hot-wire sensors made from laying down 3-micron- thick silicon layers. The amplifiers are on the structures and get their power from "ribbon cables" made from 50 micron wide × 3 micron thick layers. The ribbon cables span the space at the foot of the structure where it folds up from the substrate. He plans to chain hinged structures together to make little robot arms. Actuation would be provided by electrostatic forces acting across adjacent joints. An important aspect of his approach is that it would need only 10 volts, in contrast to Fukuda, who needs 300 volts. He has anticipated problems from air friction, and feels that he can live with the slow speeds it would cause.

"Thin Layer Distributed Piezo-electric Neurons and Muscles," by H. S. Tzou, University of Kentucky

His research concerns placing piezo-electric sensors and actuators on arbitrary shape shells, an early form of a "brain-muscle" system. Much of the presentation comprised a first-principles formulation of thin plate/shell theory combined with piezo-electric properties to obtain a unified model of such a device's behavior. Although the theory holds for arbitrary geometries, he has generated two special cases: cylinders and spheres.

For each case he has shown how to construct sensors that detect stress, thermal, or sound patterns by detecting the individual vibration modeshapes that they generate in the shell. Separate piezo detector patterns are laid down for each mode shape. In the case of cylinders, this results in piezo patterns that are sinusoids of increasing spatial frequency. Correspondingly, muscle-piezos in similar patterns can generate desired vibrations or cancel undesired ones up to some maximum mode number. Closed- loop sensor-control systems can be imagined.

[The following commentary on Tzou's approach was written by Dr. Cynthia Whitney of W.J. Shafer Associates in Chelmsford, Massachusetts]

The Tzou paper is representative of a developing research area devoted to the control of flexible surfaces in the presence of arbitrary disturbances. The paper is highly analytic in its approach.

An alternative approach used in practice in the U.S. is more pragmatic. The relationships between sensors and actuators are captured in a matrix, usually called the influence matrix, and usually measured experimentally rather than modelled mathematically. Simultaneous multi-input/multi-output control is accomplished by

inverting the matrix relationship, usually through singular value decomposition and generalized pseudo inversion. This approach works well as long as the number of sensors equals or exceeds the number of actuators and as long as the disturbances are of fairly low temporal frequency. Typical applications are in adaptive optics.

"Micromachining of Piezoelectric Microsensors and Microactuators for Robotics Applications," by Dennis Polla, University of Minnesota.

Polla discussed the use of lead-zirconate-titanate (PZT), a material that has 15 times the piezoelectric activity of the more commonly used zinc oxide materials. Both materials are suitable for integration with silicon microcircuit technology. By using these methods he has made the following kinds of sensors and actuators:

- a pressure sensor with 200 Hz - 40 kHz bandwidth with sensitivity of about 120 μV/μbar (microvolts/microbar)
- a cantilever beam accelerometer with 40 mV/g (millivolts/g) sensitivity at 100 Hz
- a thermal sensor capable of being arranged into a 64 × 64 array; each sensitive element is presently 38 microns square in a 50-micron-square region. He feels that he will be able to make the sensitive element 4 microns square; sensitivity is presently 100 times less than that of mercury telluride. However, the latter requires cryogenic temperatures whereas his unit operates at room temperature!

Other devices include an anemometer, a microactuator that presently requires too much voltage and suffers from breakdown, and little squeeze film fluid pumps and valves.

"Design, Modeling, and Control Strategies of a Three Degrees of Freedom Spherical Motor," by Kok-Meng Lee, Georgia Institute of Technology

Lee has designed and built several electric spherical actuators. Two yaw axes and one spin axis have been implemented in one integrated unit. The design was formed as a variable reluctance dc motor whose rotor contains permanent magnets while the stator comprises phase-actuated coils. The magnets and coils are arranged in spherical tesselations such that it is impossible for all the poles to align. The controller is designed from first principles of magnetic circuits, but it turns out to be too hard to implement the analytic controller because the equations need to be inverted. For now he is using table lookup, which is slow and takes a lot of computer memory.

"Silicon Microactuators - Activation Mechanisms and Scaling Problems," by W. Benecke, Fraunhofer-Institut fur Mikrostrukturtechnik, Berlin

This paper was mostly a survey, but he showed several interesting uses for microstructures, among them deep aspect ratio arrays for molding fine plastic parts such as filters for chemical processes or for use in microbiology. He also showed some thermal actuators made of micromachined bimorphs. Small fluid valves are a potential application. Valves that operated electromagnetically and electrostatically were also shown. Benecke said that there are no design tools in this field, and he alluded to a new "top-down" design project on microsystems that is just beginning at his institute.

"Optical Fiber Sensors and Systems," by Janusz Marszalec of VTT, Finland

This was mostly a survey paper of fairly well-known topics.

COMMENTS ON OTHER SESSIONS

Fine Manipulation

This session was really about sensorless pushing strategies, that is, methods for repositioning and reorienting objects without knowing their initial position and orientation. This field has matured in the last few years; well-behaved algorithms now exist that can deal with regularly shaped objects. In some cases the object's shape is assumed known but complex, while in others it is assumed unknown but regular (such as a rectangle). Some strategies operate in a minimum number of pushes. Some strategies use pushers to

move the object; others use frictionless parallel jaw grippers to reorient them. Most of the papers model friction between the object and the surface it moves over; only one paper in this session modeled friction between object and pusher. In this respect the analysis resembles the original fine motion parts assembly analysis done by my colleague Simunovic 15 years ago.

Force Control (Two Sessions)

Two papers were significant in these sessions; both appear to have advanced the art or removed nagging doubts about certain problems.

W.D. Fisher and S. Mujtaba of Hewlett Packard Laboratories showed how to remove the instability in the well-known Raibert-Craig hybrid force-position control. In the original method, a selection matrix S is used to determine which world coordinates are to be force controlled and which are to be position controlled. This matrix must then be inserted in a control loop along with the inverse Jacobian matrix J, but this loop can be unstable if the arm is in certain configurations. The solution is to invert the composed matrix SJ by using pseudo-inverse techniques.

H. Qian and J. De Schutter of Katholike Universiteit Leuven improved the stability of force-controlled arms with discrete time control by showing that coulomb friction has a stabilizing effect. This is interesting because coulomb friction is usually considered a degrading effect. Qian exploits the discovery by introducing artificial stick-slip numerically.

Neural Networks (Two Sessions)

These papers applied neural networks (NNs) to various aspects of robot arm control: dynamic control of unknown dynamics, robot ping-pong playing, touch sensors for identifying objects, making robot action plans, and so on. Of the eight papers, only two were from the U.S., an unusual pattern for this conference. The theoretical trend was significant: nearly every paper used a neural net as a tuner or adjuster for an analytically based main controller, a recognition apparently that neural nets cannot do much by themselves in complex problems. Typical NNs in these papers had four layers, with as many as 20 cells in the hidden layers. But even this was not enough to accomplish much alone. The resulting systems are called hybrids.

The most interesting hybrid was described by T. Shibata of Nagoya University and colleagues: "Hybrid Symbolic and Neuromorphic Control for Hierarchical Intelligent Control." The aim is to achieve task-level control of a force-controlled robot. To accomplish this, the robot needs to be able to recognize the geometric state it is in by reading force sensors. Is it stuck in a hole? Is it bumped up against a wall? These give different force patterns.

Shibata uses a neural net to sort out the force patterns at a low level and an if-then rule base to sort out responses at a high level. Thus his robot can detect that it is holding a foam cup half full of water (by squeezing and hefting it) and can then apply a rule for carrying the cup that is appropriate for half-full flexible cups. Only a simulation has been carried out.

SUMMARY

This conference was interesting but probably too theoretical for the state of the applications field. As stated at the beginning of this report, robotics research is both ahead of and behind applications. This curious situation also shows up in economics and psychiatry, where there is theory that can't yet be applied along with skilled practitioners whose success cannot be explained. Maybe it will always be that way.

The U.K. Government Program in Engineering Design Research

by Daniel E. Whitney

KEYWORDS: objectives; design research; technology transfer; Ph.D. program; innovation

INTRODUCTION

Great Britain has targeted design research, design tool development, and technology transfer. These areas may enjoy increased visibility in the new government, according to Prof. Peter Hills. Dr. Hills is the coordinator for the U.K. government's SERC (Science and Engineering Research Council, similar to our National Science Foundation (NSF)) program on research in engineering design. Out of SERC's annual budget of £450 million (as of July 1992, £1 = $1.90), £1.2 million goes to design research. This is roughly equal to NSF's budget in the same area. Dr. Hills keeps an office at the Design Council (DC) in The Haymarket in London as SERC's contractor to administer the program.

The DC promotes design quality and education by a variety of means, including annual awards, book publication, and sales of educational materials. The U.S. does not have anything quite like the Design Council, although the Design Management Institute in Boston is similar in some respects, with less emphasis on engineering and more on management.

The aim of the SERC Design Initiative, now just 2 years old, is "to establish a coherent body of scholarship and knowledge in engineering design, directed toward the development of design tools of real help to the wealth-creating industries of this country." There are several code words in this statement as well as several distinct differences between it and corresponding statements from NSF in Washington. (The Appendix to this report is a copy of the SERC program summary.)

The term "wealth-creation" was used often by Hills during our discussions, and reflects the emerging "politically correct" terminology among British Conservatives. Its use in a recent speech at Warwick University by the former minister for Domestic Trade and Industry (DTI), Mr. Peter Lilly, gave it correctness.

Many people hope that the new government of Mr. John Major will modify the Thatcher policy of noninterference in industry, replacing it with "benign encouragement." Furthermore, this encouragement will/ought to include more than lowering interest rates. This recalls U.S. debates about matters such as "industrial policy" and "dual use." Hills hopes that the new minister for DTI, Mr. Michael Heseltine, will push this area strongly, perhaps making it a cornerstone for the future.

In fact, the DTI has not been completely passive, as a brochure I obtained at Hills' suggestion indicates. It is from the DTI's Enterprise Initiative: a "comprehensive package of advice, guidance, and practical help for British business." It includes consulting, legal, and export advice, tips on establishing relationships with universities, pointers to EC Research & Development programs, modest funding for small businesses, and local technology centers. However, the aim is to "help businesses to help themselves," and the department dispenses mostly advice, information, and contacts.

The second code words are "development of design tools of real help" since this strongly implies applied research and technology transfer. This part of the aim has given him considerable difficulty, as discussed below, since it challenges many established norms and what he called "class barriers" among engineering disciplines and between academia and industry. He admires what he sees as the lack of such barriers in the U.S.

By contrast, NSF's newly released statement of objectives for its design research activity reads as follows: "...development of a scientific foundation of principles and procedures for engineering design...theories of design, methodologies and models of design, and organization and management of engineering design systems." This is

almost pure research. No mention is made here or elsewhere of tool development, real help, or wealth-creation.

In March 1992, DTI established an Innovation Department within the Enterprise Initiative staffed by one career civil servant and five assistants from industry. Its first job is to define innovation in relation to wealth creation. Hills has submitted his suggestion, but here, as elsewhere, the biggest debates are over the most basic things: in the U.K., innovation has in the past meant the processes downstream of the original idea for a product—the steps after identifying the need in the marketplace. By omitting market studies, this definition misses one of the most important and precarious steps, says Hills.

"Our efforts in design are equivalent to taking on all the problems of British industry"

Hills is an engineer; he strongly believes that design is an engineering activity and that design education and research should be strongly linked to industry, as the ultimate "customer." He agrees with me that manufacturing, defined in the broadest sense to include design and making things, is a practitioner's world and that researchers are often behind (in some areas perhaps permanently behind).

Yet design is so pivotal to wealth creation that he views his efforts in promoting design as equivalent to trying singlehandedly to cure Britain's ills by taking advantage of design's leverage. In short, he feels that design gains its effect by being a creature of management (as I had earlier found it to be in Japan).[1] The degree to which industry fails to see the importance of design is a source of deep concern to him since it presages a decline in industrial competitiveness. A similar concern is often expressed about the U.S., with obvious consequences for the commercial and defense industrial bases.

If management needs to better appreciate the importance of design, then the management sciences must be more involved in design research, but so far that is not happening. His program is in fact quite new; so far it supports only recognizably engineering-style activities. He has trouble finding a home for proposals he would like to fund that deal with market research and other "soft" issues. Yet he is happy with most of the centers he has funded so far and is especially gratified by the amount of outside industry funding they have attracted; this often exceeds the government input by a factor of three to five.

Another problem he has is convincing some academics to consider more applied research. They look down their noses at it, he says. The professional societies are just as bad, being very old-fashioned, aligned with the traditional disciplines, and disinclined to talk to each other. Yet design and manufacturing are inherently inter- and multi-disciplinary and are becoming more so. It seems to me that researchers who don't become more interdisciplinary and willing to engage in some development of their ideas will find it difficult to obtain funding from this program.

"Our Design Centers are rousing successes"

At present there are six Engineering Design Centers (EDCs); they are roughly equivalent in aim and structure to NSF's Engineering Research Centers but are funded much more modestly. Five of these are successes in his opinion, with one of the nonsuccesses being essentially the funding agency's fault: it was funded first, got too much money, and was expected to do "generic" research. He now feels that design research must be limited to a discipline or theme, and later centers' goals reflect this.

These centers are:

- Engineering Design Centre, Cambridge University, directed by Mr. Ken Wallace. The goal here is "mechanical systems design, functional modeling and optimal configuration of mechanical systems, and materials selection."

- Engineering Design Centre, City University, London, directed by Prof. Alan Jebb. The goal here is "quality function deployment and robust design." The Japanese technique of Quality Function Deployment (QFD) seeks to link consumers' descriptions of a product's desired characteristics ("It should be easy to close the door.") to specific engineering parameters such as dimensions, materials, forces, and so on. Robust design,

also of Japanese origin and often called the Taguchi method, is a statistical technique for improving the ability of a design to perform in the face of typical variations in materials, processes, or even patterns of use by customers. Among the topics of research at this EDC are tolerances and design for cost.

- Engineering Design Centre, Lancaster University, directed by Prof. Michael French. The goal here is "mechatronics." Mechatronics is a word coined in Japan in the early 1980s and refers to engineered items that combine mechanical, electrical, and computational elements. Typical examples include optical shaft encoders, cellular telephones, camcorders, and so on. Topics of study at this EDC include aiding the layout and component choice of mechatronic systems as well as cost modeling and estimating during concept design.

- Engineering Design Centre, Newcastle/ Sunderland, directed by Mr. Bill Hills (no relation). The emphasis here is on "marine and other made-to-order products." Some of these topics relate to offshore technology, and most of the impressive list of industrial sponsors are oil companies. Projects include feature based design, expert system shells, cost estimating, innovation in design of structures, hydrodynamics, and stress analysis. Another project is aimed at testing the new product data exchange standard (PDES/STEP) for applicability to made-to-order products.

- Engineering Design Center, Polytechnic South East, directed by Prof. Michael Denham. The goal is genetic algorithms and their application to generation of new designs.

- Engineering Design Centre, Queen's University of Belfast, directed by Prof. Gordon Blair. He is a well-known engine designer, responsible for many winning racing motorbike engines and several engines for Ford. The topics focus on integration of design systems for energy-related applications.

Based on the above descriptions, it is clear that there is some overlap.

In addition to these activities, Prof. Hills told me of two related programs. One is the new Ph.D. program, an innovation in curriculum that is currently funded by the government and grants scholarships to engineering students all over the country. Unlike the conventional D.Phil., where the student does 100 percent research and takes no courses, the Ph.D. will be like U.S. Ph.D.'s in that the student will do both course work and research. The idea is to encourage a more practical kind of person. It is the brainchild of a Mr. Parnaby, a Director of Lucas Engineering.

The other initiative is the Teaching Company program. This is a combination of the agricultural extension station and cooperative education in the U.S. Here the method is to establish and expand a consulting arrangement between a company and a professor into a long-term research activity conducted by one or more students. They may help a company to learn about CAD/CAM or new software development methods.

Not surprisingly, the students often go to work for the company when they graduate. Projects can last 4 years or more. SERC cost-shares individual activities at the rate of 50 to 75 percent. The program dates from 1975 and has been a huge success, according to Hills.

Hills also publishes an occasional newsletter. The August 1991 issue contains articles by several of the EDC directors. It explains in layman's terms what they are up to and announces a new *Journal of Engineering Manufacture*. It also announces the expansion of a program sponsored by the Fellowship of Engineering (roughly equivalent in stature and goals to our National Academy of Engineering) to fund visiting professorships for industrial people at local universities. There is also a complimentary review of a report from the National Academy of Engineering (U.S.) called Improving Engineering Design, which I helped write.

CONCLUDING REMARKS

This program is especially interesting because of the attention paid to development and technology transfer—activities that NSF, for example, does not fund. I have noted before[1] that there is no clear technology transfer path for new design tools.

The CAD vendors do not provide a route from universities to industry. They typically do not know much about manufacturing and tend to deliver what their customers ask for. The customers do not look very far ahead and are not conversant with design research. A big change in software or hardware would cost them millions. In Japan, I found that the big companies write their own CAD/CAM software to suit their own carefully developed product development process.

In the U.S., new design technology usually comes from startups. The most recent is Parametric Technology, which is the first financially successful vendor of CAD with the capability to represent algebraic constraints on geometry. The actual first, Cognition, is essentially out of business. (Both were spurred by research at the Massachusetts Institute of Technology.) Thus the technology transfer path is treacherous. The U.K. engineering design research program is to be commended for trying to sponsor and encourage the entire process from innovation to application.

REFERENCE

Daniel E. Whitney, "State of the Art in Japanese Computer-Aided Design Methodologies for Mechanical Products—Industrial Practice and University Research," *Office of Naval Research Asian Office Scientific Information Bulletin* 17(1), 89-111 (1992).

APPENDIX

General Description of SERC Engineering Design Initiative

The Science and Engineering Research Council through the Engineering Design Initiative is devoting substantial funds to research into engineering design.

Its aim is to establish a coherent body of scholarship and knowledge in engineering design, directed toward the development of design tools of real help to the wealth creating industries of this country. By encouraging innovation and the development of enabling technologies it aims to increase the efficiency of the design process and to make the time from concept to product as short as possible. It encompasses reliability, maintainability, safety and all other design areas which make our products and processes more competitive.

There is a strong argument that such research is most fruitfully concentrated in industrial sectors or specific areas of technology, although one objective is to develop design solutions and methods which can be transferred across disciplines. Consequently, SERC has begun a programme of establishing Engineering Design Centres (EDCs) where high level research capabilities may be dedicated to examining, improving and practising engineering design.

The first was set up at the University of Newcastle upon Tyne in July 1990 and brings together staff from the University and the Polytechnics of Newcastle and Sunderland. It will specialise in the design problems of heavy 'made-to-order' engineering equipment such as drilling rigs, bridges, generating plant and chemical processing systems.

Other EDCs are at Lancaster University, specialising in mechatronics design; Cambridge University, specialising in mechanical systems design and materials selection; City University, concentrating particularly on the design of high quality products at minimum cost via a technique called Quality Function Deployment. More EDCs will be set up in the coming months.

Additionally, as part of its chain of Interdisciplinary Research Centres, SERC created one in Engineering Design at Glasgow University in February 1989, known as the Engineering Design Research Centre (EDRC). Larger than a typical EDC, it brings together the design related research activities of Strathclyde and Glasgow Universities, Napier Polytechnic and Paisley College.

SERC recognises that high quality research into engineering design may also be stimulated in higher educational institutions which do not have EDCs. Support may be obtained for research into design as it features within more discipline orientated applications for funding submitted to SERC committees, directorates or commissions.

A recent addition to Design Initiative support for researchers has been the allocation by the SERC Engineering Board to its Design Management Committee of resources to fund design research in areas which may not be identified with any particular discipline or existing research area.

Since the Initiative started in 1985 SERC has consistently increased the funds given for work on Engineering Design in order to enhance the quality of scholarship, knowledge and practice in this cardinal aspect of engineering. The development of the Initiative illustrates the type of long term support for industrially relevant academic activity which is so important in securing the future of Britain's wealth creating industries.

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Information Technology

European Consortium for Informatics and Mathematics

by C. T. Owens, National Science Foundation, formerly European Representative

KEYWORDS: ERCIM; multimedia databases; informatics; cooperative projects; market opportunities

The European Consortium for Informatics and Mathematics (ERCIM) is described as "a network of European research organizations active in the fields of informatics and applied mathematics. It aims to strengthen the scientific community and its links with industrial research, and to support the establishments of cooperative research activities."

At its meeting on "Research and Technology Transfer in Informatics in Europe," June 17, 1991, representatives of important European research organizations and firms discussed, in the words of the chairman, Alain Bensoussan, ways "to help make better circumstances for informatics in Europe." Bensoussan is the president of France's premier computer science research organization, INRIA (Institut Nationale de la Recherche en Informatique et en Automatique). INRIA was a founding member of ERCIM, which now has an additional five member organizations:

- Consiglio Nazionale delle Richerche (CNR), in Italy;
- Centrum voor Wiskunde en Informatica (CWI), in The Netherlands;
- Gesselshaft fur Mathematik unds Datenverarbeitung (GMD), in Germany;
- Instituto de Engenharia da Sistemas e Computadores (INESC) in Portugal; and
- Rutherford Appleton Laboratory (RAL), in the United Kingdom.

The French Minister of Research and Technology, Hubert Curien, closed the meeting with great praise for ERCIM, which he described as a model for cooperation between research organizations and industry that he would like to see extended to other fields.

THE MEETING

The ERCIM meeting consisted of several addresses by those in charge of important European informatics-related organizations and a panel discussion by 13 people involved in various aspects of informatics research and business.

Alain Bensoussan provided a welcome and a brief review of the origins of ERCIM. He noted that today ERCIM brings together all of the informatics actors in France—users, manufacturers, public users, and France's Telecom.

C. Baayen, president of ERCIM and head of CWI, spoke of the changes in Europe since World War II and the major technologies that are determining the post-War world (space technology, telecommunications, television, and electronic data processing). He also described ERCIM's beginnings, from two years ago with INRIA, GMD, and CWI as the organizers, to today's six members comprising 2,400 researchers at 18 locations in Europe and with budgets of more than ECU 210 million

He said that ERCIM was strengthening information technology research and helping to unify the information technology industry in Europe. He noted that the industry was the largest employer in Europe, and was characterized by 10% per year growth, a low margin of profit, and a serious trade gap.

Networking and parallelism, distributed and integrated systems, large multimedia databases, and flexible manufacturing were identified as fields for further research and product development. These would find applications in telecommunications, high-performance computing, computer architecture, and scientific visualization. Europe desperately needs an independent supply of systems for use in its telecommunications products. A united Europe with 400 million people will provide a well-educated pool of researchers. Eastern Europe is a "reservoir of mathematicians." All of the ingredients are present for success.

Problems of the industry in Europe are structural and are related to currencies and national malaise. Although the principle of "subsidiarity" is in effect where EC programs are concerned, a mixture of program goals are needed that will address both the general need to innovate and strong priorities. Basic research will be increased. There will be a general scarcity of human resources in research and development, and existing systems of finance and standardization constitute barriers will have to be addressed. ERCIM brings together laboratories, faculty, and industry to cooperate in long-term international projects. It is developing a critical mass in such fields as logical calculations, architecture, and distributed systems. ERCIM can do some things that the EC cannot do.

P.Y. Le Bihan, Secretary General of the Association of Innovative Computer Projects noted that the U.S. and Japan are progressing better in informatics than is Europe, ESPRIT is doing well, and companies are growing; however, standards still come from the U.S. Research centers in Europe underestimate the crisis. Are programs such as JESSI, HDTV, and other large-scale technology development projects enough. How can the research community best be associated with the work to be done?

The panel's industry representatives concentrated on the necessity for cooperative projects to focus on a useful product (which might be economic, social, or strategic in nature), to aim for new markets rather that catching up in old market sectors, and to clearly define whatever the market objectives will be. One representative of a small firm (Oakley) noted that Europe "has not yet gotten large projects right."

Professor Tsichritzis highlighted the need to motivate researchers with goals and concerns. Clear definitions of success and adequate research support are necessities to gain researcher interest. Professor Tribolet had a firm "no" for large projects, and a great deal of emotion about the fact that "there is a European capability to do research but not much for earning lots of money from the results." He recommended that public institutions in Europe be used to let products get a three-year headstart in the market. Mr. Zimmermann said that there was a war on in informatics and the various parties involved in Europe had to pull together and help each other out to keep from losing the war. He said that it was in the interest of large firms to help out small and medium-sized firms. These firms usually have their roots in R&D, and are both innovative and aggressive.

Questions were raised about whether ESPRIT-driven research cooperation would continue after ESPRIT support is gone. Professor Tribolet had

the last word with a proposal for an informatics think-tank supported in equal proportions by industry, the EC, research universities, and large users of informatics products. He said the cost would be small compared to the potential benefits to the informatics industry in Europe.

The meeting was closed by Hubert Curien, who said that ERCIM has gained an excellent reputation and is expanding. He noted that the postdoctoral exchanges taking place in the ERCIM cooperative projects would allow students to see a little of what is going on elsewhere in Europe before they choose a job. Research and development, he said, constituted the sector in which it is easier to build European culture. "Vocal divergence" is an accepted thing and is more easily handled in science than in other realms. Curien said that it would be beneficial to bring basic research closer to applied research.

Commenting on the consensus that things were not going well for the informatics industry in Europe, Curien said that "tough competition is not a reason to give up," and that one cannot gain the lead everywhere. It is necessary to seek out the market opportunities in those niches where European qualifications give its industry the best chance. There is a need to guide laboratories to research in the appropriate areas.

Those present and speaking at this meeting all recognized that there were problems in European informatics that might best be addressed by cooperative efforts such as ERCIM. There was much less unanimity, however, about other efforts, including the programs of the EC and schemes for cooperation among the large companies or involving large and small firms.

The meeting program clearly stated that "Cooperation agreements with organizations outside Europe are under preparation," and American visitors were warmly welcomed. Among the participants, and as stated by ERCIM's leaders, there is a competition under way and ERCIM's efforts are on behalf of the European informatics industry. Despite the seeming contradictions in these two facts, it will probably be worthwhile to take up ERCIM's invitation for possible cooperation. It is an example of a cooperative effort involving industry and producers of basic and applied research in centers of considerable scientific excellence. The level and number of speakers and panel participants attracted to this conference means that its cooperative efforts are bearing fruit.

Marine Biology

An Emerging Marine Molecular Biology Group

by Randall S. Alberte, Scientific Officer, Oceanic Biology, Office of Naval Research, Arlington, Virginia

KEYWORDS: Italy; postdoctoral exchange; research programs; capabilities; biomolecular

The Benthic Ecology Laboratory, Ischia, Italy, is part of the Stazione Zoologica 'Anton Dohrn'. Under the direction of Dr. Lucia Mazella, scientists here interact with the epizoic and epiphytic communities of the region. They have published more than 40 papers in the past decade on the ecology, systematics, and production dynamics of these communities.

They are interested in developing a program that would interface with the current Office of Naval Technology contractors in the Non-Polluting Antifouling Program. I recently met with researchers at the facility to discuss their current capabilities for testing and evaluating antifoulants and antifouling coatings in the Bay of Naples. Formal collaborations with Office of Naval Research

(ONR) oceanographers would be valuable. A new course sponsored by the Stazione is looking at molecular approaches to coastal ecosystem dynamics. It is a research training program to increase the use of molecular techniques in oceanography and marine ecology.

A 6-month postdoctoral exchange is under way between the Stazione Zoologica and ONR. The goal of the exchange is for the postdoctoral students to develop expertise in molecular biology of marine organisms. It is hoped that the program will develop so that American scientists will be able to conduct research at the Stazione Zoologica for 1 to 3 years.

Clearly, a strong marine molecular biology group will be developed at the Stazione Zoologica. The priority areas are marine molecular biology and the development of molecular tools and approaches for studying ocean processes. In addition, they are exploring the development of a research focus in bioremediation, with the initial phase focused on using molecular probes to study functional changes in the biota.

The Director of the Stazione Zoologica is Dr. Luco Carellio. The point of contact for all programs in marine molecular biology is

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Materials

Superconducting Quantum Interference Devices for Remote-Sensing Applications

by Robert J. Soulen, Jr., Materials Science and Technology Division, Naval Research Laboratory

KEYWORDS: SQUID, HTS; magnetic noise; MRI; MEG

INTRODUCTION

Superconducting quantum interference devices (SQUIDs) have been studied for years. The use of SQUID magnetometers in remote sensing applications such as biomedical heart and brain scanning, nondestructive evaluation, and magnetic anomaly detection are being explored, and significant advances have taken place in the past three years.

Thus, a Workshop on Remote Sensing Using Superconducting Quantum Interference Devices provided a timely opportunity to explore the impact and benefits of these advances for all applications. Furthermore, there are common problems that thread through these rather disparate disciplines. For instance, nonuniqueness in mathematically inverting a received magnetic signal to infer properties of its source (the inverse problem) troubles them all. Therefore the workshop provided the opportunity to discuss common problems and to share progress toward their solution.

The workshop was organized by Michael Koczak (formerly of the Office of Naval Research European Office) and Robert J. Soulen (the author); it was held at Ross Priory, Scotland, June 27-29, 1991. Twenty-two experts representing relevant research activities in government, industry, and academia attended. The remote and intimate setting of Ross Priory fostered free exchanges of ideas among this small group of scientists and encouraged candor in sharing problems that vexed their research efforts.

This workshop also took full advantage of the fact that many experts in this field had been drawn

to Europe by two related international conferences [SQUID '91, Berlin, Federal Republic of Germany, and ISEC (International Superconductive Electronics Conference), Glasgow, Scotland], immediately preceding it.

Progress made in SQUID magnetometers was reviewed by Roger Koch (IBM, Yorktown Heights). He described the exciting advances made in fabricating these devices from the new high-T_c superconductors (HTS) (such as YBaCuO and T1BaCaCuO) and compared their performance with more familiar ones fashioned from low-T_c (LTS) materials (such as Pb and Nb).

A generic SQUID magnetometer consists of three separate components (Fig. 1). The heart of the circuit is the dc SQUID, which is a superconducting loop interrupted by two Josephson junctions; this gives it incredible sensitivity to magnetic flux. (Sensitivity is gauged in units of the flux quantum, $\phi_0 = 2.067 \times 10^{-7}$ Gauss cm^2; SQUIDs typically resolve 10^{-5} ϕ_0). A detection coil (also superconducting) transfers a signal of interest from the outside world to the input coil adjacent to the SQUID.

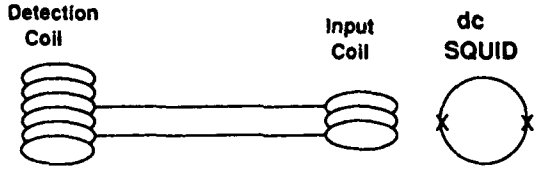

Fig. 1 — A typical SQUID magnetometer. The Josephson junctions incorporated in the dc SQUID are each represented by an *X*.

Koch assessed the performance of each component of the HTS SQUID magnetometer, starting first with the dc SQUID. He compared the noise in several HTS SQUIDs with that found in several LTS versions available commercially.

Although the performance of the HTS SQUIDs clearly falls short of the best efforts of the LTS counterparts, the fact that such data can be presented indicates the extent of progress that has been made in the few years since the discovery of HTS. Koch stressed that several problems remain to be solved in HTS magnetometers:

- the physics of the Josephson junction elements that make up the SQUID are not well understood;
- the $1/f$ noise in them is high; and
- magnetic hysteresis is a problem.

Nevertheless, complete SQUID magnetometer circuits have been fabricated. Koch described one in which a HTS transformer was coupled to the HTS SQUID; the noise of the complete circuit was not larger than that of the SQUID, and this particular circuit had a gradiometer noise of 0.1 nT/m$\sqrt{}$Hz. In all, progress made to date offers hope that SQUIDs operating at temperatures of 77 K (and thus more "user friendly" than their 4 K cousins) will soon be available. Said Koch, "The progress made in HTS SQUID magnetometers over the past two years has been so impressive that we are considering them for applications far earlier than we originally thought possible."

Mark Colclough (Conductus, Sunnyvale, California) reviewed the techniques of heteroepitaxy, by which the successive layers of YBaCuO and lattice-matched insulators are grown, and bi-epitaxy, the method developed at Conductus to produce Josephson junctions. The bi-epitaxial grain boundary junctions are formed by a peculiarity of the materials used in their construction, namely the tendency to generate a 45-degree rotation boundary in a YBaCuO film grown at the edge of a thin "seed layer" formed beneath it by a layer of MgO. This rotated grain boundary in YBaCuO forms the Josephson junction needed for the SQUID. It has the advantage over some of the other methods used to form junctions in that it can easily be incorporated into a general thin-film fabrication process.

Colclough reported success in fabricating a complete HTS SQUID magnetometer. He seconded Koch's observation that noise in HTS dc SQUIDs had large and undesirable $1/f$ noise. He also pointed out another problem: all components fabricated from HTS materials appeared to be stable under normal operation, except for interfaces between normal metals and HTS materials, which were presently being addressed by the use of noble metal contact areas.

The sensing and interpretation of biomagnetic signals was addressed in another session. Steven Robinson (Veterans Administration Center, Albuquerque, New Mexico) reviewed the application of SQUID gradiometer arrays to the measurement of the brain's electrical activity—the magnetoencephalogram (MEG). Because the magnetic fields

generated by the brain are exceedingly small (typically, 10^{-12} to 10^{-13} Tesla) and occur in a bandwidth of a few hundred hertz, extremely low-noise dc SQUID gradiometers are required.

Furthermore, several of these devices are needed to study the spatial dependence and to scan the complete brain (a system of 20 to 30 dc SQUIDs are now often used). Although the MEG appears to convey much the same information as the electroencephalogram (EEG), magnetic fields recorded by the former are far less dependent on the conductive geometry of the head than are the corresponding electrical potentials.

The present challenge of MEG is to utilize this advantage to accurately reconstruct brain activity (more properly, the electrical currents resulting from brain activity) from the magnetic fields. Robinson pointed out that, from MEG measurements, no unique solution exists for the neural currents.

However, by using a synthetic aperture approach, the neural electrical current density can be estimated in three dimensions (in a probabilistic sense). Using both computer simulations and MEG data from a 37-channel SQUID gradiometer system, Robinson showed that the synthetic aperture method produces useful—albeit blurred—images of brain activity. This method also provides inherent immunity to environmental magnetic noise. He concluded that for MEG to become a useful tool for imaging brain activity, it will be necessary to build larger and more sensitive SQUID gradiometer arrays, having 500 to 2,000 channels that cover the entire head!

Andreas A. Ioannides (Open University, Milton Keynes, United Kingdom [U.K.]) compared MEG with other techniques offering functional information about brain activity. He pointed out that with modern MEG probes with 30 or more channels, MEG offers a unique combination of good spatial resolution and temporal resolution ($\sim$1 ms). The raw spatial resolution (with minimal a priori anatomical information and no temporal constraints) is typically of the order of a few mm over the cortical surface facing the sensor array, but it deteriorates with depth at a rate that depends on the sensor geometry.

In general, activity from neighboring but distant brain centers can be spatially and temporally resolved. Substantial improvements in spatial resolution can be made if anatomical information (e.g., from magnetic resonance imaging [MRI]) is included. Ioannides reiterated Robinson's point that higher level brain functions and late-evoked responses appear to be spatially extended. Therefore, an interpretation using point sources (current dipoles) is inadequate.

This point was illustrated with examples of distributed current analysis of MEG data obtained at a number of multichannel facilities and analyzed by Ioannides. A good illustration of the capability of the MEG is provided by the analysis of steady state 40 Hz signals obtained at New York University Medical Center (NYUMC); this analysis reveals an interplay of activity between cortical (surface) and subcortical (thalamus) regions of the brain, consistent with the NYUMC hypothesis of a 40 Hz cortico-thalamo-cortical resonance. Comparisons between 40 Hz steady state MEG signals from Alzheimer patients and normal patients of the same age suggests that this interplay between cortical and deep activity is altered in pathology.

The third session treated other applications for which clear examples of dipole sources are to be found. Ted Clem [Naval Coastal Systems Center (NCSC), Panama City, Florida] reviewed the extensive effort carried out at his laboratory to harness SQUID gradiometers (made from bulk LTS components and operating at 4 K) to specifically detect magnetic dipole sources. Here the need to use these delicate instruments in actual field conditions enlarges the list of problems to be solved. Clem reported, however, that sufficient progress had been made in alleviating enough of the problems that successful field trials had been carried out, thus causing the transition of this technology from exploratory development to advanced development.

He pointed out, however, that the limit of performance had been reached with SQUID gradiometers fabricated from bulk components. He described the new program based on the use of an all-thin-film, LTS system. He reviewed the advantages that HTS systems offer for this program and announced that a research program on a field-deployable, liquid nitrogen cooled, high-T_c SQUID gradiometer is being considered.

The second speaker from NCSC, Mike Wynn, presented solutions to the inverse problem for dipole sources. He listed five situations for which

an algorithm could successfully determine the location and moment of a dipole source given a set of measured magnetic field quantities. One example suffices to convey the thrust of his presentation. A magnetic dipole source may be found if the position vector and moment vector are determined from the magnetic field vector or two points of known separation. The rotation axis used in this search algorithm is along the line of separation of the field points.

In all, Wynn gave four sets of conditions for detecting a magnetic dipole source and one set for a current dipole imbedded in a conducting slab. These results prove very useful in establishing the nature of the measurements needed to interpret signals generated by dipole sources.

The use of SQUID magnetometers for nondestructive evaluation (NDE) of materials has been widely heralded. However, the inconvenience of using the 4 K cryostat to cool such a magnetometer made from LTS materials has been regarded as a serious impediment to widespread use. Sandy Cochran (Strathclyde University, Scotland) suggested that development of a HTS system cooled by liquid nitrogen might remove this impediment. He has conducted two NDE experiments using a HTS SQUID operated in a very simple dewar at 77 K.

In the first, the SQUID was used to detect variations in the magnetic field generated by current flowing in a shaped metallic wire conductor that was passed beneath it on a moving table. In the second, the SQUID detected the presence of slots cut in aluminum plates that were passed below it. Further refinements along these lines may initiate more ambitious field tests of SQUID-based NDE.

The identification and elimination of noise in SQUID magnetometer circuits was the final topic. One of the noise sources implicated in limiting the performance of such circuits is the motion of individual magnetic flux lines, or quanta. Isolation of individual lines for study has always been difficult; for this reason the experiments reported by Blas Cabrera (Stanford University, California) were especially interesting. He showed that an individual flux line could be trapped in a superconducting microbridge by heating the film with a laser pulse, and that the pinning force of the flux line could be measured by sending a current through the microbridge. Cabrera anticipates that further measurements will explore the dynamics of trapped flux quanta which will be also very important for modelling noise in superconducting film circuits.

Cabrera also reviewed the status of his efforts to use laser switches to suppress the $1/f$ noise in SQUIDs, thereby improving their ultimate performance at low frequencies. He has achieved only a modest suppression to date, and significant improvements hinge on how successful he will be in increasing the modulation fraction. This method may provide a more useful way to suppress $1/f$ noise than is presently done using other methods.

Mike Simmonds (Quantum Design, San Diego, California) provided several suggestions for reducing noise in SQUID circuits. Recommendations for the circuits were to keep them as symmetric and as small as possible (integrated thin films preferred), and in a field-free region. Recommendations for the cryostat were to make it low loss and very flexible, and to break the liquid He space into small cells separated far from the circuits.

I presented data showing that HTS cylindrical shields at 4 K did not add any noise to an LTS SQUID magnetometer. These shields are useful in certain applications.

SUMMARY

What is the future of remote sensing by SQUID magnetometers? I offer the following perspective drawn from discussions held at this workshop and those given at the two conferences preceding it.

Fully integrated LTS SQUID magnetometers and digital processing of the SQUID response were widely discussed at the SQUID '91 Conference. In the past, all of the SQUID functions—detection, conversion, and feedback—were each performed by separate analog circuits. Improved performance (especially higher speed) has already been demonstrated when some of these functions were integrated on the same ship and when a digital version of the SQUID was used.

Complete integration by using Josephson-junction-based digital logic on the same chip for data processing would further enhance performance. Single-chip systems would be far less expensive to produce, thereby placing the multiple magnetometer systems needed by biomagnetism

within financial reach. The higher speed offered by fully integrated digital SQUID magnetometers would alleviate loss of lock induced by transients that abound in the contemporary electromagnetic environment and frustrate operation of present analog SQUID magnetometers.

If we further optimistically extrapolate the rapid progress reported in making all the SQUID magnetometer components from HTS materials, we may anticipate the development of a fully integrated HTS digital chip magnetometer to supplant the LTS version. Such a device would be the *ne plus ultra* long awaited these many years by those who would take the SQUID outside the mild environment of the laboratory into the rough and tumble world where it offers a wider service to mankind.

Mathematics

Mathematics in the Former GDR

by Robert D. Ryan, a mathematician currently serving as a Liaison Scientist for Mathematics and Computer Science in Europe and the Middle East for the Office of Naval Research European Office. Dr. Ryan is on leave from the Office of Naval Research Arlington, Virginia, where he is Director of the Special Programs Office.

KEYWORDS: Mathematics; East Germany; Rostock; Leipzig; Jena

INTRODUCTION

In the long run, mathematics in the former German Democratic Republic (GDR) will return to world-class level; in the short term, mathematics and mathematicians in the five new länder face considerable uncertainty, disruption, and hardship. This report describes aspects of mathematics, both now and before reunification, in the former GDR. It is based on interviews with senior mathematicians at the Universities of Rostock, Leipzig, and Jena, and at the Max-Planck Society in Berlin. Additional background comes from colleagues, their reports, and the public press.

Going straight to the point, about one-third of the mathematicians currently at research institutes and universities will be "on the street" by the end of 1992. This is a conservative estimate. People I spoke with hope that the reductions (and uncertainty) will be completed in a year; it may be longer. In the meantime, in the "near" short term, individuals are subject to paralyzing uncertainty; at this point, no one knows who will stay and who will go. This individual and collective anxiety has caused a precipitate decline in productivity: Before reunification, the publication backlog for the main GDR mathematics journal *Mathematishe Nachrichten* was sometimes three years. Now, there is no backlog, and the editor has solicited papers. To understand the current situation it is necessary to look at the structure of mathematics (and all science) in the former GDR.

THE ACADEMY OF SCIENCES

Professor Helmut Koch described the structure of mathematics in the former GDR and how it differed slightly from that of the other sciences. Professor Koch worked in the German Academy of Sciences, later renamed the Academy of Science of the GDR (ASGDR), specifically at the Mathematics Institute of the ASGDR. His field is algebraic geometry and number theory; he now heads a group of 5 people within the Max-Planck Society. Professor Koch is a member of the prestigious Leopoldina Society, as are the other three senior people I initially contacted.

The Mathematics Institute of ASGDR was an essential part of the mathematics research structure in the former GDR. However, mathematics

research was also done in the universities. By policy, the former GDR concentrated research in the Academy of Sciences, emphasized teaching in the universities, and tried to keep the two activities separate. This is the conventional view of the science structure in the former GDR, as well as in the former Soviet Union and other Central and Eastern European countries. Professor Koch explained that this picture is not quite correct for mathematics, and that considerable research was done in the universities.

The Mathematics Institute (officially, Karl-Weierstrass-Institut für Mathematik) employed more than 150 mathematicians in 29 groups of about 5 members each. These groups were concentrated in Berlin in much the same way that mathematics in CNRS is concentrated in Paris. The Mathematics Institute ceased to exist, along with the other ASGDR research institutes, after reunification. The story of how these research institutes were reviewed by the West-German Science Council (Wissenschftsrat) is now fairly well known, at least in outline.

The old structures were eliminated, some not to reappear. Parts of others were reconstituted within the traditional German science structure, that is, within institutions like the Max-Planck Society and the Fraunhofer Society. The Mathematics Institute received a very good evaluation, and all the employees continued to work until the end of 1991. Only 50 people of the original 150 were taken over by the newly founded Institute of Applied Analysis and Stochastics. Another 20 found jobs (limited to 2 to 5 years) in various research groups in and outside Berlin. Five researchers are in the group headed by Professor Koch; there is another "Arbietsgruppe" in Potsdam within the Max-Planck Society; and there are other small groups elsewhere. But what about those without permanent jobs in these new institutions?

There is no single answer. Some of the bright, young people have gone (or will go) to the West: Western Germany, other European countries, or the United States and Canada. But very few jobs are available, and these young mathematicians face the same problems as their contemporaries throughout the world. Professor Pietsch, who is at the University of Jena, told me that an advertized position in West Germany attracted 80 applicants, 30 of whom were considered very competitive.

On the other hand, one feels that there are, even in the short-term, opportunities for the young and bright, either in or out of mathematics research. And, of course, one hears stories of the promising math researchers "going into business." People over 35 or 40 (and this is where the curve peaks) face a much bleaker future. Professor Koch said that of the original 150 members of the Mathematics Institute, more than 60 or 70 "are in a bad situation."

By Western standards, the rolls of the research institutes and universities in the former GDR were greatly inflated. Inefficiency and underemployment have been criticized. In fact, there were about as many professors, adjusted for population, in East Germany as in West Germany. This holds for research institutes and universities. The personnel inflation was at the assistant level. Professors in the former GDR had more assistants than their counterparts in the West. The faculty-to-student ratio in East Germany was 1 to 5; it was 1 to 20 in the West. These assistants, who are mostly in the 35 to 45 age group and have typically passed the "habilitation," face particularly difficult times.

This is not to say that problems are limited to this age group. Many professors are in their mid-50s to early 60s. Even though they may have a job until mandatory retirement at 65, they share economic problems with other members of the population. For example, one senior member told me that he faced, at age 62, having to buy an apartment, since housing will no longer be provided by the state.

He also pointed out that small savings accumulated under the communists (and saving was not a mainstay of the economy) were considerably diminished with reunification and the currency conversion. Similar age-related problems face other professionals. Physicians, once employees of the state, working in state-owned facilities with state equipment, are now told to go into private practice. This requires considerable capital, an investment that banks are reluctant to make.

Although the Science Council has completed the review of the scientific institutes, and a new, reduced structure is falling into place, the universities are in the middle of the process. The

uncertainty created is at a paralyzing level. Uncertainty focuses on "who will stay and who will go," but it also involves structural issues like the total number of faculty positions that will be retained.

THE UNIVERSITY OF ROSTOCK

Professor Lothar Berg, formerly at the University of Halle, heads the analysis group and has written several books on operational calculus. Professor Berg's recent publications include work on translation equations and their asymptotic solutions.

The University of Rostock was established in 1419, and was thus the first university in Northern Europe, predating Greifswald (1456), Upsala (1477), and Copenhagen (1479). It has about 8500 students, including 1000 in the medical school. Two local schools of higher education have recently been added to the university: a "teaching school" at Güstrow and the oceanography school at Warnemünde. Thus the university's responsibilities have increased at the same time the faculty must decrease.

Professor Berg told me that about 1/3 of the faculty must go. When asked about the process, he said that two commissions were examining each faculty member. A "Commission of Honor" looks at one's political past, and a "Commission on Scientific History" considers one's academic credentials. Professor Berg indicated that once these two commissions completed their work, the decision on who stays and who goes will be made by yet a third government commission, and that the Minister for Education and Science has the final word. The faculty hopes that they will be represented on the third commission. If the rules are similar to those at the University of Leipzig, abuse of power under the communists or collaboration with the secret police (the Stasi) will be cause for dismissal.

The Minister for Education and Science will also have a strong voice in determining the eventual faculty-to-student ratio. As noted, it has been 1 to 5 in the East and 1 to 20 in the West. The Rector, Professor Gerhard Maeß, told me that the new Minister of Education recently mentioned a ratio of 1 to 9. This seems to be too good to be true considering the cost of the implied faculty increases in the West.

The mathematics faculty at Rostock has three main "sections": Analysis (Professors Berg, Stolle, Wildenhain), Numerical Mathematics (Professors Maeß, Tasche), and Algebra, Geometry, and Discrete Mathematics (Professors Burosch, Engel, Pazderski). There are also groups in biostatistics and mathematical didactics. (I note that the didactics group is a fixture in all the science and language faculties at Rostock and other East German universities.)

Professor Maeß now serves as Rector, and Professor Wildenhain is currently working in the Ministry of Culture, Education, and Church Affairs. This give credence to the suggestion that, among the academic disciplines, mathematics and mathematicians were relatively apolitical.

Of the mathematics I saw, the group in numerical mathematics seemed the most active and interested me the most. There are actually two subgroups, both working on numerical solutions of differential and integral equations, spline approximation, and fast algorithms. Professor Gerhard Maeß leads one group (when he is not Rector), and Professor Manfred Tasche leads the other. Tasche's group includes Jürgen Prestin, Gabriele Steidl, Norman Weyrich, and Gisela Brumme.

This group is very active in splines, approximation, and fast algorithms. They sponsored a meeting, Approximation Methods and Fast Algorithms, at Warnemünde, 28 May to 1 June 1992, and Professor Tasche showed me a draft of a new book on fast algorithms. The group has a strong interest in wavelets, coming naturally to the subject through spline approximation. Professor Ewald Quak, Texas A&M University, lectured on wavelets at Rostock in July 1991, and Martin Buhmann, University of Cambridge, spoke there more recently. The group has a seminar where they study Charles Chui's books on wavelets. Curiously, they did not seem to be too familiar with the French literature, but they did show me a copy of Guy David's book in the Springer Lecture Notes series.

Reunification has caused considerable economic hardship in Rostock. Rostock was *the* seaport for the former GDR. The channel is narrow, and it was never a truly efficient port. Since reunification almost all shipping has gone elsewhere, mainly to Hamburg. Rostock's manufacturing industry was shipbuilding, and the main customer was the former Soviet Union. From the several miles of

large apartment buildings between Rostock and Warnemünde, I have the impression that lots of shipbuilders were working in the Rostock yards. The shipbuilding went with reunification, and Rostock is left with very high unemployment. To make matters worse, 10 completed ships, built for the former Soviet Union, sit idle in the yards. The buyers cannot afford to pay for them, and no one else wants them.

This lack of local industry means that there are no possibilities for consulting or industrial research support, at a time when the government is encouraging academics to seek cooperative work with industry.

Some good news is that the main university building is being refurbished, thanks to state and federal funding.

THE UNIVERSITY OF LEIPZIG

One feels a strong sense of mathematical history at Leipzig: Leibniz earned his baccalaureate here in 1663;[1] Möbius, Felix Klein, Herman Hankel, Carl Neumann, Sophus Lie, Felix Hausdorff, Otto and Ernst Hölder, Wilhelm Blaschke, and B.L. van der Waerden (a few names I recognize) worked in Leipzig.

The old university was half-destroyed in the war; the new university tower, built in the middle of town in 1972, dominates the Leipzig skyline. There is also a new campus just west of the center of town.

I originally contacted Professor Rolf Klötzler, a member of Leopoldina, but my official host was the mathematics department leader, Professor Klaus Beyer. Professor Beyer brought together the heads of the several groups, each of whom gave a brief rundown on their group's activity. Briefly these are:

- Professor Eberhard Zeidler, Analysis: nonlinear problems in mathematical physics and differential geometry, from hydrodynamics, magnetohydrodynamics, elasticity, free-boundary problems, and continuum mechanics. Numerical methods in quantum mechanics, nonlinear problems in quantum field theory.

- Professor Konrad Schmüdgen, Functional Analysis/Mathematical Physics: Algebras of unbounded operators, moment problems, quantum groups, Lie group representations, C^*-algebras. Professor Schmüdgen noted that they had received four years of funding from the DFG.

- Dr. Bernd Fritzsche, Mathematics of Economics, Stochastic and Numerical Analysis: probability theory, stochastic processes, algorithms for stationary and nonstationary processes, logistics, and fast algorithms. Dr. Fritzsche said that because of a lack of good computers, they could not properly test their algorithms.

- Professor Rolf Klötzler, Optimization: theory and applications of linear, convex, and nonlinear optimization, calculus of variations, optimal control, discrete optimization (particularly for planning and resource management), and numerical methods.

- Professor Günther Eisenreich, Algebra: algebraic geometry and commutative algebra.

The computer science group has recently been placed in the mathematics department, but it was not represented at our meeting. Professor Klötzler said that they had little experience with computer science, but that two of their groups were getting a computer, funded by the Deutsche Forschungs-Gemeinschaft (DFG).

I found morale at Leipzig at the same ebb as elsewhere: overwhelming anxiety about who will stay and who will go, and poignant concern to find support to keep good people. Professor Klötzler said that 40% of the mathematicians will be fired. I have the impression that most of this reduction responds to the inflated staffs—not because so many mathematicians will be found to have abused power under the communists.

In fact, it was brought out again in our meeting that mathematics had been something of an "apolitical island." I imagine there were political

singularities among mathematicians, but I was not made explicitly aware of them, at Leipzig or elsewhere.

The vetting at Leipzig has been described by Steven Dickman his *Science* article.[2] Dickman writes that the new Rector, Cornelius Weiss, speculates that a full 10% of the 3000 faculty and staff members to be investigated will turn out to have been Stasi collaborators, which is much more than the national average of 2% to 3%.

Professor Eberhard Zeidler made some interesting, and rather humorous, comments about the relationship between mathematics and the former GDR government. He said that the government pressured mathematicians to do applied work, particularly in control theory, and that there are now many chairs in optimization in East Germany. But he added that this was "not real." He said that mathematicians renamed their work and continued to do what they had always done. Sound familiar?

Professor Zeidler also commented on the problem of retaining young people during the painful transition. He said that the biggest problem was the "psychological" one, which I took to mean that many of the younger people would have jobs if only they can "hang on." He noted that everyone, including the professors, must apply again. Still, it was clear from our meeting that these people were exploring every avenue possible, including the Office of Naval Research, searching for support for their young people.

Like the other cities I visited, Leipzig's economy is depressed, but I had the feeling that the potential is much better here than in Rostock, for example. Situated in the fertile Leipzig Basin, it has been an important industrial center. One of every three books published in the former GDR was published in Leipzig. The hotels were sold out for the week of the Leipzig Book Fair. As "clean" industry returns, there should be local opportunities for consulting and "real" joint research.

THE FRIEDRICH SCHILLER UNIVERSITY, JENA

My host at Jena was the functional analyst, Professor Albrecht Pietsch. He is well known for his work in the theory of Banach spaces, and he told be that he is writing a history of Banach space theory.

This was my last visit, and Professor Pietsch covered ground that was by now familiar: low morale, low pay (compared to West Germany), lack of support for students, and a depressed economy. But there were some new things. He told me that a computer science department had been started in September 1991, and that the students in this department outnumbered the mathematics students 3 to 1.

He also explained a change in the student support system since reunification. In the former GDR, students were supported by "loans" that carried them through the first 4 or 5 years to the diploma and then the next 3 years to the Ph.D. The loan was discounted, depending on the student's grades; by doing well, the loan could be reduced to 60% face value. This system has been adapted by all of Germany, with the difference that it no longer covers the last three years. Students must now apply separately for support to write a thesis.

Historically, Jena's leading industry was Carl Zeiss. Zeiss employed 30,000 people, and it was the main supplier of lasers and chips to the former communist block. After reunification it could not compete in the chip industry, and employment dropped to 10,000. Zeiss still produces heat-resistant glass, called Saale Glass, named after the Saale River.

The good news is that the old university buildings are being refurbished with federal funding, as in Rostock. Most of the university is housed in a huge, round tower that was built originally for the Zeiss company. After it was built, Zeiss decided they did not want it, and the university moved in. It seems completely unsuitable for the purpose. The mathematicians are all together in a "sector-of-a-circle" room. Professor Pietsch and I met in the seminar room.

My colleague, Hans Dolezalek,[3] told me that the Friedrich Schiller University was the center of the German Period of Enlightenment, and that almost all the leading thinkers of that era came at one time or another to Jena. It remains the state university of Thüringen. Its future, as are the futures of the other East German universities, is tied closely to the state and federal economies.

ISOLATION

When I was first asked to "look at" mathematics in East Germany, I checked the membership list of the American Mathematics Society. It seemed a good place to find some contacts. Only 15 names are listed under the GDR in the 1990-1991 Combined Membership List. I contrast this with 53 for Hungary, 47 for Czechoslovakia, 245 for Poland, and, the real surprise, 155 for Romania. The list under U.S.S.R. extends for about two pages. I don't know exactly what this means, but it does tend to support the hypothesis that the former GDR was, among the countries of Central and Eastern Europe and Russia, the most isolated from the West.

When I asked about this the response was that only "special people" were allowed contacts (such as society membership) with the West and that there was a lack of money to support this sort of thing. This theme—special people and lack of money—was repeated in the contexts of travel and publication.

The whole idea of isolation, whether travel, publication, or other contacts with the West, must be seen against the science policy of the former GDR. The policy that stated that universities teach and research institutes do research was complimented by one that stated that most scientists "sit and work" and a few others travel and "make contacts." The immediate implication is that most university scientists would not travel much.

As I discussed the travel issue with different people, the picture of a very spotty situation developed. Clearly, most of the mathematicians did not travel; on the other hand, some did, and fairly frequently. I have not checked the attendance, but I was told that representatives from the former GDR attended all the recent International Congresses of Mathematicians.

I had assumed that travel to Russia would have been easy, provided there was money. It turns out that this was not so. The rigid structure in both countries—universities vs institutes—made contacts particularly difficult. If, however, there was a special relationship between universities or between institutions, then travel to Russia was easier. Important contacts were made through graduate students: quite a few students from the former GDR went to Russia to get Ph.D.s.

A story Professor Pietsch told me illustrates the rigidity of the university/institute structure. He spent a half-year at the Academy of Science in Moscow. During all this time he could not enter the University of Moscow. He was a guest of the Academy, and it was inappropriate to visit the University.

Poland and Hungary were much more open, mathematically, during the last 40 years. These countries not only had more contacts with the West but also had good contacts with the former GDR. In fact, I was told that Poland (and Hungary to a lesser extent) provided a window on the West. In functional analysis, the vehicle was the Poland/GDR functional analysis seminar. But here again, "structure" in the form of structured attendance was evident: there could be only 15 people from the GDR, 15 from Poland, and 15 others. In general, there were quotas for the number of Western visitors to conferences.

Travel was difficult but not impossible. What is not clear to me is how the "special people" who were allowed to travel and allowed other Western contacts were selected. Professor Pietsch told of three mathematicians who applied to travel after having passed their habilitation. Two received a "yes" answer after a year, and the other never heard "yes" or "no," which meant "no." Professor Pietsch said that one did not receive a "no" answer, just no answer.

Professor Pietsch feels that young mathematicians, at least at Jena, are worse off today because of the lack of money. This contrasts with Professor Koch's view that the newly founded institutes are "rather well supported," but it is consistent with his view that the universities are not so well off. The universities are state institutions, and the new länder are not well off.

Finally, several people noted that travel restrictions were greatly eased "toward the end."

Problems with access to literature and publication paralleled those connected with travel. Here again it was a matter of "special people," lack of money, and a rigid structure. It was generally difficult to publish outside the GDR. One had to apply to do so, and then there was the problem of paying page charges.

Most East German mathematics research was published in *Mathematishe Nachrichten*, which was easily available in the West. Until the 1970s most

papers were in German, then articles started to appear in English; now most are in English. Small journals that recorded local seminars were published by some of the university departments. These were not widely available and were basically unknown in the West.

I was told that Western journals were available, but it is not clear that many reached the universities. One can imagine that it was difficult for "teaching" universities to justify buying journals. I believe the mathematics institutes were better off in this regard. In fact, the academics all mentioned the poor state of their mathematics libraries.

Professor Pietsch told me that, as a reviewer for *Mathematical Reviews*, he had received a subscription (either free or at very low cost) for many years. Since reunification this is no longer true, and the cost is prohibitive.

SUMMARY AND ASSESSMENT

The problems in mathematics (and science in general) did not start with the communist regime in East Germany; they began with a bad start after World War II. It was then (and of course at the beginning of the war) that scientists started leaving for the West. There has been a steady stream of talent going from East Germany to West Germany, and often on to the U.S. West Germany has been more attractive, and talented people always manage to find a place. This continues today, for the East is still poorer than the West, and will be so for some time to come.

Professor Koch pointed out that East Germany has about one-fourth the population of West Germany. He felt, however, that the mathematical impact of the East was not one-fourth of that of the West, and he pointed to the problems outlined above. As evidence he cited numbers of invitations to the International Congresses. He felt that part, but not all, of the problems of the last forty years stemmed from isolation.

Professor Pietsch made an interesting observation about the kinds of mathematics that were done well in the former GDR. He noted that because of their isolation they had to avoid areas that were new and rapidly developing. He felt, on the other hand, that they were strong in established areas such as functional analysis and probability theory.

The good news is that things are improving. German Federal policy has shifted research back to the universities as well as to maintaining research institutes. There is now money, although not a lot, from the DFG for visitors. The DFG has provided 3-year support for 109 young scientists, including mathematicians. Currently, it appears that the research institutes are better supported than the mathematics departments. We will have to wait until the transients in the universities die out to see if this persists in the long run.

And in the long run the strength of the universities will be tied to the strength of the economies of the länder since the universities are state-supported institutions. Federal funds to refurbish buildings and for student support are necessary, but it will be up to the states to make university salaries competitive with West Germany and other Western countries.

There will always be a few good mathematicians entering these universities. The challenge is to encourage these young people in the short term and be able to show them long-term opportunities at home. But this is a problem East Germany now shares with the U.S. and other Western countries. In the former Soviet Union it was more desirable to go to the university than to be rich; now there are more opportunities to be rich, and the culture may change.

REFERENCES

1. Leibniz was born in Leipzig in 1646. He studied law at the university from 1661 to 1666. In 1666 he was refused a doctor of law degree on the basis that he was too young. He went to Altdorf where he was immediately awarded a degree and never returned to Leipzig. However, his statue stands near of the university.
2. Steven Dickman, "A Grim Exorcism at Leipzig University," *Science*, 395-396, 24 January 1992.
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Physics

Fourth International Workshop on Low Temperature Detectors

by Steven E. King and Deborah VanVechten. Both are at the Naval Research Laboratory, Washington, D.C. Dr. King is a nuclear physicist in the Radiation Detection Section; Dr. VanVechten is a condensed matter physicist in the X-Ray Astronomy Branch.

KEYWORDS: detector technology; LTD; bolometers; devices; low temperature

INTRODUCTION

New detector technologies are needed to explore difficult fundamental questions in physics, such as the nature and existence of dark matter and the masses of neutrino. Other research areas such as X-ray astrophysics, interface studies in materials science, and heavy ion experiments in nuclear physics would also benefit from improved detectors. Many schemes for improving detectors require low temperatures for their optimization.

A series of Low Temperature Detectors (LTDs) workshops began in Munich in 1987. The Fourth International Workshop (LTD-IV) was held at Oxford University on 4-7 September 1991; it included 53 presentations and 121 participants from 11 countries. Enquiries concerning the conference proceedings should be directed to the organizer, Dr. Norman Booth, Department of Physics, Oxford University, Nuclear Physics Laboratory, Keble Road, Oxford OX1 3RH, United Kingdom (U.K.).

The first experimental results in the area of double b-decay spectroscopy were greeted with excitement at the workshop. Detectors for heavy ion spectroscopy and X-ray astrophysics have reached an advanced stage of development. Many LTDs are now composite structures, and the device physics determining the ultimate resolution or sensitivity is beginning to be understood.

EQUILIBRIUM DEVICES

Bolometers are the prototype equilibrium device. They respond with a signal that is proportional to the temperature rise after the energy has become homogeneously distributed over the entire crystal and global thermal equilibrium has been reached. Basically they are low-temperature calorimeters with an attached or integral thermistor. Adequate signal amplitude for good energy resolution requires rapid thermalization and distribution of the deposited energy and maximization of sensitivity to temperature excursions. The detector specific heat must be minimized without sacrificing quantum efficiency. Bolometers as a class are the most mature of the LTD technologies.

In the first major experiment using LTDs, Brofferio (INFN-LNGS, Assergi, Italy) measured both the ^{130}Te and ^{48}Ca b-b decay lifetimes by using large bolometers. The resultant lifetime limits constrain the mass of the electron neutrino to less than 10 eV. This work is part of a large effort led by E. Fiorini (University of Milan, Italy). Preparations are well advanced to use arrays of small bolometers as imaging devices on the Advanced X-ray Astrophysics Facility (Moseley, NASA Goddard, U.S.). Single-pixel versions of these devices have achieved a record 7.3 eV resolution for incident 5.9 keV X rays when biased at 100 mK. Resolution of 2.8 keV FWHM from 60 keV photons and baseline noise of only 600 eV have been obtained with a 60-gram germanium crystal [Sadoulet, University of California (UC), Berkeley].

Heavy ion detector applications of bolometers have been demonstrated by work reported by Egelhof and Von Kienlin at Darmstadt, Federal Republic of Germany (FRG). Preliminary experiments using composite bolometers with sapphire

absorbers and germanium thermistors achieved an energy resolution of 0.6 percent for beam energies greater than 200 MeV.

Significant effort has gone into the testing and understanding of thermistors (Pavan, INFN, Milan, Italy; Wang, UC, Berkeley; Stefanyi, Royal Holloway, U.K.), especially NTD germanium sensors. More problems emerge as the bias temperature drops below 50 mK, with long equilibration times between the electronic and phonon subsystems and resultant unpredictable values of the effective specific heat. Other, more preliminary work included thermometry by magnetic readout of a paramagnetic salt (Umlauf, Technical University Munich (TUM), FRG) and amplification of the temperature rise by stimulated microwave absorption in a surface superconducting layer (Tadsen, University of Neuchatel, Switzerland).

Superheated, superconducting granule (SSG) devices are a second class of equilibrium device. They sense the collapse of the Meisner effect following a thermally induced phase transition from the superconducting to the normal state. Historically, much work has been done on colloids consisting of spatially isolated spheres 10-100 microns in diameter. An experiment is underway to demonstrate that a colloidal SSG device can function as a low threshold detector of elastically scattered recoil nuclei and thereby neutral particles using 70 MeV neutrons and a neutron hodoscope (Gabutti, University of Bern, Switzerland). As shown by Turrell (University of British Columbia, Canada) with indium and tin spheres, use of lithographic techniques to produce ordered arrays of absorbers greatly enhances the uniformity of the response of the trains. Similar work using large area indium discs was described by Leoni (IESS-CNR, Rome, Italy).

NONEQUILIBRIUM DETECTORS

The detection approach showing the greatest increase in development activity since the previous conference uses bulk crystals as absorbers and senses the deposited energy at the surface. Both semiconducting and superconducting crystals are used. Localization of the event within the absorber requires the sensing of differences in the energy density arriving at different points on the surface. Thus the excess energy must be sensed before it has had time to become uniformly distributed and with considerably greater sensitivity than required for the total even energy determination.

In a semiconducting crystal, the event site information is carried by the phonons propagating ballistically between inelastic scattering events. These phonons must be distinguished from those that are also elastically scattered en route and arrive at a later time. At the Workshop, Probst and Seidel (MPI, Munich, FRG) described Ir films on Si crystals; Lee and Irwin (Stanford, U.S.) discussed Ti and W transition edge bolometers on Si with a complex optimizing geometry; and Goldie (Oxford, U.K.) described Al junction array readouts on InSb crystals.

Especially interesting were the results that the critical quasi-diffusive component is described by a different specific heat than the diffusive component (Probst) and that the conversion factor between incident energy and signal amplitude depends on dE/dx of the incident particle (Goldie). Both reflect the importance of nonequilibrium processes.

With a superconducting absorber, both excess quasiparticle (QP) and phonons arrive at the surface. Gaitskell (Oxford, U.K.) is experimenting with Nb crystals with Al junction array readouts. Forster (TUM, FRG) described Ir transition edge bolometers on V and Mo epitaxial deposits; this is a first step toward a thermally cyclable "distributed" tunnel junction detector wherein the absorbing crystal is replaced by a few-micron-thick deposit. If the QP are directly sensed, e.g., as an enhanced tunnel current, the arrival of both the QP and hot phonons will produce pulses, but the pulse height-to-energy conversions will differ.

Thus the pulses must be distinguished on some basis, such as pulse rise time, if events of unknown energy are to be analyzed. The surface tunnel barrier can be made so thick that the QP cannot tunnel. The signal amplitude can still reflect the energy carried by the QP if a lower T_c layer is added to the surface of a bulk crystal to trap the QP spatially. The resultant QP relaxation and recombination phonons then have a high probability of being sensed on the far side of the insulator. The total phonon flux can be sensed bolometrically or it can be injected into a second tunnel junction

structure that would respond only to phonons above a controllable energy threshold.

Integral tunnel junctions (wherein the events sensed occur within the electrodes) are still being pursued using Nb by several groups (University of Tübingen, FRG; SRON, University of Twente [Twente]; ESA [the Netherlands]; and NRL and Yale University [U.S.]). San Francisco State University and Lawrence Livermore National Laboratory (LLNL) (U.S.) reported work on Al devices. Despite the relatively advanced state of Nb and Al deposition and lithography technology, the energy resolution achieved does not yet match that of Sn junctions. Discussion focused on why and what can be done about it.

Houwman (Twente) experimentally confirmed the prediction (Peterson, National Institutes of Standards Technology, U.S.) that junctions with specifically curved shapes will have critical currents that die off faster than 1/H and so are easier to field bias. (The self-resonance Fiske mode steps in the IV curve were found not to be simultaneously eliminated.) VanVechten (Naval Research Laboratory, U.S.) quantified the quasiparticle loss rate expected from regions driven normal by trapped magnetic flux. Labov (LLNL, U.S.) reported that changes in orientation of the tunnel barrier relative to Earth's magnetic field changed the excess subgap current.

OTHER DEVICES

Not all detectors fall into the traditional categories of LTDs. One promising technique uses a silicon drift chamber to observe low-energy nuclear recoils based on charge collected on a pn CCD (Gebauer, MPI, Munich, FRG). Seidel (Brown University, U.S.) reported the completion of construction of a large volume detector based on the quantized evaporation of ^{4}He.

Another approach uses a liquid xenon electronic bubble chamber for dark matter detection (Cline, UC, Los Angeles, U.S.). To date, the most successful dark matter searches have used more traditional germanium diode detectors (Caldwell, UC, Santa Barbara, U.S.) to exclude much of the phase space of mass and interaction cross section for galactic cold dark matter candidates.

CONCLUSIONS

This workshop included exciting first experiments using LTDs to achieve new results in particle physics, e.g., in the double β-decay lifetime experiment. Much of the detector development work also involves attempting to understand of the device physics and evaluating the competing design requirements of LTDs.

This workshop and the recent review article by Stodolsky (MPI, Munich, FRG) in the August issue of *Physics Today* have focused attention on the new frontier of LTD research. The next workshop will be held at the University of California, Berkeley, in the summer of 1993 and will be organized by B. Sadoulet.

Policy

Universities in the New States of Germany —The Pace and Cost of Reform

by C. T. Owens, National Science Foundation, formerly European Representative

KEYWORDS: Fraunhofer Society; Mecklinberg-Vorpommern; reorganization; research programs; research funding

[Note: This article generally contains the viewpoints of the individuals interviewed. The final paragraphs of each section, however, are comments by the author and the National Science Foundation.]

INTRODUCTION

The universities in the new states (länder) of Germany are facing severe resource and personnel problems. Rostock University, in the State of Mecklenburg-Vorpommern, has dynamic leadership and excellent research capability, both in-house and nearby. Some tensions exist between the university and the state authorities over the pace and cost of reform and modernization.

MINISTRY OF CULTURE FOR THE STATE OF MECKLENBURG-VORPOMMERN

The capital of the länder of Mecklenburg-Vorpommern—one of the five new German States that comprised the former German Democratic Republic (GDR)—is at Schwerin, about 25 miles east of the border that used to divide Germany. The State Secretary for the Ministry of Culture is Dr. Thomas de Maizière.

There are two universities in the länder, at Rostock and at Greifswald. Both date their founding from the 16th century. There are also three Fahrhochschule (technical training institutes) where more practical studies are available. Very deep structural and personnel changes are taking place today in the universities, and some conflicts are involved. There are 6,000 employees in the universities educating 30,000 students. The aim of the reforms—which were called for in the reunification agreements—is to remove any doubt that those who remain in the universities are of high quality and can provide high quality education and research. The evaluation involves a "trust process" that examines every employee from the political point of view, and a review of the quality of their work in their particular discipline. Participants in the review include experts from the old länder in western Germany and from other countries. Those who do not qualify on one or the other of these tests will have to leave the university. The process will be completed by September, and those affected will have to leave in September or October.

A parallel reform is the restructuring of the education of teachers at all levels. Training of new teachers will be a function of the universities. The pedagogical higher schools and the institutes for primary studies will be put into the universities.

Contrary to the popular notion, the universities in the old GDR did have basic research projects. Some of the institutes of the former Academy of Sciences will become part of the university, others will be at (but not part of) the university, and yet others will be independent. In Rostock there will be an institute of 150 people working with the university on environmental problems, plus an interdisciplinary environmental research group in the university. Engineering and technical disciplines in the länder will be concentrated in Rostock. Wismar has engineering and technical schools that will become attached to the university in Rostock.

Greifswald will be a center for the humanities and for Baltic studies. The university there will be important for seeing how the länder can become

integrated into the process of developing relations and communications with Scandinavia and Eastern Europe. Greifswald also is an important center of research on low-temperature plasma physics.

Greifswald is one of the poorest of the länder. Only 8% of the former Academy of Sciences research staff were located here. It will be necessary to concentrate on establishing niches in which excellent performance is possible. If a variety of output criteria are considered, it is possible to conclude that there is one university too much in the länder. The Wissenshaftsrat (a kind of federal science council) has to approve all new institutions and new construction, and it has been difficult to convince them that both universities are necessary.

Today there is a scarcity of students—especially in reference to the large staff at the universities. Many students are going to universities in the old länder (in the West). Some of these are already returning, however, because of the living conditions, remoteness of professors, and other factors. Perhaps in five years, the situation will have shifted. The new generation of professors here will have set up new curricula and new and exciting research. This may draw back students from the länder and from other parts of Germany who are dissatisfied with the old and bureaucratic universities in the West.

There is a very large residual image of "the ugly American" in this part of Germany. The United States should send people to counter that image, including teachers of English. Those who come should be able to speak German since few students speak English now. English will be added to the lower school curriculum, but the process will take some time.

ROSTOCK UNIVERSITY

Meeting with the Rector

The rector of Rostock University is Professor Dr. Gerhard Maess, a Professor of Mathematics at the University until his recent election to the post of Rector. One half of the university's resources are devoted to medicine, and many of the people employed in the Faculty of Medicine have left to take opportunities elsewhere. There are approximately 3,000 people in the Faculty of Medicine, and 3,000 in the other seven faculties of the university. The Faculties of Science and Engineering have about 480 employees altogether. There are only 60 students in the sciences (Physics, Chemistry, and Biology departments) and 40 in Mathematics—out of a total 8,000 students at the university.

Research at the university is not well-funded. The länder of Mecklenberg-Vorpommern provides very little, and negotiations are still under way with the Deutsche Forschungsgemeinschaft (DFG). The DFG is in the process of establishing three Working Groups in Rostock— one in Physics and two in Chemistry. Although these groups will probably be administratively separate from the university, some of their research staff will also have university appointments. The Fraunhofer Society, which conducts industry-related research with support from the Federal Ministry of Science and Technology [Bundesministerium für Forschung und Technologie (BMFT)] is setting up a research group in Rostock in the field of computer graphics; the BMFT may provide as much as DM20 million [$12.6 million at DM1.59/$]. The university is in need of about DM300 million [$188.7 million] for salaries, equipment, and refurbishing buildings and laboratories. The fact is that it will likely get only DM7 million this year, when the real minimum needed is about DM35 million.

There will be four "Blue List" institutes (funded 50% by the länder and 50% by the BMFT) in this länder, two of them in Rostock, one in Greifswald, and one (in agriculture) elsewhere. Leaders of the blue list institutes in Rostock will have professor status at the university and will take graduate students. New institutes for science and for mathematics will be built in the Sudstadt campus of the university. DM2 million has been made available for this purpose by BMFT, but it is possible that the länder will have to return the money. There is still no planning document or architect's plans to make available to the ministry.

Department of Electrical Engineering

Dr.-Ing Heinrich Albricht is the Chairman of the Department of Electrical Engineering. The Department was founded in 1955, and today has 500 students—about 100 in each year of the five-year program. In the past, the Department had very close contacts with the electronics and ship-

building industries in the GDR. Although things have changed significantly, ties to industry will still be important—if not the same as before. (Universities in the GDR were often involved in product development and other enabling research for industry. Today, industry may benefit in a more general way from research at universities and from students involved in practicums in industrial laboratories.)

The Siemens Corporation has recently donated equipment for research (industrial controllers) in the department. Students pick their own preferred place for their practicums, and most are done today in Munich, Karlsruhe, or elsewhere in the western part of Germany.

Assistantships requiring about two-to-four hours per week teaching are available for about ten Ph.D. students. The former technical school in Warnemunde (which supported the shipbuilding industry there) has recently been attached to the department. The department now has 130 people, including 22 professors. By the end of September, the number of employees must be down to 120. This should not be too difficult because many people have already left the department, and there have been no new hires for about two years.

Lines of research in the department include acoustic imaging techniques, laser applications to highly accurate particle detection and measurement, signal processing, and noninvasive flow measurement techniques.

The acoustic imaging group has developed the electronics required to detect reflections of 0.3-0.5 millisecond sound pulses with a very high signal-to-noise ratio. A pencil-shaped beam is steered to compensate for vessel pitch and roll. The 1 meter × 0.75 meter transducer (which can be installed in 30 minutes) emits and detects the 0.5 kV pulses from 24 transmitter/receivers in 12 elements. This work was begun as an effort to develop a tool for locating gravel beds under the bottom of the sea. Currently, both applied and fundamental aspects of the work are being pursued. Image data are stored for postprocessing. They are analyzed in a search for algorithms that may apply generally to the interpretation of the data—identification of specific features, structures, and objects.

The laser beam particle sizing work also has both applied and fundamental aspects. Phase-doppler methods are used to determine the size and velocity of particles in fluid. Time-displacement measurements taken on particles moving past two crossing laser beams are highly accurate on a large range of particle sizes. The signal processing aspects of this research, as well as the measurement systems applications, are of interest to the students and faculty involved.

Another research project in the department involves the measurement of flows in pipes by noninvasive means. A pair of transducers mounted on the outside of the pipe is used to detect flow changes, turbulent areas, and points of restricted flows. Transducer outputs are normalized for the distance between them, and their sensitivity is such that small changes in flow and pattern of flows in the pipe can be detected.

NSF/EUROPE Comment: The University of Rostock is beginning a long-overdue renovation of its badly deteriorated physical plant and of its academic resources as well. Both of these efforts are dependent in important ways on the resources, which are to be made available from the länder government. There is little support at Rostock for the länder idea that the university should not try to be a "complete" university, with instruction and research in a wide variety of fields. At the same time, allocation of positions and resources from Schwerin will make it hard not to cut something from the program. The visit to the university included a fascinating session on its history—including periodic struggles across the centuries between those who ran the university and those who had the political power. Some problems of the same kind are evident today, with tensions over resources and the time required to make decisions, especially on who will and who will not be allowed to stay on at the university.

The University of Rostock has affiliations with research institutes being set up in Rostock under several other organizations. Scientific staff at these institutes, which are being well equipped and reasonably well-funded, will have university appointments. They will teach and conduct research at the university or with university colleagues. Although the physical plant is very much deteriorated, some of the laboratories have (or soon will have) new and sophisticated equipment. Most of the scientific and technical research is carried out at the Sudstadt campus, a 20-minute walk from the original university campus in the center of town.

DARMSTADT HOUSE OF COMPUTER GRAPHICS

Introduction

This report is based on a conversation with Professor Dr. Jose L. Encarnaçao. Dr. Encarnaçao is Director of the Interactive Graphics Systems Group, Technical University of Darmstadt and the Fraunhofer Computer Graphics Research Institute, and Chairman of the Board of the Computer Graphics Center. This was a follow-up to a visit to the Fraunhofer Computer Graphics Research Group in Rostock, in the eastern part of Germany. Except where otherwise indicated, the opinions expressed here are those of Dr. Encarnaçao—as understood by the writer.

The House of Computer Graphics in Darmstadt combines basic and applied research and technology transfer activities under one roof. This highly successful organization has been called upon to assist in developing a new computer graphics facility in Rostock—part of the reformation of research in the eastern part of Germany.

Organization

Work at the House of Computer Graphics focuses on advanced research in information technology and on scientific visualization. In this area, the U.S. system involves "waves" of new knowledge and approaches, but there is also a lot of "reinvention of the wheel." In Europe, there is more continuity and incremental growth. The university research program in computer graphics was the nucleus; the Computer Graphics Center was established in 1984. The Fraunhofer Society facility was formed as a research group in 1987, and beginning this year it has become a research institute. The three entities today occupy a 6,000-m^2 building in the heart of Darmstadt.

The Technical University Group carries out basic research and teaches courses. The Center specializes in technology transfer to industry and in continuing education. The Fraunhofer Institute (FhG) engages in contract research and the development of prototypes, on contract with industry. There are 130 researchers overall (a researcher has at least a Master's degree) and 30 secretarial, technical, and other support staff. In a given year, 50 Master's-level students and 7 Ph.D. students will be working more or less full-time in the three groups, together with about 250 part-time students. The budget for 1992 is about DM22 million (or about $13.75 million). Of this amount, 60-65% is for FhG operations, 20-25% is for the Center, and 15% is for the university group.

The combined effort of the three organizations constitutes the largest computer graphics activity in Europe, and one of the largest in the world. It is active internationally, with participation in joint projects and research conferences. In 1991, an external division of the FhG was set up in Gales Ferry, Connecticut, with a staff of 15. This facility may be moved to another location in the United States to put it closer to important computer graphics research groups, and especially closer to a more plentiful supply of students.

Rostock Center and FhG Branch

There was a computer graphics center in Rostock before the unification of Germany; this group has now been made a branch of the FhG and an external division of the Computer Graphics Center. It had published in German, and researchers from Darmstadt had visited them before the fall of the German Democratic Republic (DDR). Two professors at Rostock University who were influential in the political system in place at that time had been able to obtain significant resources and build a talented group. After reunification, the question was how to save that resource.

Researchers two levels down in the old group's hierarchy were chosen to lead the research in the new group to avoid political problems. The Rostock group now consists of 30 people, and it has a budget of DM3 million for 1992. A new building to house the Rostock group is scheduled for completion in October. Very good facilities are being provided in a refurbished school building.

The Rostock facility will be reviewed after three years to determine how successful it has been, whether it should be an independent FhG Institute, whether it should continue in affiliation with Darmstadt, and/or other options. In Germany, people in such institutions are not fired, but they suffer a gradual reduction of influence and significance. The FhG is a network of independent

institutes that both compete and cooperate. After a transition period, a successful institute will bring in about 50% of its money from industrial contracts.

Growth in staff, budget, and other resources is keyed to success in attracting such outside support. Rostock must find its own technical niche, selling its specialized knowledge where needed. It must look beyond (the German State) Mecklinberg-Vorpommern for clients, and it must also try to make the most of its physical location in such research areas as shipbuilding and ocean and environmental research. Historical ties of the region with Scandinavia and Eastern Europe should also be exploited.

The Fraunhofer Society has increased in size from 40 organizations to 60 organizations in the last two years. The Society President is originally from Leipzig (in the former DDR), and this may have made the original institutional decision to expand into the east easier. More overhead funding for the Society is now going to the east, and money available for the institutes on contracts from the Ministry of Science and Technology (BMFT) is about the same. The basic support cushion for each institute is therefore thinner (FhG institutes compete for contracts from industry and government; they receive the rest of their support from Society headquarters).

The FhG institutes provide industry with outside R&D capability. Industry is going to develop in the east and will need the FhG there so the Society is getting ready to grow with the market. Once a year the Fraunhofer Society has a meeting of all its institute directors. Success (or lack of it) is visible to all. The people in the east are having to learn about this kind of situation. Resources will go to those organizations that perform the best. The Fraunhofer world is not flat.

The Darmstadt facility has been affected by the absorption of the Rostock group. An important effort is required to bring the new group's activities up to western standards. This is an important contribution by the Darmstadt facility to the reunification effort. It also means, however, that money that would have been moving east anyway will be applied to advancing computer graphics, and it will have links to the House of Computer Graphics in Darmstadt as well. In five years computer graphics in Germany will be substantially stronger.

NSF/EUROPE Comment: An important part of the German strategy for reforming science and technology in the five new German States is forming teams. High-quality institutions in the west are teamed with new research organizations fashioned from the best of former DDR research personnel and resources. There is a current cost to the institutions in the west, and they may well be guiding the development of potentially important competition for funds and resources. The opportunity cost has been more than expected; this is being appreciated in detail only as more experience is gained with what is actually required. Nonetheless, this forced investment will likely in the long run pay dividends for German research overall. There is no dearth of capability in the new States.

Notes on Irish Science Policy Making

by C. T. Owens

KEYWORDS: policy; microelectronics; EOLAS; funding strategy; PATs

INTRODUCTION

Irish science policy is geared to the needs of industry and to industrial development. Under the Minister of Industry, the Minister of State for Science and Technology has a broad role, encompassing aspects of international cooperation, relations with the EC, and Higher Education. The Minister of State has an Office of Science and Technology with a budget of about IR£50 million (as of April 1992, $1.60 = £IR1.00).

The main funding for basic research in Ireland is through the Education Department in its formula-based block-grant awards. Institutions make proposals to the education authorities for support, including support for researchers. The total basic

research support in Ireland is about IR£7 million, and 86% of this is for Education Department awards. Any basic research that is funded by EC grants would not be included in the IR£7 million estimate. Although EC programs are moving in the direction of basic research, they are still overwhelmingly strategic and applied research activities containing relatively little basic research.

THE IRISH SCIENCE AND TECHNOLOGY AGENCY (EOLAS)

Summary

The Irish Science and Technology Agency (EOLAS, pronounced O LAS) is a small, semi-governmental organization devoted to improving the technical level of Irish industry and the research capabilities of Irish universities—especially in high technology fields. Working with a large award from the European Community (EC) and with national funds, EOLAS develops and manages programs that provide technical assistance, technology transfer and information services, research grants to universities. It encourages university-industry cooperation and coordinates Irish participation in research programs of the EC and of cooperation abroad. Its Programs in Advanced Technology (PATs) seek to build Irish capabilities in biotechnology, advanced manufacturing, opto-electronics, and other high-technology fields. EOLAS is a willing and appropriate partner for developing cooperative research links with Ireland.

EOLAS was set up by an Act of Parliament and is a dependency of the Office of Science and Technology. It works closely with the Ministry of Industry to help meet the needs of industry for research and development-related resources. These needs include

- highly-trained scientists and engineers,
- technical advice on standards and the attainment of high quality in Irish products, and
- encouragement for technical innovation.

It aims to improve the capacity of Irish colleges and universities to do research and to train outstanding research and technical personnel.

The 12-person EOLAS Board provides its views on management and on policy for the organization. Chairman of the Board is Professor G.T. Wrixon of University College and the National Microelectronics Research Center, both in Cork. Membership of the Board comes from academia and industry, with one person from the Ministry of Industry. The Chief Executive is Jim McBride, who manages the organization's 450 employees (there are also 50 or so contractors) and its budget of about IR£20 million. The government provides IR£12 million of the budget; the remainder comes from grants from the EC (Structural Funds) and from industry.

EOLAS has a Group for Policy and Planning that handles coordination with the national plan for R&D, coordination with the Commission and the programs of the European Communities, and program evaluation and review. The Science and Technology Promotion Group provides grants for research in universities and in firms, fellowships, and funds (from the EC) for starting special Programs in Advanced Technology (PATs). Three Groups provide assistance to businesses: Laboratory Services, Technical and Consultancy Services, and Business Development and Planning (technology transfer, marketing, and information programs). The National Standards Authority of Ireland (NSAI) is an autonomous organization that reports to the EOLAS Board and shares personnel, financial, and other services with the EOLAS Groups.

Perhaps the single greatest achievement to date for EOLAS has been devising the strategy to successfully obtain important funding from the EC, including the Programs in Advanced Technologies (PATs). EOLAS is a source of new funds for universities and firms, and adds new dynamism to the research and development scene in Ireland. Possibly its greatest weakness to date has been a certain neglect of international connections outside the EC, especially for basic research cooperation.

EOLAS and the EC

EOLAS relations with the Commission of the European Communities (EC) is managed by Dr. Killian Halpin and Dr. Noel Gillatt. EOLAS provides the personnel for representation on several of the coordinating committees established by the EC for research and development programs. ESPRIT and BRITE are probably the best known of these programs, and EOLAS also represents

Ireland in the primary intergovernmental committee for S&T, CREST. The competition for the EC Framework funds is heavy in Ireland. There is a possibility that the EC will be amending its Treaty to include programs for basic research in the Commission's work.

Ireland has done very well in competing for EC Framework Program contracts. Its universities are "hungry" — possibly because so little Irish money is available for contract research. At this time, the Framework Program is helping Irish universities more than industry. During the Second Framework Program, Irish researchers have brought in about IR£20 million per year.

The EC Structural Program (the European Regional Development Fund) is a major source of R&D funds for Ireland. The Operational Programme for Industry was devised and proposed to the EC by Ireland; it focuses on assisting the development of technical competence in industry as well as in universities. The plan runs from 1989 to 1993 and consists of elements designed to provide various types of technical services to Irish industry (including technical audits and information services), to encourage university/industry cooperation in applied research, and to finance the set of experimental programs known as PATs for developing Irish capabilities in selected advanced technologies. A total of about IR£150 million per year from both Irish and EC sources goes into these programs, and this amounts to about one quarter of all industrial development funding in Ireland. Technical training is funded from the other three-quarters of the industrial development funding.

BioResearch Ireland

BioResearch Ireland is the organization that comprises the first of the aforementioned experimental programs known as PATs. It is also the first National Program in research and development. Its mission is to commercialize publicly funded biotechnology research results. It was founded in 1988, and its objectives are to encourage research in Ireland (by companies based in Ireland or overseas); to promote high-quality biotechnology research in Ireland, thus attracting biotechnology firms to locate in Ireland; and to promote the movement of research results from universities in Ireland to industry.

The Director of BioResearch Ireland is Mr. Barry McSweeney; he and a staff of four professionals are located in the EOLAS Headquarters building in Dublin. Overall, five Centres are located at universities and university colleges in Dublin, Galway, and Cork. Total staff is 140 people, including 25 graduate students. The budget is about IR£3.5 million. Although more than IR£2 million comes from the Department of Industry and Commerce (and the EC-funded Operational Programme for Industry), about IR£1.25 million comes from contracts for research, technical services, training, and other services. Almost all of this income comes from industry, and most of that (65% in 1990) comes from Irish industry. Each researcher is responsible for about IR£70 thousand in research funds.

Researchers participate in income from BioResearch Ireland patents, receiving 25% of the proceeds, tax-free. It is BioResearch Ireland policy to encourage the spin-off of companies from its Centres to manufacture products. Two such spin-off companies are in the "about to leave the nest" stage. BioResearch Ireland does not manufacture products itself. The universities and BioResearch Ireland share rights to intellectual property that comes out of research projects on the basis of their respective contributions to the projects. There were 70 projects under way in 23 lines of research within four overall applications areas: Agriculture/Food, Healthcare, Veterinary, and Industrial.

Participants in BioResearch Ireland must get through a rigorous proposal evaluation process that focuses on both scientific and commercial aspects. The scientific review consists of an examination of the usual factors like publication rate and comments of peer reviewers. The commercial review focuses on the product that is envisioned to be developed at the end of the scientific work, an estimate of its market value, an analysis of its competitive position in the market, and the proposed strategy for obtaining a share of the market. In the end, about 5% of proposals get through these two review filters.

BioResearch Ireland funding is an investment in future capability. The ECLAIR and FLAIR competitive grants programs of the EC are biotechnology-oriented, and Ireland got 11% of the awards in these programs in 1990—up from 3% in 1987. Eight other PATs are either begun or about

to be under way in the model of BioResearch Ireland (although these programs were on the drawing board before Bioresearch Ireland began).

EOLAS Research Support Programs

Programs devoted to supporting work in institutions of higher education are managed by Dr. Brendan Finucane. Dr. Finucane has a staff of 4 full-time and 25 part-time people.

The funds available to EOLAS for the promotion of research—especially basic research—are rather limited. The Scientific Research program has about IR£1 million, with a further IR£57 thousand devoted to fellowships for Ph.D.s. Proposals received (from academic institutions) are about 50% from the biological sciences, followed by physics, chemistry, and Earth sciences. Awards average IR£30 thousand each. Strategic Research Program awards are also available to academics, in fields selected for their relevance to areas of national importance in Ireland. An annual request for proposals is issued. The budget for this program is about IR£1 million, and about 10 awards of about IR£100 thousand each are made each year. Applied Research Program awards of about IR£175 thousand each are available from the IR£950 budgeted for this year. Awards in all three categories cover only the marginal costs necessary to undertake the proposed work, with no indirect costs being covered.

Proposals are reviewed by five panels of academics, each of which has one outside member, most often from the United Kingdom, Ulster, and Germany. Strategic grants require a preproposal which is subjected to an initial review by a panel of academic, government, and industry reviewers. These reviewers decide whether the proposers should be invited to submit a formal proposal.

Another program is engaged in developing academic research capabilities in the Regional Technical Colleges. There are nine of these institutions around Ireland offering an applied science and engineering curriculum. This year, IR£900 thousand will be devoted to grants of from IR£3 thousand to IR£20 thousand. These will be for projects of high relevance to the technical needs of the regions served by the colleges.

A University/Industry Interaction grants program is funded by EOLAS and Irish industry, with each providing about IR£1 million. Irish companies contract for work at the universities. EOLAS pays one-half of the university costs for these projects, of which there are about 30 per year.

The Techstart Program places young graduates into Irish firms, subsidizing the first year of employment with IR£5 thousand. Companies participating are certified by the EOLAS regional offices, and they must provide a technical position. Support groups and training are provided by EOLAS to the employees. A related program offers consultancy services. Three hundred people have participated in this program in three years, and 70% have been hired for permanent jobs in their host companies.

This office is responsible for getting the PATs started. A total of IR£35 million to 40 million will be devoted to these programs over the five years of the Operational Programme for Industry. Advanced Manufacturing Technology, Optoelectronics (Optronics Ireland), Advanced Materials, Power Electronics, Software, Telecommunications (planned), and Sensors (planned). By the end of the program, about 500 or so people will be employed in the PATs. All of the PATs will be expected to earn at least part of their expenses. The Advanced Manufacturing Technology PAT, which is relatively new (1988), is earning about 30% of its budget, and Optronics Ireland has several Japanese firms contracting for its work.

Also handled in this office are some aspects of coordination with the programs of the EC, including participation in the review of proposals and Irish participation in the European Space Agency (ESA). Ireland's contribution to ESA is about IR£5 million per year. Contracts for ESA-related work coming to Irish firms currently do not provide Ireland with the development of much new technology.

Services to Firms

Three major units of EOLAS provide services directly to Irish firms. These include Laboratory Services, Technical and Consulting Services, and Business Development and Planning. All of these are devoted to enabling Irish firms to upgrade their

technical capabilities by assisting with technical expertise and information, patent writing and filing, and meeting the quality and technical standards required by the EC and the marketplace.

NSF/EUROPE Comment: EOLAS has the very large task of building high-technology capabilities onto a rural base. Ireland's universities are capable of producing first-class graduates in science and engineering, and EOLAS' efforts keep greater numbers of the graduates at work at home, rather than abroad. Ireland's industry is not oriented toward high technology, and EOLAS seeks to change this and make industry an innovative driver of growth. This is a tall order.

The Chairman of the EOLAS Board, G.T. Wrixon, is well-connected politically, and a distinguished researcher in his own right. He knows what a center of excellence in research should be, having founded and directed the National Microelectronics Research Centre (see companion article), which certainly qualifies as such. There are plenty of ideas for new ways to do things coming from EOLAS. These are embodied in a great number of programs run on quite small amounts of money to see what possibilities they may open up.

EOLAS staff is interested in the possibility of international cooperation, including cooperation in basic research, and there are opportunities for Americans to benefit from research cooperation in Ireland. BioResearch Ireland is one program in which such opportunities may lie, and its management also welcomes the possibility of cooperation.

NATIONAL MICROELECTRONICS RESEARCH CENTRE, UNIVERSITY COLLEGE, CORK

Introduction

The National Microelectronics Research Centre (NMRC) was established in 1981 in the wake of an Irish industrialization policy of grants, subsidies, and tax exemptions that had not been successful in bringing to—and keeping—industrial jobs in Ireland. Research and development (R&D) was seen as an endeavor with potential, both as a source of employment in its own right and as attractant for industry because of the trained people who would be necessary to sustain it. Dr. G.T. Wrixon, who had conducted research at several centers of excellence in the United States, was called upon to set up the center that would carry out R&D in microelectronics.

To support industrial development, it was decided that the center would have to be able to do everything important to the industry, including quality control and fabricating its own silicon wafers and microchips. To reach the talented people who are necessary for a center of research excellence, the center was attached to the Department of Electrical Engineering and Microelectronics, University College, Cork. The center was given its own line-item in the Department of Industry budget for its development and operation. The NMRC was born.

NMRC Today

NMRC today has about 130 people on staff, including 55 students (45 Masters students and 10 Ph.D. students), about 20 of whom are part-time at the Centre. Training of Masters and Ph.D. candidates in available in the NMR research programs, but degrees are awarded by the National University Ireland, of which the University College Cork is a constituent part.

The NMRC receives IR£800 thousand from the Department of Industry, and the University College Cork pays IR£500 thousand in overhead costs. Contract work for several organizations, including the EC program ESPRIT, the European Space Agency (a 5-year contract), Optronics Ireland, and others (see companion article) is proceeding. The work of the NMRC is divided among four groups:

- Silicon Laboratory;
- III-V Semiconductors;
- Interconnection and Packaging Laboratory; and
- Integrated Circuit and Computer-Aided Design.

There is also a Test Engineering Laboratory where failure analysis and reverse engineering are carried out. Important equipment available include a scanning acoustic microscope, a scanning

electron microscope, electron beam etcher with 0.25-μm resolution, a stepper with 0.7-μm resolution, and metalorganic chemical vapor deposition. A Facilities Usage Scheme at work in Ireland allows researchers from other universities to use the facilities of the NMRC.

In EC terms, the NMRC is a "large-scale facility" for microelectronics package—a status shared with IMEC in Brussels. Its links with Europe are strong (as they are in Ireland in general).

The silicon fabrication laboratory is being rebuilt following a fire last year that destroyed it. A temporary clean room facility is in operation that can handle MOS processing and sensor development. Ion implantation capability will not be available until the new facility being constructed adjacent to the main NMRC building is completed early next year.

Integrated circuits are designed by using Mentor workstations and software, with Apollo, Sparc, and DEC equipment also available. Through the EUROCHIP facility funded by the EC, the chip designs can be produced in small quantities for test and evaluation. Chips and other components can be packaged at NMRC and the packaging and coatings can be evaluated. Materials can be subjected to extremes of temperature by using two small temperature-forcing chambers; these are used for work for ESA and other contractors.

There is a photo-masking shop and a second clean room where primarily optoelectronics research is done. This facility contains a scanning electron microscope and a low-voltage, auto-focusing field emission microscope that can handle 6-inch wafers. Just down the hall is the metalorganic vapor-deposition epitaxy machine manufactured by Thomas Swan. This device is capable of laying down a large variety of semiconductor coatings on a large variety of substrates.

NSF/EUROPE Comment: The NMRC has an impressive array of instrumentation and equipment for research and training in fields related to microelectronics. The research staff is relatively young, and the educational component of the Centre's mission is evident. Also evident is the focus on activities either used in or of potential importance to industry. The management of the Centre would be happy to consider cooperative projects that would bring American researchers to work in Cork. The NMRC staff is engaged in an enterprise of significance to several disciplines in science and engineering as well as to industry. They are well supported, financially and intellectually.

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