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European Science Notes Information Bulletin  
Reports on Current  
European/Middle Eastern Science

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SECURITY CLASSIFICATION OF THIS PAGE

## REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION <b>UNCLASSIFIED</b>			1b RESTRICTIVE MARKINGS		
2a SECURITY CLASSIFICATION AUTHORITY			3 DISTRIBUTION/AVAILABILITY OF REPORT  <b>Approved for public release; distribution unlimited</b>		
2b DECLASSIFICATION/DOWNGRADING SCHEDULE					
4 PERFORMING ORGANIZATION REPORT NUMBER(S)  <b>90-01</b>			5 MONITORING ORGANIZATION REPORT NUMBER(S)		
6a NAME OF PERFORMING ORGANIZATION <b>Office of Naval Research European Office</b>		6b OFFICE SYMBOL (If applicable) <b>ONREUR</b>	7a NAME OF MONITORING ORGANIZATION		
6c ADDRESS (City, State, and ZIP Code)  <b>Box 39 FPO, NY 09510-0700</b>			7b ADDRESS (City, State, and ZIP Code)		
8a NAME OF FUNDING SPONSORING ORGANIZATION		8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER		
8c ADDRESS (City, State, and ZIP Code)			10 SOURCE OF FUNDING NUMBERS		
			PROGRAM ELEMENT NO	PROJECT NO	TASK NO
11 TITLE (Include Security Classification)  <b>European Science Notes Information Bulletin – (UNCLASSIFIED)</b>					
12 PERSONAL AUTHOR(S) <b>Ms. Connie R. Orendorf, Editor</b>					
13a TYPE OF REPORT <b>Multidiscipline</b>		13b TIME COVERED FROM _____ TO _____		14 DATE OF REPORT (Year, Month, Day) <b>January 1990</b>	
15 PAGE COUNT <b>67</b>					
16 SUPPLEMENTARY NOTATION					
17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP			
19 ABSTRACT (Continue on reverse if necessary and identify by block number)					
<p>The European Science Notes Information Bulletin (ESNIB) 90-01 is a compilation of reports on recent developments in European science of specific interest to the U.S. research and development community, and is issued in support of the mission of the Office of Naval Research European Office. Issue Number 90-01, in addition to European area news, notes, and abstracts, contains reports in the fields of Acoustics, Computer Science, Environment, Mathematics, Mechanics, Physics, and Psychology. The value of the ESNIB to Americans is to call attention to current activity in European science and technology and to identify the institutions and people responsible for these efforts. The ESNIB authors are primarily ONREUR staff members; other reports are prepared by or in cooperation with staff members of the USAF European Office of Aerospace Research and Development or the U.S. Army Research, Development and Standardization Group. Scientists from the U.S. who are traveling in Europe may also be invited to submit reports.</p>					
20 DISTRIBUTION/AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS			21 ABSTRACT SECURITY CLASSIFICATION <b>UNCLASSIFIED</b>		
22a NAME OF RESPONSIBLE INDIVIDUAL <b>Ms. Connie R. Orendorf</b>			22b TELEPHONE (Include Area Code) <b>(44-1) 409-4340</b>		22c OFFICE SYMBOL <b>310</b>

DD FORM 1473, 84 MAR

33 APR edition may be used until exhausted  
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

U.S. Government Printing Office: 1988-607-044

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# ESN INFORMATION BULLETIN

90-01

This publication is approved for official dissemination of technical and scientific information of interest to the Defense research community and the scientific community at large.

Commanding Officer . . . . . CAPT Victor L. Pesce, USN  
Scientific Director . . . . . James E. Andrews  
Editor . . . . . Ms. Connie R. Orendorf

## ACOUSTICS

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### International Conference on Acoustics, Speech, and Signal Processing of the Institute of Electrical and Electronics Engineers . . . . . Chrysostomos L. Nikias 3

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- The International Workshop on Physics and Technique of  
High-Power Opening Switches . . . . . Marco S. Di Capua 32**

This report summarizes some of the contributions of the Soviet laboratories. The author also provides a brief summary at the end of the report to capture the flavor of the U.S. presentations.

- The HELIOS Superconducting Synchrotron X-Ray Source . . . . . Marco S. Di Capua  
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This article, based on two independent liaison visits by the authors, presents a brief introduction to x-ray lithography, traces the development of compact synchrotron in Europe, describes HELIOS in some detail, and summarizes synchrotron source developments in the U.S. and Japan.

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A particular goal of the workshop was to consider dexterity of teleoperation and to project how the human and robot studies might assist this goal. The workshop was organized into the following four

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# ACOUSTICS

## Ship Acoustics Research at the TNO Institute of Applied Physics

*by David Feit, the Liaison Scientist for Acoustics and Mechanics in Europe and the Middle East for the Office of Naval Research European Office. Dr. Feit is on leave from the David Taylor Research Center, Bethesda, Maryland, where he is a research scientist in the Ship Acoustics Department.*

### Introduction

Located in Delft, the Netherlands, the Technisch Fysische Dienst TNO-TH (TPD) or TNO Institute of Applied Physics carries out research and development (R&D) in applied physics. In the 1920s, the Applied Physics faculty became a separate entity from the Delft University of Technology (TUD). The function of this faculty was to train students to become graduate engineers in various aspects of applied physics. In the thirties, the results of research performed within the faculty were applied to practical problems arising within society; finally in 1941, the Institute of Applied Physics was founded to pursue consultancy work and measurements in acoustics. The TPD grew to become one of the largest institutes of TNO, and is still closely linked to TUD. Professors at TUD act as advisors to the institute, and TPD shares a building with the TUD Applied Physics faculty.

The TPD performs R&D for government and industry both within the Netherlands and abroad. In addition to the activities in ship acoustics which I will discuss more fully below, other technical disciplines such as aero-, hydro- and thermodynamics and optics are included in the organization's R&D efforts. The TPD is organized into five departments, all of approximately equal size--Acoustics, Heat, Instrumentation, Materials, and Optics.

The staff numbers close to 400, of which 70 are graduate engineers and an equal number are chartered engineers. The annual revenues are about 42 million Dutch Guilders (approximately \$21 million) with 90 percent coming from specific projects (contract research) and the other 10 percent from government subsidy. The contract research is conducted for both Dutch and foreign industries, government organizations; e.g., Ministry of Defense and international agencies; e.g., the European Community, the European Space Agency, and the Interna-

tional Energy Agency. Typically, 15-20 percent of revenues come from non-Dutch sources.

### Ship Acoustics Department

This department has been conducting research and consultancy on ship noise control since the early 1950s. Since 1950, the Netherlands has been active in exploiting the oil reserves found in the North Sea; as a result, TPD has also been involved in noise control of offshore platforms. The host for my visit was H. Steenhoek who now heads the Ship Acoustics Department.

**Fluid-Structure Interaction.** During the visit, I was briefed by C. Kauffmann on some theoretical work he has done on the dynamic and acoustical response of a fluid loaded, baffled strip responding to a time-harmonic line force. This is a useful model for the radiation of sound by ship plating. In this work, he presents an integro-differential equation to describe the response, and then uses the method of boundary integral equations. Filippi first proposed such an approach to problems of this type (Filippi, 1985). This problem is fundamental to the field of structural acoustics and can be used to understand the basic mechanisms involved in acoustical radiation from ship hulls. Such problems have now been studied for close to three decades by a variety of techniques. But this work is still useful since it approaches the problem by a less widely used technique, and offers a physical interpretation of the results not offered by Filippi. Kauffmann has also found some differences between his and Filippi's results at the higher frequencies for the case of a finite strip in a rigid baffle. In order to check his program, he also has performed calculations for the line force response of a fluid-loaded infinite plate and compares these to earlier results (Feit, 1985). The agreement is good, except for small values of the nondimensional distance along the plate at a specific frequency, where the dis-

agreement is about 25 percent. No explanation of the various discrepancies has been offered.

This work is being pursued as part of Kauffmann's thesis for the Faculty of Mathematics and Informatics of the TUD, and is being supervised by Dr. Ir. J.C. Brugge-man, Ship Acoustics Department.

**Near-Field Target Strength Measurements.** I was also briefed on a near-field target strength measurement system by C.J.M. van Ruiten, Echo Acoustics Group. This particular system makes use of data acquisition and signal processing approaches adapted from seismic exploration techniques.

Conventional target strength measurements are usually performed using far-field techniques; i.e., both the projectors and receivers are located at sufficiently large distances from the scattering object such that the ensonifying and scattered waves can be considered to be plane waves. This necessitates increasing range with increasing frequency which introduces the need for propagation corrections, especially in shallow water environments where such measurements would be made.

The TNO-TPD have developed a system that measures the target strength characteristics in the near-field of elastic scatterers. The detection is made along parallel lines by a detector array. A complete data set would consist of a set of time series of the scattered signals at each point of the array with the source at every position of the array. Thus, if there are  $N$  positions along the line array, the data set for each line of the array would consist of  $N^2$  records. To complete the process, the measurements are also made along parallel lines resulting in a set of measurements over a two dimensional (2-D) plane of receivers. The data is processed into a 2-D Fourier wave number-frequency representation from which one can ultimately determine the angle dependent reflectivity of the scatterer at any plane for all combinations of incident and reflected plane wave components within the aperture.

I was shown the actual system that consists of a computer-controlled 2- by 3-meter planar positioning system that defines the measurement aperture, a LeCroy transient recorder to collect the data, and a personal computer to monitor the data collection process. The data is stored on magnetic tape and processed on a CONVEX minisupercomputer. Developed under contract to the Dutch Navy, this system provides the Dutch with a unique

capability to measure the target strength characteristics of reasonably sized models without the distorting influences of propagation effects inherent in far-field target strength measurements.

**The TCL and the Acoustic Work Station.** Over the past few years, TPD has been developing a computer software system called Technical Command Language (TCL) that can be used to control work stations that have their own data acquisition capabilities. In particular, I was briefed on its control of an acoustic work station (AWS). The aim is to have a real-time, multi-channel analyzer of acoustical signals with sampling rates up to 100 kHz per channel. The analyzer consists of an array processor, data acquisition devices, and a test signal generator. Using TCL-SIGNAL, which runs on any host computer, the operator controls the analyzer or carries out other tasks. At any time, there can be two asynchronous processes running--one on the host computer, the other in the array processor, which runs as a slave to the data acquisition unit. At any time, the host computer can request intermediate results from the array processor. The TPD-TNO has concluded that the system operates better than other dedicated systems, and makes use of TCL in many current projects with widely varying applications.

## Summary

The TPD-TNO has long been in the forefront of research in the area of shipboard and offshore platform noise control. In addition to their already well-known unique facility for making reciprocity measurements for shipboard-mounted machinery, they have now developed a new near-field target strength measurement facility that can provide useful information to naval acousticians. The same organization has organized and hosted two international symposia on shipboard acoustics--in 1976 and 1986. From discussions with Mr. Steenhock, I have learned that the next in the series will be held in 1991.

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- Feit, D. and Y.N. Liu, "The Near-field Response of a Line-Driven Fluid Loaded Plate", *Journal of Acoustical Society of America*, 78, No. 2, (1985) 763-766.
- Filippi, P., "Sound Radiation by Baffled Plates and Related Boundary Integral Equations", *Journal of Sound and Vibration*, 100 (1), (1985) 69-81.

# International Conference on Acoustics, Speech, and Signal Processing of the Institute of Electrical and Electronics Engineers

*by Chrysostomos L. Nikias, Communications and Digital Signal Processing (CDSP), Center for Research and Graduate Studies, Northeastern University, Boston, Massachusetts.*

## Introduction

The International Conference on Acoustics, Speech, and Signal Processing (ICASSP)'89 took place in Glasgow, Scotland, May 23-26, 1989. There were 1,630 participants, with the following breakdown: U.S.-690, U.K.-337, European Economic Community (EEC)-362, Non-EEC (Europe)-115, Middle East-16, and Far East-110. The technical program included 730 papers, which were presented in seven parallel sessions. The Proceedings consists of four volumes arranged in subject headings, comprising 3,000 pages, and 2,600 copies were printed. Six hundred copies of the Proceedings were delivered to the Institute of Electrical and Electronics Engineers (IEEE) Headquarters and can be purchased directly from IEEE Conference Services.

This year's exhibition was one of the largest to be held at ICASSP. The exhibition reflected the growing popularity of signal processing as a curtain raiser for new products and systems, and indicated an increasing commercial awareness of the subject area. Participating companies ranged from the largest multinationals with large multiple booths to small software houses and book publishers. In addition, several fringe meetings took place during the conference. These included a discussion meeting organized by Dr. P. Ramamoorthy, National Science Foundation, a meeting on the European COST project, a presentation on EEC's European Strategic Programme for Research and Development in Information Technologies (ESPRIT) project, and an open forum by the Royal National Institute for the Deaf.

## Overview of Technical Program

The talks presented were organized and grouped as follows:

- Audio
- Digital Signal Processing (DSP)
- Spectral Estimation
- Multidimensional Signal Processing
- Speech Processing
- Underwater Signal Processing
- Very Large Scale Integrated (VLSI) Signal Processing

Posters were presented in 17 sessions. Overview tutorial presentations were popular and well-attended, and

included recent advances in spectral estimation, parallel processing, speech recognition, and image processing. Developing subject areas and maturing themes that had received prominence in the program cover high-order spectral analysis (polyspectra), neural networks, and CELP speech coding.

In the following, I discuss papers that attracted my attention. However, this selection is based on my personal interests and background.

## Digital Signal Processing

The DSP area featured sessions in digital filter theory and design, quantization effects, adaptive filtering, discrete transforms, hardware and software, signal reconstruction, and DSP applications, especially to communication systems.

M. Quirk, Institute of Defense Analyses, presented an efficient algorithm for evaluating the frequency response of the aliased noise in far infrared down-sampling filters. N. Bhalwani, Texas A&M, introduced an implementation of trellis coded quantization of sources without memory on dedicated DSP hardware. He also described the effect of the depth of the trellis search, implementation complexity, and mean-square error encoding performance. F. Taylor, University of Florida, presented the roundoff noise in fixed-point implementation of a Discrete Wigner Distribution (DWD) algorithm. He reported that doubling the length of the DWD increases the noise-to-signal ratio by  $\sim 6\text{dB}$ . P. Moore, Naval Postgraduate School, Monterey, California, reported an algorithm that designs the optimum quantizers for signals at two remote sensors that are to be fused at a central site in order to make a detection decision. Results were presented showing the uniform convergence of the algorithm's performance to that of the likelihood ratio test with increasing  $N$ , the number of levels of quantization.

The area of adaptive filtering and signal processing dominated the DSP sessions. The blind equalization problem or blind deconvolution received a lot of attention. N. Bershad, University of California, Irvine, and O. Macchi, National Center for Scientific Research (CNRS), France, presented a remarkable result. The least mean square (LMS) algorithm usually tracks better than the recursive least squares (RLS) algorithms in a



nonstationary colored input environment, such as chirped sinusoid buried in additive white noise. J. Treichler, S. Woods, and M. Larimore, Applied Signal Technology, Inc., Sunnyvale, California, summarized the convergence rate limitations in a number of frequency-domain adaptive filters. O. Macchi studied the properties of recursive LMS and extended LS as adaptive infinite impulse response predictors. She reported that while both algorithms are stable for stationary inputs, the LMS algorithm becomes unstable for nonstationary input caused by power jumps in the signal. Finally, Y. Hu, University of Wisconsin, presented a family of parallel algorithms for computing the eigenvalues and eigenvectors of Toeplitz matrices. Specifically, a parallel multi-sectioning method has been developed on a linear array of locally connected processors.

The session on "New Directions in Adaptive Filtering" featured several new approaches to adaptive signal processing. Nehorai, Yale University, and Kaveh, University of Minnesota, presented adaptive algorithms for tracking roots of spectral polynomials. Bragad and Jourdain, CEPHAG, Dowaine Universit e, Cedex, France, presented results on fast RLS and LMS algorithms as adaptive equalization schemes for underwater data transmission by varying typical multipath parameters; e.g., delays, phases, and signal-to-noise ratio. Nikias, Northeastern University of Boston, presented a new blind equalization scheme based on tricepstrum and LMS algorithm. The key result of this paper is that the adaptive tricepstrum algorithm "opens the eye" of the equalizer faster than the Benveniste-Goursat and stop-and-go algorithms. Additional papers in the area of adaptive equalization included "Carrier Recovery for Blind Equalization" by Jablon, AT&T Bell Laboratories, Middletown, New Jersey, and "Blind Adaptive Equalization of Digital Communication Channels using Higher-Order Moments" by Porat and Friedlander, Signal Processing Technology, Inc., Palo Alto, California.

## Spectral Estimation

The spectral estimation and modeling area featured sessions on system identification and signal estimation, spectral estimation, autoregressive-autoregressive moving average (AR-ARMA) estimation, time varying spectral analysis, eigenstructure analysis, higher-order spectra, as well as deconvolution and radar. L. Marple, ORINCON, Inc., gave a highly attended 40-minute tutorial overview of modern spectral estimation methods. A. Tewfik, University of Minnesota, reported a new harmonic retrieval method in the presence of colored noise. L. Ljung, Link ping University, Sweden, reported his findings on the performance of three recursive identification algorithms with respect to their tracking capability and disturbance sensitivity. S. Lang, Sanders Associates, Nashua, New Hampshire, presented an interesting paper

on frequency estimation from phase differences, which finds important application in Doppler radar and remote sensing. M. Lagunsa, ETSI, University of Barcelona, Spain, presented another interesting result.

Higher-Order Spectra, a new and emerging technology in signal processing, dominated the interest of delegates in the spectral estimation sessions. A lot of papers were presented addressing new theories and methods on the use of higher-order spectra in signal processing. E. Power, University of Texas, Austin, presented a digital polyspectral analysis method to estimate transfer functions of cubically nonlinear systems. H. Messer, Israel, reported a new time-delay estimation method of a random multitone signal based on the bispectrum. B. Porat, Israel, presented algorithms for optimal estimation of the parameters of moving average (MA) and ARMA non-Gaussian processes. J. Mendel, University of Southern California, introduced a method for the computation of cumulants of ARMA processes using observable state-space realization and Kronecker products. M. Raghuveer, Rochester Institute of Technology (RIT), reported new, necessary, and sufficient conditions for polyspectral factorization of finite extend cumulant sequences. A. Swindlehurst, Stanford University, presented a new approach to the detection of phase coupling among sinusoids based on rank determination of third-order moment matrices. I presented analytical performance evaluation of the complex cepstrum and bicepstrum. In particular, bias and variance expressions of cepstral parameters were reported and the theoretical justification why the bicepstrum is less sensitive to Gaussian noise than complex cepstrum was established. A. Cetin, University of Toronto, presented an interesting algorithm for signal reconstruction from the bispectrum, and M. Tekalp, University of Rochester, reported necessary and sufficient conditions for polyspectra factorization based on polycepstra.

## Underwater Signal Processing

The majority of the presentations was in the areas of array processing (bearing estimation) and time-delay estimation. In particular, there were two sessions on array processing and one on time-delay estimation, sonar/radar detection and estimation and underwater acoustic signal processing.

Swingler, Walker, and Krolik, Nova Scotia Defense Research Establishment, Halifax, demonstrated that the double-steered, coherently focused broadband beamformer implementation is a practically viable technique for source location estimation. An important contribution, presented by Stoica and Nehorai, Yale University, established that in the class of weighted multiple signal classification (MUSIC) estimators, the unweighted MUSIC achieves the best performance; e.g., the minimum variance of estimation errors, in large samples. Cadzow,

Vanderbilt University, reported several methods based on the signal enhancement algorithm for solving the bearing estimation problem of multiple incoherent plane waves; better resolution results were illustrated by simulation experiments in comparison with Wang-Kaveh's CSS-MUSIC method.

Pasupathy, University of Toronto, presented an exact solution to the problem of maximum likelihood time-delay estimation over arbitrary observation time. Segal and Weinstein, Tel-Aviv University, talked about a computationally efficient scheme for estimating the location and spectral parameters of multiple source signals using passive array data. Fuchs, Institute of Research for Information, Systems and Aleatoire (Random) (IRISA), France, discussed a method for estimating the number of transmitted signals in the presence of spatially correlated sensor noise when the unknown covariance matrix is a band matrix. Picinbono, CNRS, France, reported some new and interesting results on time quantization and distributed sensors detection. Adaptive classification algorithms for underwater transient signals based on ARMA modeling were presented by Hermand, Supreme Allied Commander Atlantic (SACLANT), Italy.

Rao, University of California, San Diego, reported statistical performance analysis of the minimum-norm

method and comparisons with Root-MUSIC. A sensitivity analysis of the MUSIC algorithm to differences between the true and assumed array manifolds was presented by Friedlander, Signal Processing Technology, Inc., Palo Alto, California. Kaveh, University of Minnesota, introduced a new time-domain coherent signal-subspace wideband array processing method that requires less storage and computations than its equivalent frequency-domain approach. Finally, an important contribution was presented by Foster and Vezzosi, Thomson Sintra, France. They proposed a new method for estimating a covariance matrix from vector samples of a circular Gaussian process that it belongs both to the vector space of Hermitian Toeplitz matrices and to the set of Hermitian matrices of which the minimum eigenvalue has a given multiplicity.

### University of Strathclyde

The signal processing group of the University of Strathclyde was well-represented at ICASSP'89 with paper presentations and exhibits. Their work emphasizes the efficient implementation (VLSI, parallel processing, transputers) of existing signal processing algorithms for image processing, array processing, spectral analysis, and speech.

## COMPUTER SCIENCE

### Research and Development at Siemens in Information Technology, Telecommunications, and Microelectronics

*by J.F. Blackburn, London representative of the Commerce Department for Industrial Assessment in Computer Science and Telecommunications.*

#### Introduction

The corporate activities of Siemens include all major fields of electrical engineering and electronics, telecommunications, information technology, production automation, and materials. The company spends more than 10 percent of its world-wide sales revenue on research and development (R&D). In fiscal year 1988, this amounted to DM 6.5 billion. About 40,000 employees are engaged around the world in R&D, 20 percent of them outside Germany. Ninety percent of the R&D employees are working on the development of products, systems and manufacturing technologies, and the rest is engaged in research and basic development activities.

The largest Siemens R&D centers are in West Berlin, Erlangen, Karlsruhe, and Munich (the company head-

quarters). But other important R&D facilities are located in Princeton, New Jersey; Vienna; Stockholm; and Zurich.

#### Information Technology

The work at Siemens in information technology covers optical communications, knowledge processing, and computer-aided design (CAD).

**Optical Communications.** Optical fibers allow large quantities of data to be transmitted at high speed. This technique, which is safe against tapping and insensitive to electromagnetic interference, is of great importance for interfacing computers. The technique will provide the basis for the broad-band communications of the 1990s and for a new glass fiber transatlantic cable.

The basic physical principle--the reflection of light at the boundary layer between two media with different indices of refraction--has long been known. Putting the principle to technical use was difficult, and there are still a lot of problems.

For transmitting the information, the electrical signals are modulated onto the light from a laser diode at the transmitter end. Sophisticated couplers feed these optical signals into the transmission fiber with minimum loss. At the receiving end, photodiodes convert the optical signals back to electrical pulses from which the original information is recovered by downstream electronics.

The technology of the monolithic integration of optical and electrical components may become the basis for the cost-effective manufacture of compact components, and thus may lay the groundwork for a wide range of applications.

In today's optical fiber systems, the laser light from the transmitting diode is modulated by the electrical current of the useful signal. However, this method of modulation is unsuitable for data rates above a few gigabytes per second. Therefore, Siemens is working intensively on more efficient modulation methods.

In electrical optical crystals such as lithium niobate ( $\text{LiNbO}_3$ ), the index of refraction (and thus the speed of propagation of light) can be changed by an electrical field. This effect can be used for external intensity modulation or phase modulation.

In phase modulation, the speed of propagation in the optical fiber of a  $\text{LiNbO}_3$  crystal is modified by control electrodes so that the phase position of the light waves at the optical output correspond to the control voltage. Using this principle, Siemens has so far constructed laboratory samples for the important wavelength range from 1300 to 1500 nm with bandwidths of 3 to 5 GHz and insertion losses of 2 to 5 dB.

Contradictory requirements must be satisfied when coupling the transmission diode to the glass fiber. One aim is to inject as much light as possible into the transmission route, which has been successfully achieved while complying with mechanical tolerances in the range of 0.1 microns. However, if too much light is injected, the performance of the transmission diode suffers because of the light reflected by the fiber.

To insure the cost-effective and reliable manufacture of transmission modules, Siemens is examining different methods of coupling the diode to the fiber under realistic conditions in the laboratory. One example is a data link transmit-and-receive module for computer interfacing, which uses a spherical lens of 2-mm diameter. During assembly, the tiny ball is initially provided with a metallic vapor deposited "body belt" and is then soldered into position in a hydrogen atmosphere without flux to provide a hermetic seal. A computer-controlled positioning mechanism guarantees accurate alignment.

Monolithic integration of individual optical components; e.g., photo and laser diodes, distributors and modulators, with the electronic transmitting and receiving circuits, aims to produce compact, low-cost, and reliable modules.

Although the degree of integration of such opto-electronic, integrated circuits will be orders of magnitude below that of state-of-the-art microelectronics, the problems involved are no less daunting. To provide filters for separating different wavelengths; e.g., epitaxial layers of different composition and of thickness in the submicron range, must be assembled to form heterostructures without lattice defects at the interfaces. Modern methods of epitaxy are indispensable for this purpose. They include molecular beam epitaxy (MBE), which permits crystal growth to be inspected for accurate atomic positioning, and metal organic vapor epitaxy (MOVPE), which guarantees the throughput necessary for production while ensuring very high quality.

**From Data Systems to Knowledge Processing.** For less than DM 1,000, a home computer can be taught to "hear," but with a very limited vocabulary. Professional systems are already capable of recognizing a few thousand words. They are successfully used for "hands free" applications; e.g., stock-keeping or quality control, and in medical engineering.

All currently available systems share one feature, irrespective of price. They understand only individually spoken words. In addition to a more or less pronounced dependence on the speaker, this handicap is still a considerable obstacle to user-friendly communication in natural language. There is no shortage of potential applications; e.g., interrogation of databases, accessing information timetables, or convenient use of expert systems.

Recognizing fluently spoken texts, with contracted words, slurred endings, and grammatical errors, requires further research. In the SPICOS project, which is being conducted jointly between Siemens and Philips, scientists from many disciplines are working on converting the knowledge hitherto acquired into devices for commercially viable speech processing systems.

In conventional program systems, the knowledge for solving a problem is inseparably interwoven with the program structure. New approaches to separate the storage and programming aspects have led to knowledge-based systems (expert systems). In addition to individual facts, the knowledge base of such systems also contains definitions and statements on causal relationships. New facts or more assumptions can then be derived from these during processing; i.e., during the solution of an actual problem. Advanced systems also have an explanation component that shows the user how they arrived at the results.

Such a software architecture leads to new models of information processing and to new styles of program-

ming. However, it also calls for new programming environments that allow efficient knowledge-based systems to be constructed. Relevant applications can be found particularly for supporting activities in the fields of design, configuration, consulting, and diagnosis.

The broad application of knowledge-based systems awaits much more development in the methods and techniques for displaying and manipulating knowledge. This area delineates the central objectives of our software tools, which we use predominantly to develop technical expert systems. Our research is centered on complex problems that necessitate inference from temporal sequences or geometrical or qualitative relationships, or that involve working with revisable assumptions.

Learning is an important characteristic of intelligent behavior. Software systems with this ability can attain completely new dimensions in terms of performance and quality. Siemens is currently investigating various approaches for developing adaptive systems; i.e., systems that are capable of learning. These systems range from the description of learning processes in formal languages to the modeling of cognitive processes on neural networks.

Neural networks present a particularly attractive model for the simulation of learning processes because they allow parallel information processing, and thus a considerable increase in efficiency compared with other solutions. At present, such systems appear best suited as an interface between the conventional symbolic processing of data and knowledge and the natural environment. This is partially because they permit a high degree of error tolerance. Other knowledge-based approaches offer the benefits of high processing speeds and a relatively easy connection to existing systems.

The problem area determines the application of a learning approach. However, all approaches have several features in common; e.g., elementary modeling processes, deriving generalizations from examples, forming specific functions, or determining analogies.

**Computer-Aided Design Systems for Electronics.** The CAD tools are now indispensable for designing good quality, complex electronic systems with reasonable expenditure of time and money. Future design systems must satisfy the following requirements:

- Handling large and complex design objects
- Reducing development costs and development time
- Simplifying the design process
- Safeguarding the design quality.

With its new interactive techniques, the HERMES design environment helps the user implement his design. Expert systems guarantee high quality and release the development engineer from routine tasks. Production feasibility and function correctness are already assured at the design stage. The algorithmic description of the electronic system to be realized allows many design steps to

be performed automatically; e.g., logic synthesis. Distributed data management systems ensure design data consistency and permit the management of different versions and variants of a design object.

The subassemblies of electronic systems have also become so complex and extensive that their optimal design is virtually unthinkable without computer support. Otherwise, such a project would be very expensive, time-consuming, and risky.

The CAD system known as HERA supports the development of subassemblies with analogue and digital devices in standard technologies. In addition to simulating models of devices, digital simulation of a subassembly also takes account of real devices such as microprocessors.

Different types of devices pose no problem for HERA. The size of printed circuit board is also freely selectable. Multilayer metalization with partial or total through-plating is also possible. Components can be placed on both sides of surface-mounted devices. The system can also take into account "discrete" wires laid during the modification of a subassembly.

The HERA is incorporated into an environment of other systems: CAD subsystems on which specific design steps are performed, production and test systems, and systems for the planning and controlling production. Because of a flexible interface concept, these systems can be used to exchange product- and application-specific data with different formats. Consequently, the interface is described in a formal language and this description is then converted into system-specific data by coupling modules operating similarly to interpreters and compilers.

## Telecommunications and Information

In telecommunications and information, Siemens concentrates on office communications; the three-level structure of data processing, hardware, and software; the ergonomics of communications; broadband Integrated Services Digital Networks (ISDN); radio networks for car phones; and microelectronics.

**Information and Communications in the Office.** As the information source and exchange and as a convergence point for communication lines, the office is becoming an increasingly powerful focus for business activities.

In the Federal Republic of Germany (FRG) in 1988, the value of white collar activities exceeded that of all goods produced. However, office personnel costs are increasing out of proportion to office staff numbers. Convenient sophisticated communications and data processing machines and systems can now perform routine tasks more quickly, easily, and efficiently than ever. Yet, office productivity increased only by a modest five percent from 1960 to 1980, while a concurrent increase of 90 percent

was recorded in the production of goods. But this should be seen against the average of DM 50,000 per employee invested in manufacturing compared with only DM 5,000 in the office sector. Unnecessary repetition of activities is still endemic in many offices today. Media clashes slow down the flow of information and an inefficient division of labor weighs down the overall dynamics of office procedures.

Many processes can be vastly improved by the use of integrated multifunctional office systems. Designers of hardware and software systems face the dual challenge of streamlining routine tasks and providing effective backup for creative activity.

An open office architecture represents the critical takeoff point for realizing the available potential for enhancing efficiency and quality. In addition to the consistent application of international standards, it implies full compatibility between machines and systems from different manufacturers. The vital advantages for users are uniform interfaces and operating procedures, multiple- and mixed-mode communications via a single connection, and more performance at less cost.

International standardization bodies are striving to formulate and implement the Open Systems Interconnection Standards (OSI) based on the seven layer International Standards Organization (ISO) reference model for open communications. Since all public networks and most telematic services already conform to OSI standards, the main thrust is now toward cooperation between systems from different manufacturers and the implementation of OSI standardized service. The evolution from the closed and isolated vendor environments towards open communication systems with standardized interfaces is advantageous to both users and manufacturers. A world-wide market alone offers the latter the scope to recoup the high development costs of modern communications systems.

The OSI communication standards are being joined by other international standards designed to allow interworking between office systems such as the UNIX operating system, known at Siemens as SINEX, and between graphics languages and user interfaces such as GKS and Windows. The OSI standardization successes include the X.400 Electronic Mail Standard and the activities for standardizing the description of documents.

An important feature of modern digital communications networks is their availability at low cost even for small businesses and private homes. Efficient data communications and access to international databases are no longer a privilege for large corporations that can afford to use such services via closed manufacturers networks. In the future, we will communicate with people all over the world from our own desk or living room, and not only through the spoken word but also with written texts, images, and data.

Today's office landscape is made up of many different machines and systems, each designed specifically for a single service. Examples are telephones, telefax machines, word processors, and data terminals in in-house and public networks. This scenario will continue for communications services carrying heavy traffic and for applications involving customized user interfaces such as bank terminals and CAD work stations. But the development of ISDN will transform everyday office applications by bringing multifunctional workstation systems for voice, text, images, and data. The advantage for users, aside from lower cost and reduced space requirements, is a uniform user interface for all of these services. State-of-the-art technology and existing standards fulfill most of the preconditions for its implementation.

Siemens' contribution to the future scenario is the MY 3510 Multiterminal for the Hicom ISDN communications system. The multiterminal allows documents and data to be exchanged in the form of display copy during a telephone conversation and data to be retrieved from a central database. A central system server provides the software for word processing functions (including a filing service) and for terminal emulation and electronic mail.

**Data Processing on Three Levels.** Electronic data processing has long since ceased to be the exclusive preserve of the computer center. Decentralized computer power is now finding its way into all walks of corporate life, although it cannot take the place of central computing facilities. Major computer installations are best designed to cater for three levels of information processing:

1. The top level in the hierarchy is served by high-performance host systems in the computer center. These are used on either a company- or a function-oriented basis. Siemens general purpose computer system's operating system--BS2000--covers the entire range of machines from the personal computer to the high-end mainframe.
2. Working in conjunction with the hosts, "departmental computers" operating as stand-alone systems can be used to hold and process local data within individual company departments or branches.
3. Data processing at the workstation is the province of professional personal computers running under different operating systems or of powerful terminals of a variety of types, which are linked in turn to departmental computers and hosts.

The three-level structure gives the departments and branches within a company access to autonomous data processing facilities, without depriving them of the benefits of central services. All computers can be networked under the TRANSDATA concept to form a high-powered integrated system.

**Hardware as an Innovative Force.** Over the last two decades, the price/performance ratio in the hardware

sector has improved tremendously. This has been because of the enormous progress made in miniaturization and performance enhancement in microelectronics. The current state-of-the-art indicates that this pace of development will continue for some time. Internal switching times of the order of picoseconds and memory chips with a capacity of more than four million bits are within the bounds of current technological feasibility. This kind of dynamic development will certainly be reflected in computer architecture. The conventional computer with just one main memory and one general processor is gradually evolving into the parallel processor system.

Through sophisticated interworking with their peripherals, uniprocessor systems can already support several nested programs on a quasi-simultaneous basis. But genuine simultaneous operation is only possible with more than one processor. Parallel processor systems can execute several steps in a program at once, opening up completely new horizons in information processing. New program structures are now needed to allow us to expand toward these horizons. Full use of a computer's internal processing speed presupposes input and output devices of sufficient power. Among input devices enjoying increasing popularity are multifont reading systems for text input and scanners for graphics input.

In the realm of output devices, a distinct trend is currently underway toward nonimpact printers. Among these are Siemens laser printers, with performance ranging from eight to two hundred pages per minute.

**Software in Transition.** Today's computer programs are generally structured to conform with the architecture of uniprocessor systems, which execute instruction sequences in series. To run on a parallel system, a program must consist of instruction sequences that can be executed simultaneously. The flow of instructions and data must be adjusted to permit parallel operations wherever possible. New programming methods and software tools are needed to structure programs in this way. Parallel compilers are available to convert sequentially structured programs into machine code capable of parallel execution.

Whatever the technological progress made in person to person communication, the written word will lose none of its significance. As products and systems become more extensive and complex, the importance and volume of the documentation increases. On today's international market, much of that documentation must be available in several languages; this is an enormous translation task.

The machine translation system--Machine Evaluation and Translation of Natural Language (METAL)--was developed in cooperation with the University of Texas Linguistics Research Center. The METAL is a knowledge-based system capable of processing about one word per second, or about 200 pages per eight-hour day. The

translation needs postediting, but the translator's work is made easier and faster.

The METAL is conceived as a modular system independent of any one language. The system's core is a software system that controls text analysis based on grammatical rules and lexicons. Both of the latter are unavoidably bound to individual languages, but the underlying analytical process is not. Thus, for any new pair of languages, it is only the grammars and lexicons that need to be developed; the core software can remain unchanged. Systems for English and German as source languages have so far been evolved in Austin and Munich. Research teams are at work in Belgium on components for Dutch and French, and in Barcelona on a Spanish component. The German/English version of METAL has already been used to translate several thousand pages of technical documentation, and prototypes for the other language pairs will be available soon.

The results of experience gained from the METAL development program are significant not only to practical machine translation contexts. The analyzing and generating natural language forms the basis for many other applications. The applications range from natural language interfaces for accessing databases and expert systems to future components in communication systems and facilities for marshalling information content and compiling abstracts automatically. Possibly, a doctor can use his own language to interrogate an expert system on the diagnosis of tropical diseases, or texts can be compared editorially and content differences can automatically be identified.

Software is the major factor determining the power and the user-friendliness of personal computers and mainframes, of switching systems, of individual machine tools and whole production lines.

Software lends itself to pioneering work in R&D, design, testing, and production. For instance, determining the performance limits of aircraft need no longer involve the hazards of test flights. A simulation program does the same job better, cheaper, and faster. Expert systems, ISDN, computer-aided instruction (CAI) concepts, and electronic typesetting systems are some of the innovations that would have been impossible without software.

Software also provides the basis for new product development methods. In what is known as evolution strategy, computers apply statistical deviations to parameters to generate variants of a product. If one of these variants is better suited to the intended practical environment, it is taken as the progenitor for a new generation of variants. This evolutionary technique, copied from nature, is used in work at Siemens on the development of reflectors; e.g., street lights.

Software is a huge market whose volume can be illustrated by a comparison. If all the public telephone networks throughout the world were to be replaced now, the

cost would be around DM 2000 billion. Today's entire base of software is worth several hundred billions of DM. Given its annual growth rate of around 25 percent, it will overtake the value of the world telephone network, which is growing at the rate of about four percent per year, in less than 10 years.

**Communication Ergonomics.** The ergonomics design of workstation hardware has reached a very high standard, particularly in Western Europe. Within the limits of practical technology, almost every conceivable requirement has been met.

In software, the design of interfaces has also made substantial progress, not least through the use of windowing, menus, and the electronic mouse. Computer handling techniques are approximating more and more to man's accustomed ways of working.

This results from systematic interplay between man and machine; i.e., communication ergonomics. Specific studies in this field have produced important findings relating to the amount and arrangement of data onto the screen, interactive interfacing techniques, and different forms of user guidance for novices and experts. The research methods used include both field tests and laboratory studies. For instance, an eye movement monitor is a rich source of information on user stress at a workstation. This information can be combined with statistical analyses of the user's productive work to determine the effects of differing levels of stress on the quality of work.

**Office Systems in Integrated Communications Networks.** As a result of international standards for voice switching and transmitting, seven hundred million people throughout the world can talk to each other by telephone irrespective of who manufactured the networks and handsets. Information technology will follow this example because open communications are indispensable to the increasing communications needs of industry, science, and administration. Voice, text, images, and data must be transmitted by fully standardized telecommunications services.

International open standards for communications networks and office systems provide a new basis for creating, processing, and exchanging information in public and private communications and information systems. Siemens is actively involved in defining and implementing the necessary standards for network and terminal functions and communications protocols. Office systems that release the power of modern communicating and information processing in the workplace, while being adaptable to evolving open standards and services, are already a reality. The architecture of Siemens systems offers workstations, digital communications systems for various types of network, an array of processing systems, and access to public networks including ISDN. This ensures that all of these systems can be incorporated in an optimized communications network.

**Broad-Band ISDN.** Users today are asking for functions such as mailbox for voice, text, and image transmission, as well as new broad-band services including:

- Transmitting moving images for video telephones and video conferences with television quality
- Transmitting images with higher resolution for professional applications and greatly superior picture quality for television, comparable to the cinematographic effect (high-definition television [HDTV])
- Exchanging documents and data rapidly, as for coupling local area networks (LANS)
- Retrieving information stored as data, graphics, images, films, and documents
- Accessing information processing for scheduling, booking, ordering, cash transfer, computation, and design services.

The need for such broad-band services already exists to some extent, and will increase as networks, storage systems, processors, and terminals are further developed and as costs decrease. A suitable infrastructure is required to meet the current and future needs of information and communications services:

- A comprehensive, need-oriented, and low-cost spectrum of services should be available to a broad group of users including private subscribers, businesses, government agencies, and administrative bodies
- Professional users should be offered the basic facilities to allow individual solutions to special problems.

Until now, telecommunications has been principally concerned with preparing and transmitting information, whereas processing and storing was the province of computers. The convergence of telecommunications and computers provides an effective basis for satisfying growing user demands. Future telecommunications systems will not only transmit messages but will also process and store them, retrieve information, and access data processing systems. They will include all types of information: stationary and moving images as well as text, voice, and data.

The immediate goal of telecommunications efforts is a configuration based on ISDN and its expansion to broad-band ISDN in line with international standards. Siemens' transmission and switching systems offer an environment for these developments. The architecture of the EWSD (German/English translation: digital switching system) switching system allows the implementation of new services and features and the use of new processors and hardware components. For example, the new high-power CP113 coordination processor multiplies EWSD switching capacity by many factors. The system is a multiprocessor whose basic version can handle 250,000 busy-hour call attempts; its capacity can be increased flexibly to 1.2



million busy-hour call attempts if required. Individual components can be replaced by future devices without affecting the system as a whole.

The EWSD ISDN switching systems are already in service in the networks of the Deutsch Bundespost and Swiss PTT, as well as in Finland, and the U.S. The PTTs in Denmark and Colombia also plan to use EWSD to provide their subscribers with ISDN services and features.

A feature of ISDN that is vital for the user is its uniform "communications socket." Users can dial a single number to communicate with others using standardized service for voice, text, data, still and motion images, retrieve information, and use processing features within and via the network. Terminal and services handling is made easier by simple and largely uniform procedures for setting up and clearing down connections.

All ISDN information is uniformly transmitted and switched as "bit streams" or "bit packets." Transmission rates up to 140 Mbps are required for video telephones. Optical fiber cable can handle the 600 Mbps flowing in both directions when a single line is used for multiple services.

Further technical and economical improvements lie ahead for broad-band ISDN. Along with optical amplification and processing, optical heterodyne reception promises to increase the transmission capacity and range of optical fiber cables.

The establishing of ISDN and its expansion to broad-band ISDN is a medium- to long-term goal in many countries. In the FRG, an obvious solution is to expand the most widespread network, the telephone network with its 27 million main stations, to the kind of universal network needed for all services (see Table 1).

**Table 1. Broad-Band ISDN Expansion Phases**

1. Digitizing the telephone network without initially digitizing subscriber lines
2. Introducing ISDN with all its integrated narrow-band dialog and retrieval services, and digitizing subscriber lines
3. Expanding ISDN to broad-band ISDN with broad-band dialog services using optical fiber cable as subscriber lines
4. Transmitting audio and television programming through broad-band ISDN.

#### **Procedures and Components in Broad-Band ISDN.**

A new and cost-effective generation of digital terminals for narrow- and broad-band services is emerging. Functions that have hitherto been purely local can now be included in integrated networks. This applies to business with increasingly intelligent communications devices, personal computers, and workstations. This also applies to private television and home computer users with a wide

variety of add-on components. Greatly enhanced picture quality will have a considerable effect.

Networks and services must be modified and terminals must be adapted to ensure that present equipment can continue to be used, and that all ISDN and broad-band ISDN subscribers are still accessible via the conventional networks during a lengthy transition period. Optical transmission must be simple and cost effective if it will be used on subscriber lines (see Table 2).

**Table 2. Optical Transmission Techniques**

1. Only a single optical fiber is used for both directions. Wavelength multiplexing ensures that the transmitters operate on different wavelengths and the signals are separated by wavelength-selective fibers. These allow light of one wavelength to pass almost unimpeded, while the other wavelength is almost totally reflected.
2. The transmitter, receiver, and wavelength multiplex chip are integrated in a single optical module. The first modules of this type have already been analyzed and successfully tested in the laboratory.

Broad-band ISDN must cover a multitude of different applications ranging from slow data transmission at 1000 bps to full motion video communications at 10 to 100 Mbps. Convenient transmission and switching principles are neither fast nor flexible enough for such tasks. In the coming broad-band network, the time division multiplexing, and packet switching techniques already in use for narrow-band ISDN will fuse to form a new powerful principle--the asynchronous transfer mode (ATM). At present, a laboratory model of an ATM-based switching system is being used to gain experience for developing future telecommunications systems and for promoting international standardization.

Integrated circuits for broad-band switching must process several billion bits per second. This requires technology of high dynamic range and a high degree of integration. A switching network chip in emitter coupled logic (ECL) with 32 input ports and 16 output ports is currently being used in laboratory experiments on a broad-band switching network. A compact CMOS chip with 32 output ports is being developed. In this extended chip, each port can carry a signal of 135 Mbps. Synchronous time division multiplexing can be used to combine four signals of 32 Mbps each to a single data stream and switch them independently of each other. These chips are combined to form switching modules. A broad-band switching network consists of several rows of such modules interlinked with optical fiber cables.

In modern switching technology, software is indispensable for processing complex ISDN signaling protocols. Software is also used to realize the convenient menu- and mask-controlled operating procedures for switching equipment. Software now accounts for 80 percent of the



developmental costs for switching equipment, partially because of the growing demands of users and operators for largely software controlled networks. Such software must support the transition to broad-band ISDN and new signaling technologies (ATM), and also allow the combination of classic services (telephone) with more sophisticated ones. The wishes of network users and operators, together with the effects of new hardware technology, all contribute to defining a wide range of requirements for broad-band switching software.

Thus, modern software engineering technologies are also essential for developing software-designed specifications for switching systems. This includes the systematic monitoring of product development, detailed planning, and a clear layout of the developmental process in line with a phase model. Targeted use of review methods for documents and programs as well as formal description languages allow easy recognition and exclusion of possible sources of error. To this end, Siemens developers use powerful software workstations and user-friendly testing and production tools running on mainframe computers.

**Radio Networks for Car Phones.** Siemens' mobile telephone system provides users with the same telephone convenience as in the office or at home. The system is currently designed to handle 400,000 users, whose availability is constantly checked. This permits automatic switching to any user at any time anywhere in the service area. The mobile telephone network is connected to the public network by mobil switching centers from the EWSD family of digital electronic switching systems. Telephone confidentiality is ensured by a voice encryption system.

International standards are being created to allow convenient phoning from the car throughout Europe. Siemens' technical expertise is helping to set these standards. Fifteen European PTTs intend to introduce the "D network" based on international ISDN standards in the early 1990s, when it will have a capacity of several million users.

## Microelectronics

The fields of telecommunications and data systems, process and control engineering, and even consumer electronics call for circuits with typical gate-switching times of less than 100 picoseconds, a period in which light travels three centimeters. In less than 10 years, the 64-kilobit memory has evolved into the four megabit memory. The text of 250 typewritten pages can be accommodated in an area of less than one square centimeter on one chip of this kind. Developmental engineers are now working intensively on the 16-megabit memory chip. As the scale of integration increases, more and more functions can be concentrated onto a single chip. The complexity of the

circuits is leading to greater problems in design, production, and testing.

**Technologies for High-Speed Circuits.** Classic bipolar technology uses the effects at the boundary layer of p- and n-type silicon. Small changes in a low-control current lead to large changes in the collector current, enabling the transistor to operate as an amplifier or as a switch.

In order to attain high operating speeds, both the parasitics on a chip (bulk resistances and capacitances) and the transistor dimensions (emitter penetration depth and base width) must be reduced. With a self-aligning nitride sidewall-masking technique, Siemens has developed a new oxide isolation that permits an almost ideally planar surface as well as a clear reduction in horizontal dimensions.

The critical vertical dimensions can be reduced by rapid annealing with an optical energy source in place of conventional furnace annealing. They have achieved emitter depths of less than 50 nanometers and base widths of less than 120 nanometers at considerably higher electrical activation rates.

These endeavors have resulted in gate switching times of 40 picoseconds. With a static 16:1 frequency divider as a test circuit, operating frequencies of 15 GHz have been obtained. A word generator consisting of delay flipflops, multiplexers, and frequency dividers operates at a data rate of 5 gigabits per second. This rate has been doubled to 10 gigabits per second by means of a downstream 2:1 multiplexer.

Short switching times and high driver capability are the characteristics of bipolar devices. Small size and low power loss are typical of metal oxide semiconductor (MOS) technology. In this technology, the electrical field of a control voltage between the gate and source electrodes of a transistor influences the current between the source and drain electrodes. The MOS transistors are therefore also known as field-effect transistors (FETs of MOSFETs).

The structures of integrated MOS circuits have already gone below the one-micron limit, and they can achieve the speed ranges of bipolar technology while maintaining a high current yield. With MOS common base transistors in the submicron range, Siemens has obtained gate switching times of 60 picoseconds with low power loss. The product of switching time and power loss was only 60 femtojoule ( $10^{-15}$  joule).

**Gallium Arsenide.** Semiconductor compounds consisting of elements from groups III and V of the periodic system offer particular advantages for components and circuits in the highest speed range--high mobility and a high maximum speed of the electrons. For certain applications, their insensitivity to ionizing radiation is also an important criterion. Gallium arsenide (GaAs) has proven to be a promising candidate. Through the specific incorporation of deep traps, the GaAs substrate can be

given a very high resistance. This allows conductors with low parasitic capacitances to be manufactured, an important requirement for complex high speed circuits. However, the considerably higher price for the material compared with silicon as well as the technologically more complex method of production have limited the use of GaAs circuits to special applications.

Siemens is developing the entire technology for high-speed circuits based on MESFETs, heterobipolar transistors (HBTs), and high-electron mobility transistors (HEMTs): crystal growing, ion implantation and epitaxy, deposition and structuring of metals, and dielectrics.

Together with Cornell University, Ithaca, New York, Siemens Research and Technology Laboratories, Princeton, New Jersey, has built an HEMT-based on GaAs/GaAlAs with a transition frequency of 113 GHz. Since GaAs also plays an important role in optoelectronics, the possible combination of different GaAs circuits with optoelectronic components on the same chip opens up completely new application possibilities.

**Very Large-Scale Integration.** Because of their regular structures, simple logic, and ease of manufacture, memory chips are particularly suitable for the development of new technologies for the series production of large-scale integrated circuits. They act as the driving force behind developments to master and perfect the design and production processes for highly complex logic circuits.

The 4-megabit memory chip is characterized by 8,900,000 components with structures of 0.8 microns and access times of around 70 nanoseconds. Using special lithographic and etching techniques and new concepts for memory cells and peripheral circuits, Siemens produced the first working samples of the 4-megabit chip on their development line in 1987. In order to reduce the space required by a single cell to 10  $\mu\text{m}^2$ , trenches of 4-micron depth and 1-micron diameter are etched into the silicon for the storage capacitor. A capacitance of 0.04 pF is obtained with these trench capacitors. The 4-megabit chip consists of three polysilicon layers and one layer for the aluminum interconnections. Like the 1-megabit memory chip, the 4-megabit chip is also manufactured using CMOS technology.

**Megalogue for Customized Circuits.** Large-scale integrated (LSI) logic circuits, at present, contain some hundreds of thousands of transistors in an extremely wide range of different configurations and with function-specific wiring. Since application-specific integrated circuits (ASICs) are often required in comparatively small numbers, it is necessary to achieve a drastic reduction in the time and cost required for their development. Ideally, the customer should be able to develop his own integrated circuit (IC) to the production stage, using a fast, low-cost, and error-free process. For many users, the protection of

their know-how may be even more important than any savings in time or money.

Siemens CAD system, VENUS-S (semicustom) supports all phases of circuit design by using powerful and convenient tools. The developmental process is simplified by extensive libraries for various technologies with gate arrays, standard cells (digital and analog), generated macrocells (such as RAMs, ROMs, systolic arrays), and the option of integrating existing microprocessor cores. Particularly important for complex circuits is the support offered by VENUS-S for testing.

The VENUS-S contains initial steps towards a silicon compiler in the form of a logic synthesis. Ideally, a silicon compiler should be able, largely automatically, to generate all further data required for production from the logical description of a circuit or an entire system.

**Designing and Manufacturing at the Limits of Technology.** The LSI circuits no longer provide any leeway for tolerances in their operational parameters. With powerful tools and processes, the designer or manufacturer ensures that design, manufacture, and testing procedures make optimal use of the physical possibilities without exceeding the technological limits. Even with the usual supply voltage of only 5 volts, the extremely small structures involved lead to high-field strengths inside an IC, which may lead to a breakdown at critical points and thus the destruction of a cell. By simulating the process steps, the spatial distribution of the doping atoms, and thus the electrical field strength, can be calculated in advance. For example, with the 4-megabit chip, optimized dimensioning has allowed dispensing with special techniques for voltage reduction, thus shortening switching times by 20 percent.

In order to raise yield and safeguard quality, design or production errors must be discovered and rectified quickly and accurately. In addition to a sophisticated technique for analyzing the materials used, this often calls for measurements inside an IC. Electron beam measurement allows switching operations to be displayed with a high degree of resolution with respect to location and time in a specially developed electron microscope, in which short electron pulses (pulse duration 7 ps) are focused on the measuring point in synchronism with the clock frequency of the circuit. The energy of the secondary electrons released by this process is a measure of the potential at that point. The energy can be measured and evaluated to display the signal with respect to time, as on an oscilloscope. This measuring technique permits direct on-wafer characterization with clock signals up to 12 GHz.

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# Real-Time Systems

## International Seminar on the Teaching of Computing Science

*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. Mr. Ryan is on leave from the Office of Naval Research where he is the Director of the Special Programs Office.*

### Introduction

On September 3-5, 1989, the 22nd International Seminar on the Teaching of Computing Science at the University Level, was held at the Computing Laboratory (Laboratory), University of Newcastle Upon Tyne, U.K. This series began in 1968 with initial support from IBM, based at the time on the installation of new IBM equipment at the Laboratory. Since then both equipment and sponsor have changed, with this year's seminar being cosponsored by International Computers Limited and the University of Newcastle Upon Tyne.

Over the years, this seminar has attracted many of the top researchers in computer science, or, as they prefer at the Laboratory, computing science. The list of speakers at previous seminars reads like a "Who's Who" for the field. Although the title mentions teaching of computing science, this annual seminar presents research results in a selected area of computing science; this year it is real-time systems. There was discussion after the talks about what parts of the presented material were appropriate for the classroom, but the talks dealt with the speakers' research. On the other hand, the invited audience consisted mainly of European professors of computing science, most of whom are not experts in any given year's seminar topic. By attending this seminar over the years (and many are regulars), they can keep abreast of topics and trends. Thus, they are in a good position to keep their computing science curricula up to date.

### Lectures

Professor Brian Randell, who directs the research program at the Laboratory (see following article), will edit the Proceedings. They will be available (as are past issues) from Professor Randell, Computing Laboratory, University of Newcastle Upon Tyne, Claremont Tower, Claremont Road, Newcastle Upon Tyne, U.K., NE1 7RU. With this in mind, I will present only brief reviews of the talks.

**Real-Time Computing-Basic Concepts, Design of a Real-Time Computing System, and Clock Synchronization**, Professor Hermann Kopetz, Technische Universität Wien, Vienna. In the first lecture, Professor Kopetz de-

scribed the differences between real-time (actually hard real-time) systems and conventional systems. The talk focused on the interface between the computing system and the environment, stressing that the maximum response time is determined by the environment. He also stressed that explicit flow control cannot be exercised over the environment, that real-time data are invalidated by the passage of "real-time," and that the system must handle reliably the rare event or peak load.

Building on the foundations of his real-time concepts in his second lecture, Professor Kopetz described a methodology for the actual design of a real-time system. He began with a description of the timing and functional requirements of the application, and ended with timing analysis once the transactions have been allocated to the hardware.

The third lecture dealt in considerable detail with the problem of time synchronization. In addition to presenting an extensive taxonomy of the various times extent in a real-time distributed system, Professor Kopetz described several clock synchronization algorithms and analyzed their timing properties. He pointed out that if you wish to have synchronization to better than 100 microseconds, then you must look for engineering solutions (better crystals, corrections for time on the bus) rather than depending solely upon algorithms. He indicated that by using these techniques, his group has achieved 5-microsecond accuracy for more than 60 nodes.

**Real-Time Logic Scheduling**, Professor Aloysius Mok, University of Texas, Austin. The three talks dealt with (in order) modeling and specification, verification, and scheduling; they provided a connected exposition of previously published work. The central idea is the introduction of a language of timing behavior--based on Real-Time Logic (RTL)--that can be superimposed on block-structured programming languages to specify absolute timing properties.

The first lecture described the language and showed, by a small example, how it can be used for problem specification. The second lecture also invoked a small example to illustrate using a restricted subset of RTL to formally verify the safety assertion. Professor Mok described a graph-theoretic algorithm for safety analysis of the timing specifications expressed in this subset of RTL. In the third lecture, Professor Mok illustrated his process

for creating a run-time scheduler given the annotated program and timing constraints.

**The Classification of Failures, Logically Synchronous Replicas, and Failure Tolerant Clock Synchronization,** Dr. H.R. Strong, IBM Almaden Research Center, California. The first lecture developed a classification of failures within the context of distributed systems. Dr. Strong argued that a classification of failures was necessary in order to describe and compare the failure tolerance of algorithms. This led to the definition of several failure classes such as crash, omission, timing (early and late) and Byzantine (read other), and to the notion of "covers." A failure class A is said to cover a class B, if for any number  $k$ , any algorithm that tolerates any failure from class A at any  $k$  components also tolerates any failure from class B at any  $k$  components.

Armed with this machinery, Dr. Strong went on in the second lecture to describe an algorithm that was tolerant to omission and timing or clock failures. This example was presented in the context of a distributed system with a clock at each node and where the memories  $M$  at each node are replicas. Dr. Strong used this model in the third lecture to present simple failure tolerant clock synchronization algorithms and their real-time systems requirements.

**Synchronous Programming of Reactive Systems and Specifying, Programming, and Verifying Real-Time Systems Using the Language LUSTRE,** Dr. N. Halbwachs, Laboratoire de Génie Informatique (IMAG), Grenoble. Dr. Halbwachs defined a reactive program as one that interacts continuously with the environment. The assumptions regarding the synchronous model are that: (1) the time of all events is precisely known, (2) all the processes in the system have exactly the same knowledge, and (3) time is multiform in that there is no privileged time scale or unit.

In the first lecture, Dr. Halbwachs presented an overview of two different synchronous languages--the imperative language ESTREL and the declarative language LUSTRE. The second lecture focused on LUSTRE, where Dr. Halbwachs presented arguments in favor of a declarative language for real-time applications. He showed that LUSTRE is, in fact, the synchronous, real-time version of the language LUCID. From its declarative nature, it follows that LUSTRE may be used not only to write programs, but also to express their required properties. In fact, LUSTRE may be viewed as an executable subset of temporal logic.

**Controlling Discrete Real-Time Systems with Parallel Processes,** Professor C. Bron, University of Groningen, the Netherlands. Professor Bron changed the pace of the seminar by using a manufacturing plant case study (making bicycle tires) to illustrate general ideas about the control of real-time events as encountered in manufacturing plants, automated warehouses, transport systems, and

similar applications. These are all real-time applications where the computing demands are not great since events in the environment happen slowly compared to available computing power and speed.

Basically, Professor Bron presented a recipe for building controllers for this class of processes, which have historically been managed by Programmable Logic Control (PLC). The recipe calls for decomposing the system into a set of cooperating sequential processes, where a process is not necessarily associated with a particular mechanical component, but with a prescribed event sequence. The software is modular Pascal. Professor Bron contrasted this scheme with that provided by PLC, and argued that modular Pascal does the job better. In particular, he indicated that it is possible to specify, validate (using simulation), and implement these control systems as one integrated activity. Of more importance is that the control process at various levels; i.e., machine control, production control, financial control, follow the same basic scheme and can be linked to realize a fully integrated system.

**Real-Time CSP or A Uniform Mathematical Theory for Real-Time (and Probabilistic) Distributed Computing,** Dr. G.M. Reed, Computing Laboratory, Oxford University, U.K. Dr. Reed presented an overview of the ambitious task that he and Dr. A.W. Roscoe (also Oxford University) have undertaken to provide a uniform mathematical theory for the definition, specification, and verification of communicating sequential processes. This formidable task began several years ago when Reed and Roscoe reformulated the earlier Communicating Sequential Processes (CSP) models (untimed CSP) and structured them into a well-understood hierarchy. Dr. Reed indicated how this hierarchical structure has been extended to include several timed models of CSP, and how these models relate to each other through projection mappings that preserve information. The next development will be the extension to timed models that admit probabilistic operators. As it is, this is an elegant theory based on an underlying topological structure wherein all recursions are contraction mappings; its full practical potential awaits the development of suitable software tools for its mechanical analysis.

**Time and Computation and Transformational Methods for Implementing Correct Real-Time Programs,** Professor Mathai Joseph, University of Warwick, U.K. In the first lecture, he explored answers to the question, "How should time be represented in computation?" He began by introducing the notion of a computational action as an equivalence class of executions of terminating commands. An ordering was defined on the set of computational actions, and in turn, an instant defined in terms of the actions and their order structure. Professor Joseph then showed that the set of instants is isomorphic to the reals provided the set of instants satisfies certain proper-

ties, some of which can be derived from the definition of actions and their ordering. Finally, different assumptions about computation can be related to necessary and sufficient conditions for the denseness of the instants. The point of all this is that the choice among different time domains for representing computational time is really a choice among different models of computation: choosing a model of computation implies a model of time.

Very roughly, this is the idea of the second lecture: Ignoring the timing constraints, the functional specifications are used to refine the design into successively smaller units, which are implemented using sufficient computing resources to meet all of the timing constraints. Professor Joseph calls this the "maximum resource implementation." If the functional specification and the refinement are correct, then this "implementation" exists and does the job. Next, one steps back with transformations that preserve function and time constraints, mapping the design onto real hardware. Of course, these transformations are not unique in general; in fact, they may not exist if one is hardware-constrained. However, the methodology produces verifiable real-time systems when it is not halted by lack of resources.

**Timing Considerations Will Damage Your Programs and How To Cope With Many Processors In No Time At All**, Professor Wladyslaw M. Turski, Institute of Informatics, Warsaw University. These two lectures were philosophically 180 degrees out of phase with the rest of the seminar. In the first instance, Professor Turski argued that time, as it usually enters into the design of programs, has no special role; that there is no need to distinguish time events from other events. He believes that timing considerations may enter implementation considerations, but that they should never be made transparent at the specification level, and that, in fact, it is dangerous to do so.

In the second lecture, Professor Turski outlined his scheme for specifying time-independent computation.

He argued that his method, which removes the differences between "before" and "after," leads to implementable systems that efficiently utilize arbitrary many processors, and that smoothly collapse to Dijkstra-style guarded command iterative systems when there is but one processor available.

## General Observations

Most of the results presented at this seminar have appeared previously in one form or other, some as long ago as 1987. This is not a criticism, for the seminar agreeably fulfilled its objective of presenting a panorama of current activity in real-time computing. Attendees heard a spectrum of work from an actual application to manufacturing to philosophical considerations about the proper representation of time in computation; from complex results on programming languages incorporating timing to a point of view that would eliminate timing completely, at least at the specification level. The curriculum builder received ample material for thought and choice.

The lectures and discussion highlighted once again the fact that real-time computing (and computing science in general) is not a mature subject. Few paradigms are accepted as "the way to go," while, on the other hand, practitioners are building systems that work. One sees "satisficing" but not much "optimizing." Individual favorite schemes work, but one often has the feeling that they would fall apart as the size of the problem grows.

Real-time systems being in a state of flux and rapid advance, I believe that researchers should pay particular attention to the more controversial ideas such as those expressed by Professor Turski. Rather than being dismissed, they deserve careful study; if appropriate, they should be refuted with the same logical precision as that in which they were expressed.

# The Computing Laboratory University Of Newcastle Upon Tyne, U.K.

by Robert D. Ryan

## Introduction

The Computing Laboratory (Laboratory) at University of Newcastle Upon Tyne, U.K., fulfills, by any definition, all of the functions of a department of computer

science--teaching, research, and the provision of computing services to the university. The Laboratory was recently ranked, on the basis of research performance by the Universities Funding Council (formerly the University Grants Committee), as one of the top nine computer

science departments in the U.K., the others are Oxford, Cambridge, Manchester, Edinburgh, Imperial College London, Sussex, Warwick, and University College London.

The Laboratory was created 32 years ago by Dr. E.S. Page, who became the Vice Chancellor at the University of Reading in 1979. Since that time, Professor Harry Whitfield has been the Director, as well as Professor of Computing and Data Processing. Miss E.D. Barraclough is the Executive Director of the Computing Service. Professor Brian Randell, who is well-known in the computer science community for his work on reliability, directs the overall research program. The Laboratory employs around 100 people, of whom about 30 are on the teaching faculty. At a given time, there are from 15 to 20 graduate students studying for the Ph.D. and about 50 Masters Degree students.

## Research Areas

Professor Randell told me that the Laboratory's research interests and objectives can be generally characterized as "computing systems research," and that within this context the work ranges from research focused on relatively near-term applications; for example, work within Alvey and the European Strategic Program for Research and Development in Information Technologies (ESPRIT) precompetitive projects, to long-term fundamental research. For ease of presentation, they divide their research into five topics--dependability, distributed systems, parallelism, theoretical computing science, and very large-scale integration (VLSI) design. I will discuss each of these separately; in fact, considerable interaction takes place among the several groups.

## Dependability

The people at the Laboratory define dependability as "that property of a computing system which allows reliance justifiably to be placed on the service which it delivers." They judge that a significant accomplishment of their research has been the recognition that various separate systems issues, such as reliability, safety, performance, and security, are best regarded as special cases of dependability.

Professors Randell and Anderson lead the work on reliability and security funded by Science and Engineering Research Council (SERC), Alvey, and Ministry of Defence (MoD). The focus of this research is identifying and refining effective system structuring mechanisms to achieve multi-level security.

They now plan to link their long-established research on performance modeling (of distributed computing systems and networks) to their reliability and security research through the major ESPRIT Basic Research

Project on "Predictably Dependable Computing Systems." This project was initiated and is led by the Laboratory. The ultimate aim is the development of a support environment that will make the process of designing and constructing dependable systems much more predictable and cost effective than is currently possible.

## Distributed Systems

Professor Shrivastava directs work on distributed systems, which is closely allied with the work on dependability. This research covers both theoretical work; e.g., on formal derivation and verification of protocols, and extensive experimental work. This effort has led to the completion of a system named ARJUNA that supports object-oriented distributed programming, and to work on distributed transputer-based, fault-tolerant computers.

This work is expanding based on new projects funded by SERC, ESPRIT, and industry. The objectives now include the achievement of high performance and fault tolerance in large real-time multiprocessing systems involving both local- and wide-area networks, and the development of effective replication techniques for high availability. A new ESPRIT project on system management tools aims to apply object-oriented, fault-tolerant concepts and techniques to the "systems" constituted by multiple (possibly distributed) computers and their administrators.

## Parallelism

Professor Peter Lee directs work on parallelism research for shared-memory multiprocessors. The research focuses on software techniques and languages, and debugging and performance monitoring. The long-term objective is to provide new software tools and techniques that make it easy to write parallel programs that fully exploit the capabilities of multiprocessor architectures.

This group has recently been awarded a major grant from the Department of Trade and Industry to establish a center for multiprocessors. In addition to doing research, the center will provide consulting and experimenting facilities for industry.

## Theoretical Computing Science

The theory group, led by Dr. R.P. Hopkins, has developed a theoretical model for Dynamically Structured Communicating Systems, a process algebra for dynamically structured systems with both synchronous and asynchronous communication. This work is continuing under a major ESPRIT Basic Research Project on Petri Net theory, with the particular aim of rectifying the theory's deficiencies regarding support for modularity of specification, design, and analysis. This ESPRIT project is

jointly led by Drs. Hopkins and Best of Gesellschaft für Mathematik und Datenverarbeitung (Society for Mathematics and Data Processing), Bonn, and involves eight other European research centers.

Other work includes declarative languages research aimed at extending the parameter unification mechanism to accommodate interactive communication between concurrent processes. This research draws upon lattice and category theory, and constructive logic. There is also work on parallel complexity classes and on the representation of corresponding logics and programming schemes aimed at extending existing results to further complexity classes.

### VLSI Design

In addition to being the Laboratory Director, Professor Whitfield leads the VLSI design group. This group collaborates with the Department of Electrical and Electronic Engineering on research into VLSI design tools. The group has close ties with industry, including Plessey, Ferranti, Racal, and British Telecom. Their research has produced the definition and implementation of the STRICT language and design system, a releasable version that is now under development.

Future plans include work on fault-tolerant VLSI architectures done in conjunction with several industrial partners. The aim is to combine other Laboratory research interests such as reliability and software engineering with the design of very complex silicon systems.

### General Observations

The Laboratory is a full-service computer science department with long-standing and successful ties to industry. While the traditional strength has been and continues to be in systems research, the Laboratory has strength-

ened significantly its theoretical group over the last few years.

The Laboratory is competing very successfully for funds in the European arena. Motivated by the decline of national support for computer science (the ending of the Alvey Programme and slim SERC support), they sought ESPRIT funds for the first time in 1988. They were most successful; of the eight proposals submitted to ESPRIT, six were funded, including both of their ESPRIT Basic Research proposals. The total value of these contracts amounts to about 2m ECU.

In 1979, members of the Laboratory played a major role in establishing the locally based Microelectronics Applications Research Institute (MARI), and they continue to have close links with this firm. The MARI now has a staff of over 200 and an annual cash flow of £5m, and has provided a valuable channel for industrial exploitation of the Laboratory's research. The 20th Institute of Electrical and Electronics Engineers (IEEE) International Symposium on Fault-Tolerant Computing, the premier international conference on reliability, will be held in Newcastle Upon Tyne in 1990. I regard it as recognition of the Laboratory's stature and an honor in the international computer science community, for it will be the first time that the symposium is held in the U.K.

The Laboratory clearly plays a key role at the University of Newcastle Upon Tyne and in the greater Northumberland community. The Laboratory provides a full range of teaching and computing services; additionally, its research, the transition of that research, and extramural training have been and continue to be a significant force in a community economy in the midst of changing from heavy industry to the information age. This Laboratory represents a healthy counterexample to the often-heard criticism that computer scientists only speak with other computer scientists.

# ENVIRONMENT

## Living in the Cold II (La View Au Froid II)

by Richard F. Ochillo, Professor of Pharmacology and Toxicology, Xavier University of Louisiana, New Orleans

### Introduction

The second annual conference on Living in the Cold II was held April 23-31, 1989, in Le Hohwald, near Strasbourg, France. The meeting included investigators from the U.S., Canada, the Soviet Union, France, Great Britain, Japan, Federal Republic of Germany, China, Australia, Sweden, Finland, Norway, German Federal Republic, Holland, Czechoslovakia, Switzerland, and Italy all having research interest in cold. Approximately 150 representatives attended this international meeting. Apart from the bound copy of the abstract booklet, the major proceedings of the meeting were published.

Living in the Cold 2nd International Symposium  
Coloque Inserm Vol. 193, 1989  
Andre Malan and Bernard Canguilhem, Editors  
John Libbey and Company Ltd.  
13 Smiths Yard, Summerley Street  
London SW18 4HR

Six sessions of platform presentations and six poster sessions comprised the 5-day meeting (see Table 1).

**Table 1. Symposium Topics**

- Seasonality of exposure to cold and food scarcity I and II
- Seasonal depression versus hibernation
- Food availability, starvation, and torpor
- Natural and artificial depression of metabolic rate
- Effects of cold and resistance adaptation to cold; I.  
Biochemical aspects of cold sensitivity
- Cold sensitivity and cold adaptation at cell and organ level II;  
cell and organ function
- Metabolism in hibernation
- Nonshivering thermogenesis and brown adipose tissue
- Temperature regulation, torpor, and sleep
- Central nervous system, sleep, and hibernation
- Challenges and perspectives for future research

The format of the meeting was of special interest and such novelty that it merits particular mention. Each symposium topic was led by several distinguishing presenta-

tions, followed by the viewing of relevant posters before reconvening for the discussion of each poster. Special scientists were assigned to lead the discussion of each poster. Since the posters were displayed throughout the meeting period, each poster received maximum exposure and permitted the participants to address most of the interesting points in each. Poster presenters had maximum contact with participants, which is an unusual situation.

Living in the Cold is the flower of a series of meetings held at regular intervals since 1948, devoted to the physiological and biochemical aspects of interactions of animals and humans with cold (Heller et al.). There is a growing interest in such studies because of their clinical applications, especially to organ preservation and the use of artificial hypothermia for surgery.

The participants presented a variety of scientific interests. They included the molecular biology of the adaptation of thermogenesis; the psychiatry of seasonal affective disorders through cold effects of membrane transport and enzyme function; the mechanism of heat generation; neuroendocrine control of biological rhythms; eco-physiological responses to cold and food scarcity; receptor responsiveness to endogenous transmitters; and therapeutic agents in hypothermic conditions. Like any other frontier of modern research, this area has fostered potentially expansive collaboration between neurophysiologists, thermal physiologists, specialists in brown adipose tissue thermogenesis, and molecular biologists. This collaboration has led to the elucidation of the sequence of events by which the repetitive stimulation of cutaneous cold receptors, acting through the hypothalamus and sympathetic pathways, ultimately promotes the synthesis of mRNA for the uncoupling protein of brown adipose tissue of the mitochondria.

Traditionally, this type of convergence with specific interest in living in the cold has been dominated by environmental biologists with special interests in physiology and ecology. However, in contrast to the Living in the Cold Symposium I (Lake Tahoe, 1985) where this emphasis was apparent, new research areas with great



potential emerged, especially in the areas of experimental hypothermia and clinical hypothermia. The following summaries highlight some of the unique ideas in these new research areas.

## Clinical Hypothermia

The most interesting presentation in this field was made by Dr. T.A. Wehr, Clinical Psychobiology Branch, National Institute of Mental Health on "Environmental Triggers of Seasonal Depressions." Patients afflicted with depression, a recurrent illness, typically experience several episodes of the disease during their lives. These episodes may vary in length, but usually last several months and terminate spontaneously. Frequently, depressive episodes recur on an annual basis. In such cases, there appear to be principally two patterns of seasonal recurrence--a winter type and a summer type. During winter seasons, patients with each pattern can be less depressed, well, hypomanic, or manic. Mania is an excited state that is opposite in many respects to depression.

There are a few points that were especially intriguing in this aspect of clinical hypothermia. Winter depression appears to be triggered by light deficiency, and there is considerable evidence that it can be treated effectively by exposing patients to bright, artificial light. Unlike winter depression, factors that trigger summer depression are not yet clearly identified. However, preliminary data suggest that summer depression may be triggered by heat and may possibly be treated by exposing patients to cold. The key question here would be: "Is there a parallelism of seasonal forms of depression and mania with the seasonal rhythms seen especially in hibernating animals?" Many of the changes that occur in seasonal forms of depression and mania resemble changes in behavior and physiology that occur in connection with seasonal rhythms in animals. In considering these similarities, it is important to realize that depression is an inherited medical illness characterized by numerous changes in behavior and physiology, that go far beyond what is usually meant by "depression" as a normal human emotional response.

This is a fascinating research frontier that will definitely expand. The research can provide linkages between basic research and clinical research as investigators formulate hypotheses to explain the clinical observations and, as they proceed, to generate data to support the hypotheses. Already, the melatonin hypothesis and the circadian rhythm phase shift hypothesis have been advanced to explain the clinical observations. According to the melatonin hypothesis, changes in daylight trigger winter depression by modifying the pattern of nocturnal melatonin secretion. According to this theory, phototherapy should be effective only when it is administered before dawn or after dusk, thus interrupting the long winter night and shortening the phase of active

melatonin secretion. Unfortunately, experimental evidence does not provide strong support for the melatonin hypothesis. According to the circadian rhythm phase shift hypothesis, winter depression occurs when circadian rhythms become abnormally phase-delayed relative to sleep. Since morning light advances and evening light delays, the phase position of circadian rhythms become abnormally phase-delayed relative to sleep. Since morning light should improve winter depression, evening light should have the opposite effect. In general, investigators have found that morning phototherapy is superior to evening phototherapy.

## Experimental Hypothermia

The relevant research presentations in this area were largely focused on specific body systems. In my presentation about comparative study of the influence of hypothermia on the onset and offset of action of phenoxybenzamine and dibenamine at muscarinic receptors, we demonstrated that at high temperature (37°, 32°, 24°, and 22°C), these agents will alkylate muscarinic receptors by forming covalent bonding, which are stable and take a long time to wash off. However, at lower temperatures (18°, 14°, and 9°C), they block the muscarinic receptors by occlusion. The blocking effects wear off very rapidly making impossible the use of Burstyn and Furchgott method of investigating receptor activities. Our goal is to use hypothermia as a form of stress such that we can elucidate the effects of temperature on activities of agonists and antagonists at receptors.

Since the 1950s, experimental hypothermia has found clinical application in cardiac surgery. Dr. Perroud's presentation, "Experimental Hypothermia: Clinical Application with Extracorporeal Circulation," emphasized this area of research. Generally, hypothermia, as used in cardiac surgery, can be divided into two parts: (1) selective hypothermia of the heart at 12-15°C, which is routinely used for complete ischemia of the myocardium; and (2) general hypothermia of the patient by extracorporeal circulation, which is usually a moderate hypothermia (25°C). In certain cases, complete circulation arrest is carried out for 45 minutes with profound hypothermia at 18-20°C. Hypothermia in cardiac surgery is interesting for two reasons: (1) hypothermia of the entire body makes it possible for the organism to tolerate insufficiencies and even to stop blood circulation; and (2) localized heart hypothermia permits anoxia and ischemia for a limited time during reconstructive surgery.

In organ preservation, hypothermia has been applied experimentally. Dr. Southard's presentation addressed this aspect of clinical application. According to the general method, cryoprecipitation procedure is used to remove most of the lipoproteins that are in the vasculature and cause injury to the organ to be preserved for

transplantation; e.g., the kidney. Most organs that have been identified for transplantation are stored at 0-4°C. The success of organ preservation is an understanding of how hypothermia affects cellular metabolism and the mechanism of tissue injury during prolonged preservation periods. The hope is that in the future, advances in knowledge concerning how hypothermia affects metabolism will lead to further improvements in organ preservation methods.

In his closing remarks, "Perspectives in Hibernation Research: Concepts and Executions," Dr. Wang not only articulated the mistakes and experience the investigators have learned in more than 20 years of involvement in torpor and hibernation research, but also identified five areas where both theoretical and practical problems might potentially exist even though proposed possible solutions to some of these might have been made. The problem areas are:

1. Depressed body temperature ( $T_b$ )
2. "Duration of impact" of cold exposure
3. Circadian endogeneity of the measured variables

4. Interpreting seasonal differences in measured variables

5. "Biology and temperament" of the studied species.

Dr. Wang further identified major areas of recent studies at different organizational levels to illustrate some of the points alluded to in connection with the aforementioned problem areas--central nervous system thermoregulation, cardiac-contraction coupling, and membrane structure and function. This presentation was thought-provoking and left in each of the participants some whimsical feelings that will remain a driving force for each participant to want to attend the next meeting in the U.S. Pacific Northwest in 3 to 4 years.

### References

Heller, H.C., X.J. Musacchia and L.C.H. Wang, eds., *Living in the Cold*, (Elsevier, New York, 1986).

## MATHEMATICS

### International Workshop on Multivariate Approximation and Interpolation

*by Richard Franke, formerly the Liaison Scientist for Mathematics and Scientific Computing in Europe and the Middle East for the Office of Naval Research European Office. In September 1989, Dr. Franke returned to the Naval Postgraduate School, Monterey, California, where he is a Professor of Mathematics.*

#### Introduction

The International Workshop on Multivariate Approximation and Interpolation was held August 14-18, 1989, at Duisburg, Federal Republic of Germany (FRG). This meeting was the second edition of a meeting first held in Santiago, Chile, in 1986. The meeting was organized by a committee consisting of Professors Charles K. Chui, Texas A&M University; Werner Haussmann, Universität Duisburg; Kurt Jetter, Universität Duisburg; Larry L. Schumaker, Vanderbilt University; and Florencio I. Utreras, Universidad de Chile. The meeting was organized in a workshop format with all speakers being invited, each giving a 30- or 40-minute survey or research lecture. The meeting was sponsored by several FRG agencies and a company, as well as Office of Naval Research European Office (ONREUR). The intent of the organizers was to cover the whole spectrum of approxi-

mation, including computer-aided design, data fitting, interpolation, and smoothing with multivariate splines, and approximation methods in partial differential equations. One of the objectives of the meeting was to generate interest in the area among young scientists, both from academic institutions and in industry. There were 75 attendees from 18 countries, including most Western European, four Eastern block, and two South American countries, the U.S., Canada, Singapore, and China. There were more than 15 people who were either from industry or students.

#### Applications-Oriented Lectures

There were 29 invited lecturers; all but one accepted. The lectures ranged from applied to rather theoretical, with the predominant emphasis being somewhat theoretical. I will briefly discuss a few of the more applications-

oriented talks and list the lecturers, affiliation, and titles for the remaining talks.

**On Some Recent Methods for Bivariate Shape Preserving Interpolation**, Paolo Constantini, Università di Siena, Italy. This talk reviewed some interpolation methods that preserve monotonicity and/or convexity (see *ESNIB* 89-08:30).

**Construction of Curves and Surfaces by Subdivision Techniques**, Nira Dyn, Tel-Aviv University, Israel. Dyn discussed a subdivision technique for generating a curve that interpolates the control points, and that contains a parameter acting as a tension parameter. Unlike subdivision by a scheme such as de Casteljau, where previous points are discarded, this method builds up the curve by retaining all points. The method is easily extended to tensor product surfaces. Examples illustrated the effects of the tension parameter.

**Objective Analysis of Meteorological Data**, Richard Franke, Naval Postgraduate School, Monterey, California, and ONREUR. My talk concerned the idea of a uniform treatment of observed and background data in numerical weather prediction. The usual practice is to obtain objective analyses by calculating an estimated error obtained as a difference between the observed values and the background values, and a subsequent correction to the background values. Uniform treatment of all the available data has potential benefits, especially if observations are sparse, or if the background error is poorly correlated, but at the cost of significantly more computation.

**$GC^{n-1}$  Functional Splines for Interpolation and Approximation of Curves and Surfaces**, Josef Hoschek, Technische Hochschule Darmstadt, FRG. This talk concerned a generalization of Liming curves (see *ESNIB* 89-09:31).

**On Ridge-Type Functions with Elliptic Contour Lines**, Franz Locher, Fern Universität Hagen, FRG. Locher discussed the idea of modeling surfaces with creases by using a modification of radial basis function approximations. With radial basis functions (see *ESNIB* 89-04:24-25), the approximation is of the form

$$\sum_{k=1}^N A_k g(\|x - x_k\|)$$

Depending on the univariate radial function  $g(r)$ , this approximation may be very smooth. Locher proposed replacing

$$g(\|x - x_k\|) \text{ with } g(\|x - x_k + y\| + \|x - x_k - y\| - 2\|y\|).$$

The effect of this is to make the argument of the basis function zero whenever  $x$  is on the line joining  $x_k - y$  and  $x_k + y$ , thus building into the approximation a ridge be-

tween those two points. The contours of a given basis function are ellipses (degenerate for the value of  $g(0)$ ). Some examples of surfaces generated by the scheme were shown.

**Selective Refinement/Derefinement Algorithms for Triangular and Tetrahedral Meshes**, Maria-Cecilia Rivara, Universidad de Chile, Santiago. Rivara discussed the refinement of meshes for adaptive finite element methods. The basic idea is to bisect the long edge of triangles, which must be refined. This causes a cascading refinement effect since adjacent triangles must be divided (again, always by bisecting the longest edge) to maintain an allowable mesh. In addition, it is desirable to have a "smooth" transition in triangle sizes. Rivara showed examples of her algorithm, which appeared to work well. In addition, the reverse of the ideas can be used to collapse smaller triangles to form larger ones, as necessary.

**Recent Advances on Multivariate Smoothing Splines**, Florencio I. Utreras, Universidad de Chile, Santiago. This talk surveyed recent results on computation of smoothing splines, especially for scattered data. Special emphasis was put on the problem of computation of the smoothing parameter using generalized cross validation. Cross validation requires computation of the trace of the inverse of the coefficient matrix, and it has recently been discovered that the quantity can be quickly estimated by evaluation of a quadratic form for a few (perhaps one) random vectors.

Table 1 provides a list of other topics, lecturers, and affiliations.

## Final Comments

This meeting brought together an international group of well-known researchers and practitioners in approximation theory and its applications to discuss recent results and old and new problems. Even though August is not a good time for a meeting in Europe because of summer holidays during that period, the meeting was well attended. The local arrangements for the meeting were very well planned and executed. The Proceedings (Haussmann et al.) will be typeset using TEX in the same pleasant format as that for the previous meeting (see Chui et al.), and thus should appear in less than one year. The next meeting in the series will be held in Santiago, Chile, in 1992 (said to be in celebration of the discovery of the Americas by Columbus, although not so seriously as to be held at an appropriate site for that celebration).

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**Table 1. International Workshop on Multivariate Approximation and Interpolation**

- Construction of Approximation and Interpolation Formulas, Charles K. Chui, Texas A&M University
- Approximation of Functions with Singularities, Yu.A. Brudnyi, Yaroslavl' State University, U.S.S.R.
- Asymptotic Nonparametric Spline Density Estimation and Approximation by Positive Spline Operators in Several Variables, Zbigniew Ciesielski, Instytut Matematyczny PAN, Sopot, Poland
- Regular Subdivision, Wolfgang Dahmen, Freie Universität Berlin, FRG
- Some Applications of Approximation Theory to Boundary Value Problems of Potential Theory and Elasticity, Willi Freeden, Rheinisch-Westfälische Technische Hochschule Aachen, FRG
- Best Uniform Approximation by Harmonic Functions, Werner Haussmann, Universität Duisburg, FRG
- Numerical Aspects of Cardinal Interpolation Using Box Splines, Kurt Jetter, Universität Duisburg, FRG
- Lower Bounds on the Dimension of Spaces of Bivariate Splines, Rong-Qing Jia, University of Alberta, Canada
- The Use of Homogeneous Coordinates in Spline Functions and Polynomial Interpolation, S.L. Lee, National University of Singapore
- On Composite Finite Elements, Alain Le Méhauté, Université des Sciences et Techniques de Lille, France
- Interpolation by Translates, W.R. Madych, University of Connecticut
- Minimum Norm Interpolation of Periodic Data in Translation Invariant Spline Spaces, Hennie ter Morsche, Technische Universiteit Eindhoven, the Netherlands
- Some Polynomial Reproduction Properties of Radial Basis Function Approximation, M.J.D. Powell, Cambridge University, U.K.
- Multivariate Uniform Approximation over the n-Dimensional Cube, João B. Prola, Universidade Estadual de Campinas, Brazil
- Nonproduct Interpolation and Approximation. Results and Open Questions, Manfred Reimer, Universität Dortmund, FRG
- Dimension of Kernels of Differential Operators Associated with a Matroid Structure, S.D. Riemenschneider, University of Alberta, Canada
- Optical Neurocomputers, Walter Schempp, Universität Siegen, FRG
- Elliptic Regularity with Continuous and Branching Asymptotics, B.W. Schulze, Akademie der Wissenschaften der DDR, FRG
- Fast Algorithms for One- and Two-Dimensional Real Discrete Fourier Transforms, M. Tasche, Wilhelm-Pieck-Universität Rostock, FRG
- Approximation by Solutions of Elliptic Boundary Value Problems, G. Wildenhain, Wilhelm-Pieck-Universität Rostock, FRG
- The Obstacle Problem and Best Superharmonic Approximation, D. Zwick, University of Vermont

## Computer and Automation Institute

*by Richard Franke*

### Introduction

My visit to the Magyar Tudományos Akadémia (MTA) Számítástechnikai és Automatizálási Kutató Intézet (SZTAKI) in Budapest was organized by Dr. Tamás Várady, head of the Department of CAD/CAM in Mechanical Engineering. The SZTAKI consists of several scientific divisions and departments, including Applied Mathematics, Electronic, Process Control, Mechanical Engineering Automation, Computer Networks, and Computer Sciences Divisions, and some other smaller groups. About 500 people are employed at SZTAKI, two-thirds of whom work in scientific and technical areas. In addition to the research activities, MTA also grants advanced degrees. The SZTAKI receives about 85 percent of its financial support from contracts with industry and others, with MTA furnishing the remainder. Thus, the organization depends to a great extent on delivering marketable basic and applied re-

search. Some contracts have been negotiated in the West and these bring in desired hard currency. A continuing problem for SZTAKI employees occurs because currency restrictions make travel to Western countries difficult. Purchases of Western books and equipment are also difficult, independent of the amount being spent; hopefully, liberalization will help to overcome this problem.

The SZTAKI is located on the Buda side of the not-too-blue Danube River, within a kilometer or two of the downtown area. While office space is not overly generous; it is perhaps no worse than that at many universities or other research facilities in the West. There appears to be a reasonable number of microcomputers (mostly AT-type machines) available for both the scientific and secretarial staff, although not every office I saw was equipped with one. The Computer Division (which I did not visit) supplies central computer services using IBM 3031 and 370/148 computers as well as mini- and microcomputers.

I was very impressed by the openness of the facility itself (for example, the door was open to the street, with no guard nor name badges evident). Happily, this open atmosphere carried over to the scientists I talked to. Almost everyone I met at SZTAKI spoke excellent English; many had visited or worked for extended periods in Western Europe or the U.S. Because my visit was during the summer, I was not able to meet as many people as would have been possible during a period when vacations are not so popular.

### Principal SZTAKI Activities

One of the principal activities of SZTAKI is in geometric modeling. This emphasis was initiated by Dr. Joe Hatvany, and was given an impetus because early visitors to SZTAKI included Steven A. Coons, from the U.S. (deceased; originator of a transfinite blending interpolant now known as a Coons patch), and Malcolm Sabin from the U.K. (well-known contemporary in computer-aided geometric design [CAGD] and related areas). More recently, close contacts have been established with Cambridge University and the Cranfield Institute (both in the U.K.) through Graham Jared and Mike Pratt. There have been a series of Anglo-Hungarian seminars on CAGD in 1982, 1983, and 1985 (see references for the Proceedings), with the next one planned for 1990.

Early work was to automate two-dimensional (2-D) engineering drawings in a program called GRECO. This work then evolved into design and representation of free-form shapes (the FFS system) used to design and manufacture free-form parts. This system was originally implemented on a PDP 11/40. Another system has been developed especially for shoe design and last manufacturing, carried out in cooperation with VICAM-ATOM in Vienna. The work on FFS has evolved in two further ways. First, to a solid modeler based on the BUILD modeler at Cranfield, called FFSOLID. Second, a new modeler for free-form surfaces with a general underlying patch topology. This system is called FFS-GT.

The FFSOLID system creates a fully evaluated boundary model of objects that can be bounded by planar, quadric, or free-form surfaces. The free-form surfaces are parametric double-quadratics (dq-s), defined and investigated by Várady in his dissertation (Várady, 1985). Simply, curves that are dq-s are two quadratics defined on left and right halves of an interval and joined with tangent continuity. The curve has the same number of free parameters as a cubic, with the curve more closely approximating the Bezier polygon than do cubic curves. The rectangular patch is the straightforward generalization of the curve. The system was discussed at a recent conference (see ESNIB 89-04:24) and the paper will appear in the Proceedings (see Várady, 1989).

The FFS-GT system is based on a general patch topology, resulting in different patch boundaries than are usually allowed. While four-sided patches are convenient, three- and five-sided patches often occur naturally at places such as corners and aircraft wing-body joins, respectively. Since these kinds of patches are necessary, there seems to be little additional complexity in allowing an arbitrary topology, with  $n$ -sided patches, and T-nodes where one side of a patch joins two others, having a node along the interior of the boundary. Given a general parametric patch topology, a network of curves over the patch boundaries is defined using parametric cubic curves, with the surface then being completed using a  $C^1$  blending scheme. Smooth blending schemes for  $n$ -sided patches are nontrivial and have received much attention in the CAGD literature recently; the method used in FFS-GT will be discussed later. One option available for monitoring the quality of the curve network is an interrogation of curvatures resulting in a display of line segments directed toward the center of curvature having magnitude proportional to curvature. Similarly, one may display tangent vectors, torsion vectors, and the Bezier polygon. Naturally, as the system deals with space curves, it may be necessary to change the viewpoint to obtain an accurate assessment of the geometric behavior of a given curve.

The surface may be defined by the designer, or data may be input from an existing surface. In the former case, the system is still in a primitive developmental state. In the latter case, the results of measurements taken from a front fender of a Polski Fiat (a Fiat 650 made under license in Poland) was demonstrated to me. The network of curves was drawn on the actual fender by someone familiar with design, in a way that was felt to capture the important aspects of the surface, but without regard to the connection topology of the patches. As a result, there were the usual four-sided patches as well as three- and five-sided patches, but including one nine-sided patch (this patch may have been treated as a patch with fewer sides, but with T-nodes, although there seems to be little advantage in doing that). Of course, the network also included a number of T-nodes. The digitized data for the patch boundary curves are fit using least square methods. Incompatibilities between tangent vectors at a vertex are resolved by fitting the best tangential plane at the vertex and then projecting tangent vectors into it; the system gives the user a warning message.

The surface is completed using the Gregory (1974) patch. The subdivision of nonfour-sided patches into four-sided patches is described in Hermann and Renner. The boundaries of the subdivision are parametric cubic curves, and the choice of curves has a significant influence on the surface, so appropriate choices are important. Special considerations are necessary in order to assure  $G^1$  continuity. Additional complications occur in the case of T-nodes on the boundary. The T-nodes are

handled by subdividing the adjacent area into two four-sided patches, using an extension of the T-node curve to ensure satisfaction of compatibility conditions. The process involves some parameters, and choices for these are described in the referenced paper. The surface for the Polski Fiat fender was demonstrated as a ray-traced image, which appeared to be quite satisfactory.

Several additional papers related to the CAGD effort at SZTAKI are included in the references. I also saw a demonstration of NC milling software used by Hungarian industry such as the IKARUS Coach Factory, and the results of a previous effort on design and numerically controlled grinding of cut glass (for the VEB Numerik Factory in the FRG).

I spoke with Dr. Dmitry Chetverikov, the head of a research group in image analysis. The group was formed about 1974 and now includes about 4 or 5 persons. Some of their work has been in the development of 2-D recognition schemes using techniques based on the extraction of contours and geometric invariants such as area, perimeter, and moments. The objects were then classified by matching with a catalog of possible objects. Recent work by Chetverikov has been in textures, including texture regularity, imperfections, and rotation-invariant features. Some references are given below.

Present work involves tracking and recording the movement of small, somewhat cylindrical objects from a series of pictures. The problem is complicated by several features, including that there may be many objects, their speeds and directions can vary greatly, and they may "pop" into or out of the next picture in the series. The approach used is to pair the objects (insofar as possible) in successive pictures by using the series of pictures to estimate the speed and direction of the objects in a given picture and comparing this prediction with the next picture. While the problem has several applications, this investigation is the result of a project investigating a means of monitoring (and hence determining the quality of) the sperm population of bull semen used for artificial insemination.

## Final Comments

The work I discussed with personnel at SZTAKI is interesting and seems to be of good quality. The working atmosphere seems pleasant and is definitely in the spirit of open scientific investigation. The geometric modeling work is handicapped by the lack of state-of-the-art hardware and adequate financial support to allow programming of the necessary handles to be used in interactive design work. The SZTAKI is attempting to interest

Western companies in FFS-GT (and in helping to fund completing it). While some earlier programs were not very portable, FFS-GT is written in C and runs on a MicroVax computer. The system has some useful features not available on any other system that I know about (there are many I am not familiar with, however), and appears to have some potentially interesting capabilities. Funding from Western companies would be useful beyond just allowing completion of the project, since it would be in the form of needed hard currency as well.

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# Kaiserslautern University, Federal Republic of Germany

by Richard Franke

## Introduction

I visited two departments, Mathematics and Computer Science, at Universität Kaiserslautern, Federal Republic of Germany (FRG). The university was founded in 1970 and its facilities are being expanded at a rapid rate, with the Computer Science Department recently occupying a building that is still undergoing final touches. Professor Dr. Hans Hagen was my host; he heads the "Arbeitsgruppe" (Research Group) in Computer Graphics and Computational Geometry.

## Laboratory of TechnoMathematics

Professor Dr. Helmut Neunzert directs the Arbeitsgruppe Technomathematik at the Universität Kaiserslautern, consisting of about 6-7 Professors plus about 15 staff members who are funded from outside the university. The funding amounts to about DM 1M (about \$500,000) per year and is obtained from foundations and industry. The purpose of the Laboratory of Technomathematics (Laboratory) is to foster connections with industry (or to "build bridges to industry," in Neunzert's words). This is accomplished through the research and education process in several ways.

One of the important ways is through continuing education for engineers and scientists working in industry. Some of this effort is directed to short courses, which typically treats new developments in a given area. Neunzert emphasizes that it is important to teach courses with the right content, but it may be even more important to have the right course title. As an example, he noted that a course entitled "Stochastic Vibrations" would not have nearly as much appeal as the same course entitled "Random Vibrations in Vehicles" (a course in which the automobile industry is very interested).

A second avenue is to bring students (and faculty) into contact with industrial problems. This is achieved by having presentations by industrial engineers and scientists on problems they need to solve. For presentation to small groups of students (3-4 students with a more advanced student for an advisor), the problems are carefully screened for suitability as a one-semester study. Neunzert calls these "easy" problems. "Intermediate" problems may be assigned as a thesis for a student working for the Diplom degree.

A third way is through the solution of "hard" problems, that require a significant amount of effort on the part of the faculty and advanced staff members. Neunzert em-

phasizes that it is important that the industrial partner be willing to put money into this project, for two reasons. The first is obvious since the Laboratory must somehow receive funds. The second is a kind of quality control: the problem must be important enough for the company to invest in finding a solution to it, otherwise it is questionable whether or not the problem deserves significant effort.

Before any of the above can begin, companies must be contacted. Neunzert feels the only way is to visit them, see what they are doing, and what their problems are. He points out that it is not helpful to ask if they have any "mathematical problems," because they rarely recognize that they do. The mathematician can more easily recognize that certain problems can be put into a mathematical context and (perhaps) then be solved. Neunzert has visited more than 120 companies over the past few years. Often times the problem that is revealed is not one his group has the expertise to solve. However, being familiar with a large group of mathematicians throughout Europe (such as members of the European Consortium for Mathematics in Industry [see ESNIB 89-01:28-31]), it is likely that he knows of someone who does have the expertise to solve the problem.

Neunzert's group is working on several different projects (see Table 1).

Some projects are discussed in more detail below.

**Numerical Solution of the Boltzmann Equation.** The source of this problem is flow about the European Space Agency shuttle, HERMES, at high altitude (about 100 km). Dassault, France, is the project sponsor. The flow is simulated using a kind of stochastic model to track the collisions of the atmospheric particles with each other and with the body. A subdivision is used to attempt to maintain essentially similar behavior throughout a given cell. Cell subdivision is driven by nonuniformity in the cell, provided this nonuniformity is not caused by too few particles in the cell, in which case the subdivision cannot (and should not) be carried out. The body surface-particle interactions are of two kinds--spectral reflection and diffusion reflection. The proper mix of the two is not known well enough at present and they hope to get better information from wind tunnel tests. An advantage of the code is that it is highly vectorizable (they use the Siemens VP-100 computer in the Center), and is highly parallel as well. Mathematical convergence of the method has been shown. They are happy with the performance of the code, and it does predict the difficult-to-measure "back-heating" that has been observed. The code does not presently

include the effects of chemical reactions and they are attempting to formulate the proper way to include these. Ultimately, they hope to extend the model to work at a lower altitude so the results can be used as initial conditions for the Navier-Stokes equations.

**Table 1. Arbeitsgruppe Technomathematik Projects**

- European Space Agency Project HERMES - Numerical solution of the Boltzmann equation
- Simulation of flame-fronts in the cylinder of an internal combustion engine
- Quality testing and analysis of synthetic fabrics
- Optimal design of gear teeth
- Calculation of eccentric gear teeth
- Optimization of sewing machine mechanisms
- Tolerance calculation for pressure gauges
- Computer-aided modeling in the auto industry
- Algorithms for intersection curves and contact points for ruled surfaces
- Simulation of water temperatures in outdoor swimming pools
- Sewing as a dynamical system
- Reduction of the degrees of freedom of elastomechanical systems
- Flow in channels with parallel entrance ducts
- Optimization of camshafts for internal combustion engines
- Construction of pallets for circular tools
- Simulation methods for semiconductors
- Inverse scattering and linear transport theory
- Applications of wavelet theory in signal analysis and picture processing
- Chair and seat design
- Forest damage research

**Applications of Wavelets.** Wavelets are becoming a very important concept in signal analysis and related fields. I spoke with Professor H.G. Stark about his work. Wavelets are somewhat akin to Fourier transforms, but unlike Fourier transforms, have the ability to detect the position of local behavior (such as discontinuities of value or derivatives) in addition to their mere existence. This is accomplished by the expansion of the function in a series, which involves local sampling as well as scaling (Fourier series can be thought of as only involving scaling). For a suitable function  $\varphi(t)$  and positive parameters  $a$  and  $b$  ( $a \neq 0$ ), the "continuous wavelet transform,"  $(Uf)(a,b)$ , is given by the expression

$$\langle \varphi_{a,b}, f \rangle = a^{-1/2} \int f(t) \varphi\left(\frac{t-b}{a}\right) dx.$$

This is called the "continuous wavelet transform." An often quoted example of a suitable

$$\varphi(t) \text{ is } (2/\sqrt{3})\pi^{-1/4}(1-x^2)\exp(-x^2/2).$$

Looking at  $\varphi(\frac{t-b}{a})$  one sees the translation is to the vicinity of  $b$ , while the scaling (or dilatation)  $a$  results in the assessment of fine detail as  $a$  decreases. In practice, the "discrete wavelet transform" is used; this is achieved by restricting the parameters  $a$  and  $b$  to take on values of the form  $a = a_0^m$ ,  $b = nb_0a_0^m$ . This gives functions

$$\varphi_{m,n}(t) = a_0^{-m/2} \varphi(a_0^{-m}t - nb_0).$$

For a suitable function  $\varphi(t)$ , with positive parameters  $a_0$  and  $b_0$  ( $a_0 \neq 1$ ), the set of functions  $\{\varphi_{m,n}\}$  are orthonormal (see Daubechies, 1988), and  $F(t)$  can be expanded as

$$F(x) = \sum_m \sum_n \langle f, \varphi_{m,n} \rangle \varphi_{m,n}(t)$$

By looking at the two-dimensional array of coefficients, it is possible to pick out both the scale and location of the feature. The applications at which Stark is looking include speech processing and image analysis. For the detection of discontinuities in higher order derivatives of the function, it is necessary that the  $\varphi$  function have continuous derivatives of at least that order. Wavelets are also potentially useful for constructing fractals since it is an infinite repetition of the same kind of function. Applications in *chaos* may be possible as well.

**Semiconductors.** I spoke with Professor Joachim Wick about his work in modeling semiconductors. The diffusion model for semiconductors has been quite successful; however, with the Gallium Arsenide thin-wafer semiconductors, they are less so. Their behavior is modeled by the a kinetic equation, which is similar to that of plasma physics. The phenomenon is primarily driven by collision processes that are described by an integral. So far, according to Wick, an approximation to the integral that also allows proper handling of the differential part of the equation has been difficult. He is investigating the use of number theoretic approximations for the integral, and he feels this promises to be useful.

**Computations of Magnetic Fields and Eddy Currents in a Generator.** Wick also works on the computation of magnetic fields and the resulting eddy currents in a large generator. The problem is important because the eddy currents lead to losses in efficiency. The problem is difficult for several reasons. The generator consists of parts made of copper, iron of various types (in particular, solid and laminated), with air spaces. The laminated iron leads to a singular conductive tensor that complicates the relation between the magnetic field and the current. The permeability varies greatly over various parts of the structure.



There are many ways to write the equations. Wick uses a linearized version of the equations, but even so the resulting system of equations does not have the usual nice properties associated with an elliptic problem. The matrix is nonsymmetric and nonpositive definite. Because the system is very large (but sparse), iterative methods of solution must be used. The proper ordering of the equations is crucial. Another problem is that care must be taken so that the discretization is consistent, and Wick mentioned that while perfectly reasonable results can sometimes be obtained with a given mesh size, convergence may be to the solution of the wrong equation as the mesh becomes small.

**Research Group in Computer Graphics and Computational Geometry.** This group is a recent addition at the University of Kaiserslautern. Hagen was at the Technical University of Braunschweig before moving to Kaiserslautern and establishing the research group in early 1988. The principal research interests of the group fall into two areas--geometric modeling (especially computer-aided geometric design [CAGD]) and computer graphics (especially for scientific visualization purposes). Within these areas, five research projects are underway (see Table 2).

Hagen's recent work concerns estimation of twist values (second cross partial derivatives) for Coons patches, or for specification of inner control points for Bezier and B-spline patches. Proper specification of these values is necessary for high-quality surface definition. In Farin and Hagen, the values are determined by minimization of the integral of curvature squared, over the set of patches. This work is a generalization of the work in Hagen and Schulze, where the technique was first applied to twist estimation.

The interpolation of arbitrary position and normal vector data in three dimensions is an important problem for the construction of smooth surfaces in CAGD. Hagen and Pottmann have recently generalized results of Nielson to include the interpolation of curvature data as well. The use of these patches over a triangular network then yields a surface with geometric continuity of order two. First, a transfinite interpolant is generated that interpolates to given boundary curves and normal derivative information. The construction involves some parameters that can be used to control the shape of the surface. This representation is then discretized by generation of the curve and normal derivatives to interpolate the vertex data in the standard way, although certain aspects of the problem must be handled carefully.

Hagen has an aggressive campaign for short-term visitors and has had several from the U.S. and Canada, including T. DeRose, University of Washington; G. Nielson, G. Farin, and T. Foley, Arizona State University; R. Goldman, University of Waterloo; and me. These visits have resulted in work on geometric continuity (see

DeRose and Hagen), surfaces defined on surfaces (see Foley et al.), surface interrogation (Barnhill et al.), and nonuniform rational B-splines (see DeRose et al.). Pottmann is presently a visitor from Austria.

**Table 2. Computer Graphics and Computational Geometry Projects**

**Geo-Data/Computer-Aided Geometric Design Methods.** The objective of this research project is the mapping of surface or volumetric properties on geographic or geometric data structures. The use of CAGD techniques is being investigated because current methods are not flexible enough. Now the interface is being tested on applications with real data, along with work on database integration.

**Solid Modeling and Free Form Surfaces.** Solid modeling has become a very useful design principle in computer-aided design/computer-aided manufacturer (CAD/CAM) technology. Use of free form surfaces can increase the areas of applications for these methods. As a first step in this direction, modeling of solids by cross sectional input data is being investigated and will be implemented.

**Visualization of Tunnel Microscopic Data.** In many applications, a lot of data is generated that cannot be analyzed without further processing. The general goal of this project is to reveal hidden patterns in a mass of data by using various visualization techniques. Because of the tremendous progress being made in both hardware and software, in the near future the generation of photorealistic three-dimensional scenes will be possible in reasonable computation times. In a particular engineering application, pattern recognition techniques are to be used at a molecular level to test the properties of new materials under extreme loads.

**Geometric Modeling of Smooth Surfaces.** Computer-aided design of complex surfaces of three-dimensional objects is the central problem in CAD technology. The most successful approach to modeling of surfaces is by free-form, piecewise defined surfaces. Because it is not always possible to use rectangular patches, a continuing investigation is into the use of triangular patches along with rectangular ones.

**Quality Analysis Algorithms.** Surfaces constructed by free-form methods can be analyzed for overall quality and suitability in terms of smoothness before they are actually manufactured. The use of simulated reflection lines and isophotes make it possible to detect small curvature irregularities before nonequilibrium conductivity machining. Because the existing algorithms for this are too slow for many applications, the goal of this research project is to find more efficient algorithms for quality analysis of surfaces and to make them available for applications. The work, as well as classwork, is supported by a dozen Hewlett-Packard graphics workstations, including ten 9000 series 300 models, and two of the recent Turbo SPX models.

## Final Comments

The University of Kaiserslautern is a relatively young school, but I was impressed with the amount of scientific activity in mathematics and scientific computing. Neunzert has assembled an active group that aggressively pursues industrial applications. Hagen is a recent addition in a new discipline for Kaiserslautern, but has attracted first-rate students and is expanding the program rapidly. His program of short term visitors will help to keep new ideas coming into the group.

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# MECHANICS

## The European Mechanics Colloquia - Bifurcation Phenomena In Solids August 29 - September 2, 1989, University of Glasgow

by Michael J. Koczak, the Liaison Scientist for Materials for the Office of Naval Research European Office. Dr. Koczak is on sabbatical leave from Drexel University, Philadelphia, Pennsylvania, where he is a Professor of Materials Engineering.

### Introduction

The phenomena of bifurcation in solids can be utilized to explain compressive buckling of elastic solids and structures; e.g., shells, necking phenomena of sheets and bars in tension as well as the hydrostatic expansion of thin-walled weather balloons. The practical implications involve buckling and instability prediction of structures; e.g., compressive buckling of thick- and thin-wall structures, instability in supported tubes and pipes with internal flow at various velocities. A practical example of bifurcation phenomena is the unstable oscillation of a garden hose as a function of length and water velocity variations. Nevertheless, the question of prediction and control of these oscillations in engineering structures; e.g., tubes, shells, is a vital concern.

The concept of bifurcation theory involves the collaboration of applied mathematicians, mechanical, and materials engineers. The mathematicians can provide for the mathematical framework and continuum methods for the buckling analysis. The mechanical and materials engineers can respectively assess the variety of structural shapes and material's characteristics and degradation

that can be applicable as the input structures and material properties utilized in bifurcation analysis. The conference was funded by Office of Naval Research European Office, held in cooperation with Euromech, and organized and efficiently hosted by Professor Ray Odgen, Department of Mathematics, University of Glasgow, and Dr. Viggo Tvergaard, The Technical University of Denmark. The objective of the conference was to unite these three diverse technical groups under a common topic, review recent advances, and chart future directions. The difficulty with the identification of future research directions involves the broad technical scope of the topics and the necessary expertise required to understand the subtlety and limitations of each discipline.

### Technical Program Review

The symposium involved 35 presentations within a blend of mechanics, materials, and applied mathematics-related topics. A sampling of the structural mechanics papers included:

- Plastic Buckling/Collapse of Internally Pressurized Torispherical Shells - G.D. Galletly and J. Blachut, University of Liverpool, U.K.

- Analysis and Mode Interaction of Stiffened Panels Built Up of Anisotropic Composite Laminates Using "Pregnant" Beam Elements - S. Sridharan, University of Washington
- Some Observations on the Interactive Buckling of Thin-Walled Columns - J. Rhodes, University of Strathclyde, U.K.
- Surface Instabilities and the Complimenting Conditions - S.J. Spector, University of Minnesota
- On the Elastoplastic Buckling of Thin-Walled Structures - D. Durban, Technion, Israel
- Quasistatic Buckling of Viscoelastic Rods - D.W. Reynolds, University of Dublin, U.K.
- Progress in the Understanding the Buckling of Imperfect Pressurized Axially Compressed Cylinders - J.M. Rotter and J.G. Teng, University of Edinburgh, U.K.
- On the Instability of a Plastic Bar in Tension - N.C. Owen, University of Bath, U.K.
- Bifurcation of Elastic-Plastic Tubes under Internal Pressure - V. Tvergaard, The Technical University of Denmark

Materials and microstructural related topics included:

- Flow Processes in Layered Elastoplastic Materials - A.A. Prinaris, University of Colorado
- Rate Sensitivity, Void Nucleation, and Localization of Plastic Flow - A. Needleman, Brown University, Rhode Island
- Numerical Simulation of Shear Bands Comparison With Experiments - B. Schaeffer, Courcouronnes, France
- Bifurcation and Stability Analysis in Damage Mechanics - C. Stolz, Laboratoire de Mecanique des Solides, France
- Strain States Effects in Ductile Fracture - J.W. Hancock, University of Glasgow, U.K.
- Bifurcation in Cold Drawing Polymer - K.W. Neale, University of Sherbrooke, Canada

Fewer in number, the applied mathematicians contributed with regard to several diverse topics relating to perturbation analysis, behavior at multiple eigenvalues, stability of conservative systems under unilateral constraints, and spiral patterns of localizations. As judged by the diversity of topics, many of the audience (including me) did not have a complete grasp of the various presentations, and interaction was naturally limited. Possibly, an initial overview of the materials, mathematics, and mechanics aspects could be presented as a conference tutorial in order to stimulate enhanced interactions.

### Conference Highlights

**Bifurcation Analysis - Mechanics Aspects.** The plastic buckling response of internally pressurized torispherical shell was examined by G. D. Galletly et al., at the

University of Liverpool. The experimental results on 25-cm to 5-m diameter shells with a diameter to thickness ratio of 400, 500, and 600. The shell geometries were selected to accentuate the differences between deformation and flow theory. The deformation theory correctly predicted the failure mode buckling response in all six conditions, while flow theory was correct in only two geometries. The flow and deformation theory predictions and experimental results for buckling pressure for steel were compared with a yield strength of 310 MPa. The relative accuracy ratio for deformation theory prediction/experimental results were in the range of 0.71-0.94 while the flow theory results were lower; e.g., 0.65-0.81. The onset of failure was characterized by low-amplitude waves leading to wrinkling of the shell.

J.M. Rotter and J.G. Teng, University of Edinburgh, discussed the buckling response of large cylindrical structures. The authors bridged the gap between the classical theories; i.e., Hutchinson Model with the low strength projections, and experimental studies. The studies examined the competition between inward versus outward buckling and the sensitivity to imperfections; e.g., welds. The authors commented that matching of experimental testing, imperfection measurements, theoretical bifurcation predictions, and design allowable limits has not been resolved. In addition, they question what appear to be low design stresses for cylindrical civil engineering structures and the strength gains from internal pressurization. Professor Rotter provided for a good linkage between the analytical models and civil engineering practice.

Viggo Tvergaard, The Technical University of Denmark, presented additional papers on bifurcation analysis on analysis of elastic-plastic response of cylindrical tubes using membrane analysis and the prediction of secondary bifurcation points. S. Sridharan, Washington University, addressed the analysis of stiffened panels subject to interactive buckling. Sridharan's model was in excellent agreement with Tvergaard and Koiter's model and the experimental results of Thompson et al.

**Bifurcation Analysis - Materials Contributions.** Dr. A. Prinaris, University of Colorado, is examining the deformation processes in layered elastoplastic materials. The local instability wave or strain localization is followed from one plate to a second during tensile loading. The ferrous plates are modelled by a Von Mises yield criteria coupled with isotropic work hardening and Prandtl Reuss flow equations. The experimental results examine the velocity and local instability of the strain wave through a weldment and preliminary results were provided. Further studies seek to model weldments of HY100 where the strength of the weldment will be varied above and below the strength of the base material.

A. Needleman, Brown University, provided a review paper on strain rate sensitivity and micromechanical failure modes. The competition between local micro-

structural failure; e.g., microvoid formation, and macroscopic instability; e.g., localized buckling was discussed. In a similar discussion, J.W. Hancock, University of Glasgow, characterized flow localization processes under axisymmetric and plane stress conditions. The linkage between the bifurcation theorists and the materials engineers appears tenuous particularly when dealing with anisotropic materials in nonbuckling modes where the theories are generally applied.

## Conclusions

The future efforts of bifurcation analysis must try to address mathematics and mechanics of complex structure shapes and loading regimes, if the theories are to

serve more practical and complex engineering structures. The issues local geometry/property variations in weldments, cutouts, and geometry variations at joints should be assessed. The question of anisotropic material properties and property degradation should also be included. In addition, since most *isotropic* metals are truly anisotropic because of microstructural and texture effects, the variation in strength, modulus, and fracture toughness should naturally influence the results.

The organizers are to be commended for trying to bring in coincidence such a diverse group and focus the program on bifurcation theory. A more structured conference with greater time for focused discussion and, perhaps, a tutorial session could bring the participant into a better understanding and a more synergistic interaction.

# PHYSICS

## The Institute of Nuclear Physics, Siberian Branch of the U.S.S.R. Academy of Sciences, Novosibirsk

*by Marco S. Di Capua, the Liaison Scientist for Physics in Europe and the Middle East for the Office of Naval Research European Office. Dr. Di Capua is an experimental physicist from the Lawrence Livermore National Laboratory, University of California.*

## Introduction

During a recent visit, the director of the Institute of Nuclear Physics (Institute), Siberian Branch, U.S.S.R. Academy of Sciences, E. Kruglyakov, reviewed the three main directions of the Institute's work on electron beam and accelerator related topics:

1. Research with colliding beams in the 100- to 1-TeV energy range comprise about one-half of the effort
2. Controlled thermonuclear fusion (CTR) including plasma formation, heating, and confinement in open (mirror) magnetic systems (about one quarter of the effort)
3. Industrial applications (about one quarter of the effort) of electron accelerators that include
  - Synchrotron radiation sources for microelectronics
  - Electron sources for materials polymerization
  - Bremsstrahlung radiation sources for food irradiation, sewage disinfection (1 MeV, 100 kW continuous)
  - Electron beam sources for cutting and welding of materials.

At the end of the presentation, D. Ryutov led a tour of the laboratory.

## The GOL III Experiment

Since the early 1970s, Ryutov has been active in heating of open (mirror) plasma confinement systems heated by MeV, multi-kA,  $\mu$ s, electron beams delivered by pulse power sources. According to Ryutov, the goal is to enter a new regime of plasma conditions ( $1.0E + 16 - 1.0E + 17 \text{ cm}^{-3}$ , 1 keV) in a 6-8-cm diameter, 22.5-meter-long plasma column. The plasma is radially wall-confined (a 6 to 7 T field prevents radial energy transport) and multiple mirror axially confined (12-T mirror fields). The energy source for plasma heating is a 1-MeV, 50- to 100-kA beam with a duration of 5- to 7- $\mu$ s and an energy of 100- to 150-kJ (Ryutov, 1988). Turbulent heating (2 stream instability driven) takes place through collective interactions between the completely current neutralized beam and the background plasma.

The GOL III experiment, which was planned 10 years ago to test the concept, is close to operation in a new building. A thyristor switched, 10-MJ store of 6-kV capacitors charged at 4.8 kV feeds single turn Beryllium copper coils to produce the fields. A series connection

of four 2.5-kV thyristors switch one hundred 150- $\mu$ F capacitors that deliver a current of 8 kA from each 250-kJ section.

A field emission diode coupled to the "U 2," SF<sub>6</sub> insulated, LC generator electron source (Arzhannikov, 1989) (80-kA peak, 1 MeV, 100 kJ, 5  $\mu$ s) is presently under test. This large area, ( $\sim 1000$ s of cm<sup>2</sup>), large gap (5-10 cm) slit-shaped foil-less diode produces a ribbon beam with small angular spreads. The large dimensions of the foil-less diode reduce the difficulties that arise because of gap closure and the ribbon beam geometry circumvents problems associated with self-pinching of the beam at the diode. Another advantage of the ribbon beam is that multiple diodes could produce staggered beam pulses that can be switched into the plasma using techniques used in conventional particle accelerators.

After current neutralization, a transformation of magnetic flux tubes (through a Ying-Yang coil), which is not installed yet, will provide a 20-fold compression of beam area into a circle with 1-5 kA cm<sup>-2</sup>.

At present, a 20-kA peak, 50- $\mu$ s ring down discharge with a 15- $\mu$ s period produces a  $1.0E + 15$  cm<sup>-3</sup> H plasma in 1.0E-02 Torr prefill of H<sub>2</sub> in preparation for injection experiments. The foil-less configuration will require gas injection through a puff-gas valve.

### Ion Beam Diode Research

V.M. Fedorov uses the last water dielectric pulsed-power accelerator in Novosibirsk (VODA 1-10, 1 MV, 150 kA, 10 kJ, 60 ns) in a small ion beam research program. The diode configuration is a 15-kG applied B field ion extraction diode with a 9-cm inner radius and an emission area of 100 cm<sup>2</sup>. The anode is a 20-turn spiral of interleaved 0.3-mm Al and 0.75-mm Mylar. Fedorov operates the diode at a peak voltage of 0.7 MV producing equal amounts of electron and ion currents with a total

current of 100 kA with a mean energy of 0.5 MeV. A recent reference describes his latest results (Deichuli, 1988). The generator achieves grading of the stack through a "flux sucking" configuration. The flux sucker, unlike designs attempted in the U.S. that utilized cast epoxy dielectrics (Chen, 1979) that failed by puncture, is a cylinder consisting of a wound, water-impregnated mylar spiral. Fedorov has successfully operated the cylinder with fields of 700 kv cm<sup>-1</sup>.

### Conclusions

The GOL III experiment is unique since it is one of the last mirror configurations left in the world and the only mirror configuration heated by a relativistic electron beam. The experimental apparatus and the building constitute a very large investment by Soviet or Western standards and E. Velikhov's interest in the experiment had a large bearing on its funding. The results, which will be reported in the 8th International Conference on High-Power Particle Beams in July 2-9, 1990 in Novosibirsk, should be interesting indeed.

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## The International Workshop on Physics and Technique of High-Power Opening Switches

by Marco S. Di Capua

### Introduction

On July 1 and 2, 1989, the International Workshop on Physics and Technique of High-Power Opening Switches took place at Akademgorodok in Novosibirsk, U.S.S.R. The origins of the workshop go back to the 1984 East

Berlin Conference on Electrical Insulation and Discharges in Vacuum. During informal get-togethers, Soviet physicists in the pulse power field expressed great interest in plasma opening switches (POS), a field that was undergoing very rapid development in the U.S. On a quid pro quo exchange of pulse power information about Angara

5, their U.S. colleagues discussed some of the underlying physics of POS. This marked the beginning of Soviet activities in this area.

The scientific secretary, V. Bystritskii, performed an outstanding job in organizing the workshop and the connected scientific tours (ESNIB 89-10:39-41). Participants were from the U.S.S.R. (75), the U.S. (22), and Rumania (2), and the workshop languages were English and Russian, with simultaneous translation.

The workshop goal was to review the last 2 or 3 years' progress in theoretical and experimental investigations of high power POS over a wide range of time scales; to review their application to generation of x rays, charged particles and neutrons; and to provide a forum where common problems with this technology could be discussed.

This report summarizes some of the contributions of the Soviet laboratories. There were excellent presentations from U.S. pulse power centers: Naval Research Laboratory (NRL), Washington, D.C.; Los Alamos National Laboratory (LANL), Los Alamos, New Mexico; Sandia National Laboratories (SNLA), Albuquerque, New Mexico; Lawrence Livermore National Laboratory (LLNL), Cornell University, Texas Tech University, Lubbock, Texas, and Pulse Sciences Incorporated, San Leandro, California. A brief summary at the end of this report will attempt to capture the flavor of the U.S. presentations.

### **Contributions from The Institute of High Current Electronics in Tomsk (IHCE) and Tomsk Polytechnic Institute (TP)**

B.M. Koval'chuk, a corresponding member of the U.S.S.R. Academy of Sciences, and the head of the Pulsed Engineering Department at IHCE discussed experimental results obtained in GI-4, an experimental installation devoted to investigation of POS with microsecond conduction times.

The basic GI-4 pulse power driving module is an oil-insulated, 500-kJ Marx generator with an erected voltage of 1 MV, an inductance of 400 nH, and an erected capacitance of 1.1  $\mu$ F. Four modules connect in parallel to a 1.2-m-long, 100- to 400-nH coaxial inductive energy store with an outer diameter (anode) of 0.21 m, an inner (cathode) diameter that can be changed from experiment to experiment. Depending on the cathode used, the interelectrode gaps are from 3 to 7 cm. The inductance between the switch and the load is 60 to 150 nH. The peak short circuit current for this generator is 2.8 MA at 700 kV with a current rise-time of 1.5 to 2  $\mu$ s.

D. Getman and A. Kim described the 32 plasma sources on GI-4. They appear to be conventional polyethylene ablation plasma sources driven by a 10-kA pulse with a

2- $\mu$ s half-period. The guns are located at the outer electrode. Getman and Kim measured the properties of the gun plasma with Langmuir probes. The gun ejects the plasma in two bursts, a fast one with a velocity of  $1.0E + 07$  cm s<sup>-1</sup> and a slower one with one third the velocity. They measured a current of 25 A cm<sup>-2</sup>, 9 cm away from the gun in the first burst. The electron temperature in this burst was 7 eV.

A. Bastrikov, IHCE, carefully measured the electron flow to the anode and the ion flow to the cathode of the POS to establish the energy balance in the conduction and opening phases. As determined by calorimetry, the energy dissipated in the switch is consistent with energy calculated by integrating the product of switch current and voltage. More detailed measurements with Faraday cups appear to indicate that the energy deposited at the anode (about 30 to 40 percent of the total) is not connected with the electron flow. Filtered Faraday cup and activation measurements at the cathode (inner electrode) reveal that a flux of protons with energies comparable to the voltage drop across the switch account for the energy flux to the cathode. In early experiments, using plasma field diode loads with conical cathodes and axial plasma injection, a 480-kV Marx voltage delivered 2.1 MA to the switch and a peak current of 1.7 MA at 1.5 MV to the load. Koval'chuk described an attempt to increase the voltage in the switch through a systematic sweep of Marx voltages, plasma gun delay times, and diode geometries.

Since POS open more effectively with loads that draw large currents, Koval'chuk discussed a scheme to cascade a plasma opening switch and a plasma-filled diode. The description of the experiments emphasized the details of such a large number of diode geometries that I could not capture how effective this cascaded technique was in raising the load voltage.

The main conclusion of the GI-4 experiments is that the POS resistance drops dramatically for delay times longer than 1.5  $\mu$ s. However, long delay times are necessary to allow the generator to attain peak current. Koval'chuk apparently operated GI-4 in a "no-win" parameter space where he was unable to raise the "open" impedance of the switch above 1  $\Omega$ . A consensus developed at the workshop that POS on GI-4 could not achieve higher impedances because an increasing number of neutrals in the gap accompany the longer delay times. I could feel that the GI 4 experiments were a disappointment so far. The measured 1.5 to 2x voltage gain is below the 5x voltage gain that was expected in the design of the experiment.

Ya. Krasic described the beam research facilities under his direction at the Institute for Nuclear Physics, Tomsk Polytechnic University (INP TP). These are Vera, a 600-KV, 8- $\Omega$ , 80-ns generator; Tonus (1.2 MV, 50 kA, 50 ns, 0.03 Hz) and Double. Double, built by Koval'chuk at IHCE, is a 3- $\mu$ s, 600-900-kV, 8- $\Omega$ , 250-kJ

accelerator that delivers pulses of either polarity. With POS, Double delivers an 80-ns pulse to drive particle beam diodes.

In the Double experiments, Krasic found, as Koval'chuk did, a low opening voltage for long switch conduction times and improved performance of the switch for large plasma velocities and shorter delay times. A switch cathode configuration with spiral conductors that provide an additional axial magnetic field component increases the impedance of the switch by 1.5 x. This magnetic field component also appears to inhibit plasma motion towards the load. Krasic also drives an applied B-field diode with the short pulse from Double. He found that the diode magnetic field degrades the performance of the switch. The magnitude of the currents and voltages in the switch and the load are not available at this time. Nor am I able to confirm, from other sources, an 8- $\Omega$  impedance for the switch.

Krasic also discussed an intriguing technique to drive ion diodes with two short sequential pulses of opposite polarity from the nanosecond accelerator tonus. The first pulse creates a plasma on the cathode electrode. The reverse polarity pulse that follows extracts ions from the plasma preformed by the first pulse on the electrode that was the cathode, and that becomes the anode with the reverse polarity pulse.

V. Bystritskii, IHCE, is developing ion diodes in the Parus accelerator to produce high-intensity ion beams that V. Fortov will use as energy sources at the Institute for High Temperatures (IVTAN) in Moscow (ESNIB 89-10:33-35) to produce Mbar pressures in matter through ablation of target materials. Parus is a 800-kV, 2.8- $\Omega$ , 0.3-TW, 80-ns generator with a large (200-keV) prepulse. A spherical, applied B-field, magnetically insulated ion diode, where electron impact to the anode dominates anode plasma formation, produces about 100 A cm<sup>-2</sup> of ions that deliver about 600 J at  $1.0E+04$  A cm<sup>-2</sup> in a 2-cm diameter focal spot. Diode efficiency at 700 kV was about 20 percent. A spring pendulum and an acoustical probe determined the momentum coupled to the target through ablation of the target material. By coupling the 5.5- $\Omega$  ion diode with a shunt POS that conducts 300 kA and opens to 25  $\Omega$  in 10 ns, Bystritskii shortened the diode pulse to 40 ns producing a 1.5 x voltage gain in the diode.

In a poster, Bystritskii presented an idea for a Z-pinch experiment that has a remarkably different twist. In his concept, developed in collaboration with G. Mesyats' group at the Institute of Electrophysics in Sverdlovsk, Bystritskii proposes to focus the energetic ions that the POS produces as it opens onto an imploding deuterium liner. This liner is the electrical load that carries the generator current once the switch opens. With this approach, Bystritskii believes he can overcome the ion range limitation in the plasma caused by decreasing electron ion

collision cross sections. This bootstrapping approach, which could produce up to  $1.0E+13$  neutrons with a 100-kJ generator, is perhaps the most original concept I saw at this conference.

### Contributions from the Kurchatov Institute of Atomic Energy, Moscow

V. Smirnov, Troitsk Branch, I.V. Kurchatov Institute of Nuclear Energy, discussed the application of POS on Angara 5-1 (ESNIB 89-10:28-31) to reduce the effect of the jitter between the 8 modules and to improve trapping of the electron flow in the coaxial to disk current collector transitions.

The disk collector that connects the convoluted outputs of the 8 modules is very convenient for installation of the POS. The 24 plasma sources 30 cm away from the power feed, fire from a master trigger 8 to 10  $\mu$ s before the power pulse. A 1.5- $\mu$ f capacitor charged to 25 kV delivers a 30-kA pulse with a 2- $\mu$ s risetime to each gun. The plasma, produced in a carbon-coated polyethylene disk, reaches the switching region through rods in the anode. A spiral electrode collimates the plasma flow from the guns. A plasma burst of  $1.0E+13$  cm<sup>-3</sup> with a velocity of  $1.0E+07$  cm s<sup>-1</sup> is optimum for current commutation.

The POS, at a radius of 50 cm, carries 2 MA during the conduction phase of the switch. When the switch opens, current rise rates of  $1.0E+14$  A s<sup>-1</sup>, allow a current rise of 3.5 MA in 30 ns into an imploding liner load composed of thin wires. Smirnov estimated a 2.5 to 3 power amplification in this experiment that shortens, from 70 to 30 ns, the current rise time to the load. Smirnov concluded that he needs more detailed information to assess the effect of shorter current rise times on liner stability and liner radiation output.

L. Zakatov described G. Dolgachev's opening switch experiments on the Taina facility at the Kurchatov Institute in Moscow. In Taina, two coaxial energy stores meet at a common plane, which is the location of the POS. The 500-kV Marx generators deliver 100 kA to each of the 1.5-m-long, 30-cm OD, negative inner conductor coaxial stores. The clever idea behind locating the switch at the symmetry plane of a double-sided feed, is to eliminate axial acceleration forces and to produce exclusively radial ion acceleration, thereby causing switch operation exclusively in the erosion mode. This eliminates the opening physics associated with axial ion acceleration.

Zakatov injected a  $1.0E+13$  -  $1.0E+14$  cm<sup>-3</sup> (5- to 10-mC) plasma into the gap from 72 guns along a 10-cm distance and along a 50-cm distance. The translator missed the difference in the details of the physics for these two configurations. The peak current in the switch was 200 kA with 1.2- $\mu$ s conduction time, and the peak opening voltage was 1.5 MV with a 150-ns pulse width with a 150 kA into the load. The ion current density was 500 A cm<sup>-2</sup>.

Zakatov measured electron density in the plasma through Stark broadening of the H alpha line and obtained the distribution of radial ion energies with Thompson parabolas. In another experiment, Zakatov cascaded two POS and established that the switch opens caused by the erosion of a critical amount of charge rather than at a threshold current. This observation suggests that the experiment operated in the desired radial ion current mode.

To settle the issue of current versus charge control of POS opening, L. Zakatov suggested feeding the switch with a current wave form with a spike. A variable timing and magnitude for the spike would produce current pulses with the same charge and variable peak current.

### Contributions from the D.V. Yefremov Scientific Institute of Electrophysical Apparatus

V.I. Engelko described work on a magnetically insulated vacuum transmission line (MITL) with 3- $\mu$ s pulses. This is a long pulse compared to the 50-ns or so pulses that are normally associated with MITL operation. The 2-m-long coax has an inner radius of 6.25 cm and an outer radius of 15 cm. The pulse power source is a 1-MV Marx generator with a 120-nF capacity. Several diode configurations (planar, spherical, and blade) terminated the transmission line. Engelko mapped the electron flow in the gap by inserting charge collectors and determined that the current density peaks at radius where Creedon's parapotential flow theory predicts the edge of the sheath should be. However, unlike predicted by theory, the electron flow extends as far as the anode. These data settles a long-standing question on how far across the gap the current sheath extends in a MITL and profiles of current density could be used to validate the results from numerical simulations.

### The U.S. Presentations

The general caliber of the U.S. presentations was excellent. The speakers had taken the time to prepare their work and spoke clearly, slowly, and distinctly so that translators, as well as English-speaking U.S.S.R. scientists in the audience, could follow. Presenters, affiliation, and topics follow.

- C. Mendel (SNLA) - electron flow launched during the POS opening process
- P. Ottinger (NRL) - theoretical POS work at NRL
- R. Commiso (NRL) - short and long conduction experimental results
- N. Roderick (University of New Mexico) - two-dimensional single fluid MHD simulations of POS

- R. Mason (LANL) - the ANTHEM and ISIS simulations that use an implicit moment method to circumvent time step and cell size limitations normally encountered in plasma calculations
- D. Hinshelwood (NRL) - experimental work on microsecond conduction switches
- D. Mc Daniel (SNLA) - POS experiments on PBFA II
- R. Stinnett (SNLA) - ion diode experiments on PBFA II
- R. Reinovsky (LANL) - exploding foil switches
- A. Guenther (LANL) - laser activated switches
- P. VanDevender (SNLA) - pulse power switching for ICF
- I. Vitkovitsky, (RDA, Alexandria, Virginia) - high voltage characteristics of metal vapors
- R. Bartsch (LANL) - plasma flow switches
- H. Kirbie (LLNL) - magnetic switching techniques
- J. Osher (LLNL) - exploding foils as opening switches
- P. Turchi (RDA) - plasmadynamic processes in opening switches

### Conclusions

Roundtable discussions at the end of the sessions underscored a substantial progress in the understanding of POS for short pulse operation (50-100 ns). Recent progress in numerical simulations of short conduction times POS (Mason, 1988, 1989) suggests that the POS opening process is more complex than a simple combination of ion erosion and magnetic insulation. The present understanding of physical processes in the POS suggests that opening takes place through three mechanisms:

1. A magnetic piston opens a gap in the plasma at the cathode. Some ions propelled into the cathode account for the "erosion" feature of the opening suggested in previous theories.
2. Magnetic insulation at the anode as  $v \times B$  forces push the conduction electrons towards the load.
3. Advection as magnetic fields get carried downstream with emission electrons.

On the basis of these mechanisms, an "opening current", or "charge transfer" may be overly simplistic parameters to characterize the opening of the switch.

There still remain many open questions about the underlying physics of the switch for long conduction times (300 ns or more). There are phenomena that may be important and are not included in simulation models. For example:

- Do plasmas formed at the electrodes affect the physics of the switch?
- Can neutrals become a source of charged particles in the switch?



- Do ions conduct a large fraction of the currents?
- Do ions with directed velocities (inertial ion conduction) have a role in POS conduction and opening?
- How does the self-magnetic field affect the conductivity?

Better diagnostics could provide an answer to these questions: mapping of magnetic fields, electric fields, electron density; and diffusion of electrode plasmas.

Some technology issues were also brought up in the question period were:

- Can plasma switches be synchronized?

- Triggering of POS with transient applied magnetic fields and enhancing (toggling) switch operation with self fields as suggested independently by C. Mendel, SNLA, and Ya. Krasic, INP TP.
- How to retrap electron currents launched by the switch?

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# The HELIOS Superconducting Synchrotron X-Ray Source

by Dr. Marco S. Di Capua, the Liaison Scientist for Physics and Dr. Dean L. Mitchell, the Liaison Scientist for Solid-State Physics in Europe and the Middle East for the Office of Naval Research European Office.

## Introduction

The High-Energy Lithography Illumination by Oxford Instruments (HELIOS) is a compact (6m x 2m x 3m), high-power (8.2 kW), superconducting (4.5 T), 200-mA @ 0.7-GeV synchrotron source of 0.8-nm x rays for x-ray lithography that will be operational in the summer of 1990. This article, based on two independent liaison visits by the authors, presents a brief introduction to x-ray lithography, traces the development of compact synchrotrons in Europe, describes HELIOS in some detail, and summarizes synchrotron source developments in the U.S. and Japan.

## The Motivation for X-Ray Lithography

The improvements in integrated circuit performance since their invention in the 1950s depend, to a large extent, on successive reductions in the scale of features on the surface of the wafer, thus increasing the density of junctions per unit area of silicon chip. However, optical technology has reached the limit imposed by diffraction of light so that creation of features that are smaller than 0.5  $\mu\text{m}$  will require radiation of much shorter wavelengths; i.e., x rays. An added benefit of the shorter wavelength radiation is a larger depth of focus for well collimated beams. Therefore, features in the wafer can be thinner as well as taller.

In the past few years, a substantial amount of effort has been devoted to the development of intense (100 mW  $\text{cm}^{-2}$  at the wafer surface) well collimated x-ray sources

(1-mrad divergence). Promising candidates, such as gas puff Z-Pinches, plasma focii, and laser-produced plasma sources have fallen short of the semiconductor fabrication industry requirements for reproducibility, intensity, divergence, and compatibility with a clean microfabrication environment. Consequently, the only sources at present that appear to meet industry requirements are compact electron storage rings configured as synchrotron radiation sources.

A parallel development effort on the basic processes for x-ray lithography has been underway for over a decade at synchrotron radiation centers in the U.S., Japan, and Europe. All of the steps necessary for processing silicon chips with submicron feature sizes, as may be necessary for developing the next generation 64-M bit chips, have already been demonstrated at these centers. However, sources at synchrotron radiation centers are not suited to the scaleup of silicon chip fabrication to pilot line or production line processing. Therefore, projects are now underway to develop compact electron storage rings as x-ray synchrotron sources that would be suitable for commercial x-ray lithography.

## Compact Synchrotrons in Europe

The compact electron storage ring for synchrotron radiation (COSY) at the Fraunhofer-Institut für Mikrostrukturtechnik (IMT) at Berlin-Dahlem, Federal Republic of Germany (FRG), was the first of the "table-top" synchrotron projects to be carried through to the construction of an actual machine. The design, assembly, and

commissioning phases of the COSY project, now over 5 years old, are performed by the machine physics group at the Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung (BESSY) located adjacent to IMT.

The COSY synchrotron is a split-dipole ring with superconducting magnets, similar in over-all features to the HELIOS ring described in more detail below. The bending magnets are designed for a field of 4.5 T with a bending radius of 0.44 m. Siemens, FRG, is developing the superconducting magnets. The COSY injector is a 50-MeV microtron, supplied by Scanditronix of Uppsala, Sweden.

Difficulties in developing superconducting magnets that could meet design specifications have delayed the COSY project. Because of the delays, conventional resistive magnets were retrofitted to COSY in 1988 to allow machine assembly to proceed. The superconducting magnets have now been installed (spring 1989) and the commissioning phase is underway.

Oxford Instruments (Oxford), Oxford, U.K., a superconductor magnet specialist company, was involved in the early planning for the COSY synchrotron source and submitted a bid for a compact storage ring but was unsuccessful. In June 1987, IBM approached Oxford; Oxford was awarded a contract to build HELIOS, a 700-MeV storage ring, scheduled for delivery in June 1990. The HELIOS source will be used to develop advanced lithography techniques at IBM's East Fishkill Advanced Lithography Facility (Pool, 1988). The HELIOS project employs 70 people and is expected to cost \$15 to \$20 million when complete.

## HELIOS Description

The motivation to construct a superconducting synchrotron radiation source lies on the scaling of the radiation wavelength  $\lambda_c$  (nm) with radius  $\rho$  (m) and magnetic field  $B$  (T):

$$\lambda_c = \frac{20.7}{\rho^2 B^3}$$

and the scaling of the product of radius and magnetic field with particle energy  $E$  (MeV):

$$B\rho = \frac{E}{300}$$

Considering 0.6-1.2-nm x-ray wavelengths for present mask/resist technologies, iron core magnets, limited to fields of 1.3 T result in bending radii of 3.4 m and electron energies of 1.3 GeV. These accelerator dimensions and electron energies are far too large for a microfabrication environment. On the other hand, 4.5-T fields from a

superconducting magnet result in 0.5 m bending radii and 0.7-GeV electron energies, reducing not only the size of the ring but reducing the shielding requirements arising from smaller electron energies.

The main components of the HELIOS source are a LINAC injector, an injection transfer line from the LINAC to the ring, pulsed septum and kicker magnets, a radio frequency (RF) accelerating cavity, two 180-degree superconducting bending dipole magnets, four conventional focusing magnets, and ancillary vacuum and cooling equipment. The HELIOS operation is shown sequentially in Table 1.

Table 1. HELIOS Operation

- LINAC injector produces 200 MeV electron bunches
- Transfer line guides the electrons to the septum magnet
- Combination of pulsed fields from the septum and kicker magnets switches the bunches into racetrack orbits
- Bending and quadrupole magnets constrain the electrons to follow the racetrack orbit
- When 200 mA of electrons are accumulated, the RF cavity raises the electron energy to 700 MeV as the dipole field ramps
- Electrons radiate x-ray energy in their orbit around the dipole magnets
- Power from the RF cavity replenishes the 8 kW of power radiated as x rays
- Collisions with residual gas molecules in the vessel will extinguish the beam in time scales of about 5 hours

After the beam has decayed to unacceptable levels, the process begins again.

The biggest technical challenge in the HELIOS has been the development of the superconducting dipole magnet. Field design required the refinement of highly sophisticated magnetostatic computation codes (Simkin, 1989). The interface of structural components to withstand forces of several hundred tons with cryostats, radiation shields, liquid helium vessels, and vacuum systems while keeping tangential radiation beam lines open is a major technical feat. The repetitive pulsed power modulators that drive the pulsed septum and kicker field magnets are also an advance in the state of the art (Kitchin, 1989).

According to Martin Wilson, who heads the HELIOS project, the dipole magnet is possibly the most challenging of the 10,000 superconducting magnets designed by Oxford because of the precise shaping of the magnetic field, the clear gap for the x-ray output, the large forces it must withstand, and the ability to maintain field quality as the field ramps between the injection value and the full value in a few minutes.

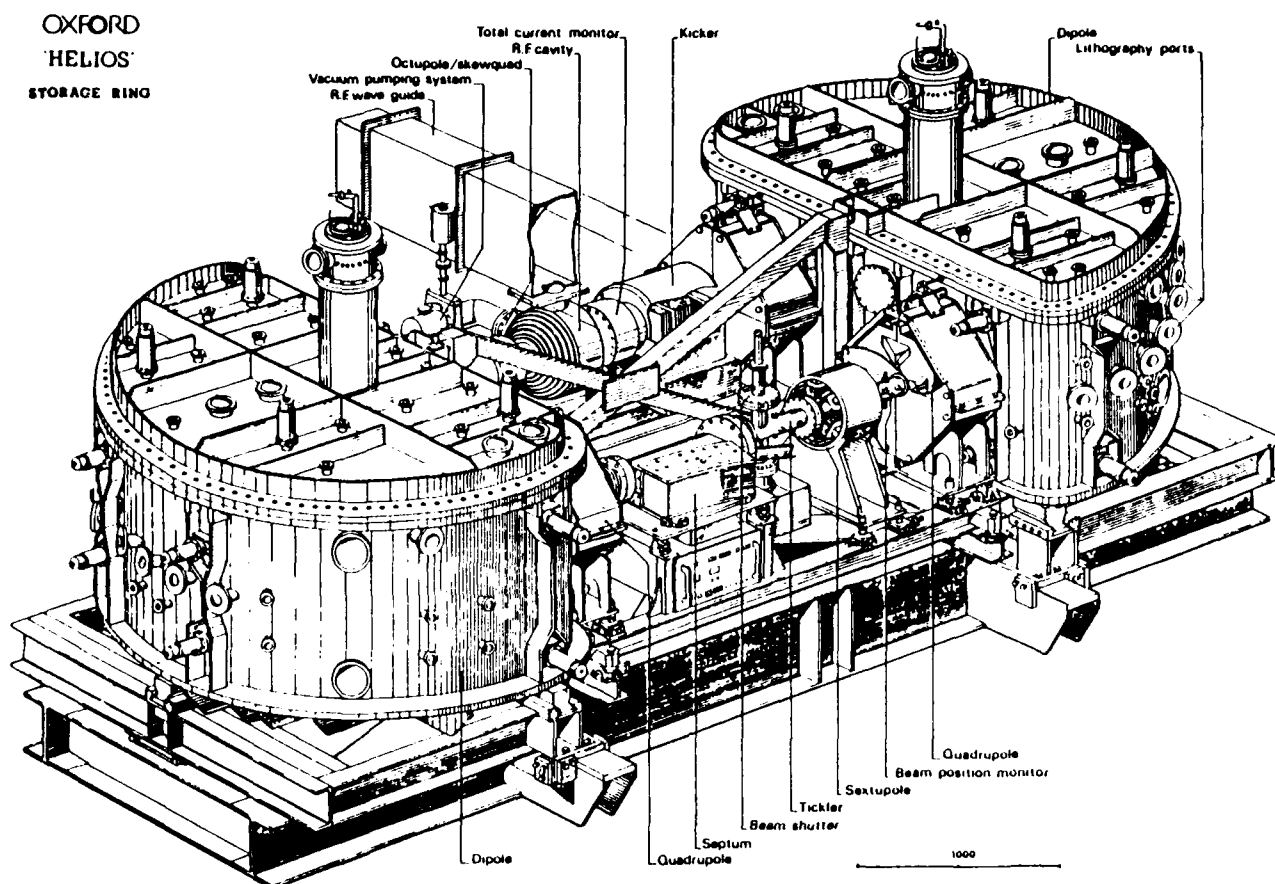


Figure 1. The HELIOS compact storage ring is shown as assembled in the Oxford Instruments Research Center, Oxford, U.K. The base, vacuum line, and quadrupole magnets are shown. The dipole magnets, not yet installed, will be installed on the base at the extreme left and behind the injection magnet for the LINAC in the foreground.

## Status of HELIOS

The 200-MeV LINAC injector supplied by CGR MeV, a subsidiary of GE Medical, has been installed and tested up to the entrance septum for the storage ring. The injector exceeds all specifications and delivers 20 mA of electrons at 200 MeV in 120-ns pulses at 10 Hz with an emittance that is one third of what was specified. All components of the ring, except for the dipoles, are in place and the magnets have been powered under computer control. The RF cavity is also operational. An illustration of the assembled machine but without the dipole magnets is shown in Figure 1.

One of the dipole magnets has been assembled and tested at cryogenic temperatures; it achieved its design field and the field profile has been confirmed experimentally. There are no observable distortions of the field from computational errors, fabrication tolerances, or magnetization of the structural steel. Measurements will continue throughout the end of 1989 and the dipoles will be installed in their operational cryostats in spring 1990.

The first circulating beam is expected in summer 1990 and shipment of the system to IBM, aligned and under vacuum, will take place 2 to 3 months thereafter.

Tests will be run during commissioning to determine whether operation is possible at lower injection energies than the full 200 MeV, which was conservatively chosen for the prototype. If so, then the size of this, and subsequent installations can be reduced accordingly.

## Developments in Europe, Japan, and the U.S.

According to Wilson, two similar rings are under construction in Europe, one at the IMT Berlin, as mentioned earlier, and HELIOS. Also, Scanditronix, the Swedish company that built the BESSY storage ring in Berlin, is studying the possibility of building a commercial synchrotron source by using a superconducting microtron as an injector to an electron storage ring along the COSY lines.

Projects for the construction of compact rings are also in progress in the U.S. and Japan. In the U.S., the Defense Applied Research Agency is providing support to build a source with machine design by Brookhaven National Laboratory; and, Maxwell-Brockbeck of San Diego is developing a source for the Louisiana State University Advanced Microstructures and Devices Center. The Office of Energy Research of the U.S. Department of Energy will also invest \$15 million in 1990 in a similar effort (Crawford, 1989).

In Japan, Sumitomo Electrical Industries' conceptual design has four superconductor 90-degree magnets; Sumitomo Heavy Industries has a circular weak focusing synchrotron/storage ring with a large superconducting magnet and a novel injection scheme; Nippon Telephone and Telegraph is sponsoring a conventional eight-sector ring at Toshiba and a superconducting two-sector ring at Hitachi. Finally, SORTEC, a consortium of 13 Japanese companies, is planning a ring at the photon factory in Tsukuba.

For more information, contact

H. Kitchin  
Bournlea Instruments  
Bentley Manor  
Ipswich IP9 2LS, U.K.

J. Simkin  
Vector Fields Limited  
24 Bankside  
Kidlington OX5 1JE, U.K.

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## PSYCHOLOGY

### International Workshop on Dexterous Manipulation and Teleoperation

*by Gerald S. Malecki and John M. Hollerbach. Gerald Malecki is the Liaison Scientist for Human Factors and Behavioral Sciences at the Office of Naval Research European Office. He is on leave from the Office of Naval Research, Arlington, Virginia, where he is a Scientific Officer in the Cognitive and Neural Sciences Division. At the time of the workshop, John Hollerbach was Associate Professor in the Department of Brain and Cognitive Sciences at MIT. In September 1989, Hollerbach became Professor at McGill University with joint appointments in Mechanical Engineering and Biomedical Engineering; he holds the Natural Sciences and Engineering Research Council, Canadian Institute for Advanced Research Chair in Robotics.*

#### Introduction

An international workshop on dexterous manipulation, sponsored by the Office of Naval Research, was conducted at Oxford University, U.K., August 7-10, 1989. The meetings were cochaired by J. Michael Brady, Oxford University, Department of Engineering Science, and John Hollerbach, MIT, Department of Brain and Cognitive Sciences. Approximately 30 scientists and engineers from Europe and North America participated. The purposes of the workshop were to review recent research findings in biological motor control and robotics, and to discuss the potential convergence of these two lines of scientific inquiry toward the development of new theories and models for sensing, grasping, coordinated movement, and manipulation.

A particular goal of the workshop was to consider dexterity in teleoperation and to project how the human and robot studies might assist this goal. From a biological perspective, there were discussions of muscles, cutaneous receptors, kinesthesia, haptics, grasping, and the human

operator transfer function. From the engineering perspective there were presentations on contact mechanics, tactile sensing, grasping, arm control, teleoperation (including force-reflecting master gloves), and novel actuators.

#### Background

Interdisciplinary research in the biological sciences and engineering sciences related to sensory-guided motor control of robotic systems is an expanding area of scientific investigation both in Europe and North America. One of the goals of this line of research is to develop robotic devices capable of accomplishing dexterous handling and manipulation in unstructured environments. That capability will require significant improvements in sensing and end-effector performance--capabilities that would approximate the high levels of human perceptual-motor performance.

End effectors of the majority of operational manipulators are essentially some form of a vise gripper rather

than a mechanical hand and the sensing capabilities of these grippers and arms are rudimentary. Current robot grippers are largely inadequate in unstructured environments in that they can only handle parts of restricted shape, have limited sensory feedback, and cannot execute fine motions to complete a task. To overcome this shortcoming, research on multi-fingered robot hands with tactile sensing, has flourished in recent years. Comprehensive and very informative overviews of previous research on tactile sensing and dexterous robot hands are contained in Dario & De Rossi (1985), Siegel (1986), and Hollerbach (1987). Hollerbach traces the progress of multi-fingered hands starting with the pioneering work in 1977 by Okada with the development of the Electrotechnical Laboratory (ETL) three-fingered hand in Japan through the development of the sophisticated hands; e.g., the three-fingered Stanford/JPL Hand and the Utah/MIT Dexterous Hand (four fingers, 16 degrees of freedom, Jacobsen et al., 1986). Figure 1 is an artist's drawing of the UTAH/MIT Dexterous Hand.

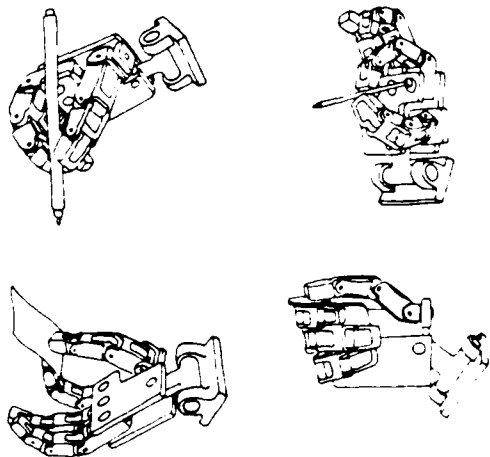


Figure 1. Artist's Drawing of UTAH/MIT Dexterous Hand

These hands still reside in laboratories and the goal of the research with these devices is fully autonomous computer control; substantial progress towards this goal has been made, and the body of literature is growing on how to plan a stable grasp, how to execute fine motions, and how to interpret tactile information. However, much remains to be accomplished to meet the extreme demands on performance and packaging, particularly with regard to sensor-driven control strategies, computational control architectures, integration of force, tactile and thermal sensors, the display of tactile information, and the design of more effective actuators.

With the recognition that autonomous control of multi-fingered dexterous robot hands is a long-term goal, there has been growing emphasis on teleoperation. Here the human brain substitutes for the computer and the

human hand itself is the interface to the slave hand. Human factors then becomes an issue, particularly with regard to the design of the master controller, which should have the capability of force-reflection, tactile sensibility, sense of finger position, and grasping control properties. In addition, an understanding of the human operator transfer function becomes important for dynamic control.

## Organization and Structure of the Workshop

The workshop was organized into the following sessions:

- Human and Robot Tactile Sensing
- Dexterous Hand and Arm Control
- Novel Actuation
- Teleoperation and Current System Applications

Each session was comprised of four or five lectures given by leading investigators in the field. The purpose was to summarize recent research results and to suggest promising lines of investigation to deal with priority research questions. The lectures were followed by discussion periods designed to elicit comments from all participants.

## Human and Robot Tactile Sensing

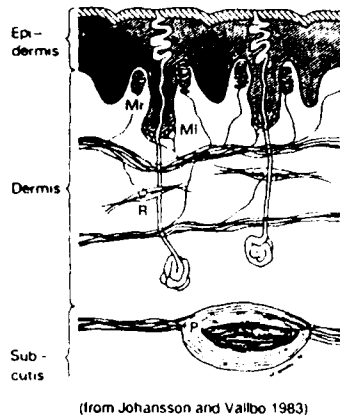
The first session addressed two topics--mechanisms and processes underlying human tactile sensation and perception, and the design of novel robotic tactile sensors.

**Human Sensing.** Two lectures were presented on human tactile and force sensing. The first was given by Ken Johnson, Johns Hopkins University, Baltimore, and the second was presented by Roland Johansson, University of Umea, Sweden. These presentations were concerned with elucidating the following issues about tactile sensation and perception--the nature of stimuli, their transduction and representation, what to sense, and how to engage the sensory system.

Johnson's presentation discussed the physiology, psychophysics, and modeling of the mechanoreceptors; and the representation of the mechanoreceptor afferent information in the somatosensory cortex. He first described the response properties of three receptors--the Meissner, Merkel, and Pacinian. The Meissner and Merkel endings lie close to the skin surface and have sharp receptive fields. The location and characteristics of these receptors are shown schematically in Figure 2.

The Meissner endings respond only to moving stimuli, while Merkel endings respond to static pressure as well. Skin mechanics for small deformations can be modeled as an ideal continuum elastic medium. The Meissner

response can be modeled as a linear strain sensor responding to tangential tensile stress, and the Merkel response as a strain sensor responding to maximum compressive stress regardless of direction. The Pacinian receptors lie deep in the skin and have broad receptive fields. They respond to high frequency dynamic stimuli up to 500 Hz. Altogether, the sensor density in the fingertip is 1 unit/mm<sup>2</sup>, and the spatial acuity is 1mm; the density systematically decreases proximally. The Merkel endings are responsible for fine form discrimination (features larger than 1mm). Below 1mm, the perception is of roughness or texture, and it is not fully understood how the mechanoreceptors contribute to this perception. The Meissner and Merkel responses are replicated intact in the somatosensory cortex, indicating that up to this level the neuronal processing does not compress the afferent information or lose resolution.



KEY	RECEPTOR	FIELD	TYPE	SENSED PARAMETER
Mr	Meissner corpuscles	3-4mm	FA I	Skin stretch
MI	Merkel disks	3-4mm	SA I	Compressive stress (curvature)
P	Pacinian corpuscles	>20mm	FA II	Vibration
R	Ruffini endings	>10mm	SA II	Directional Skin stretch

Figure 2. Human Mechanoreceptors

In particular, Johnson investigated tactile letter recognition and the representation of this tactile form in the somatosensory cortex (Phillips, Johnson, and Hsiao, 1988). Experiments demonstrated that letter recognition performance in humans is the same whether the subject actively scans the letters or the letters are passed over the passively restrained finger. In primates, processing of the afferent information by 40 percent of the cortical neurons could be represented by a simple, multilayered network with linear synaptic mechanisms, essentially implementing a Walsh-Hadamard transformation. These clear findings provide descriptive evidence concerning the nature of the transformation and representation of tactile stimuli; they also afford a basis for the design of an improved tactile display.

Roland Johansson's presentation dealt with tactile afferent units in precision grip-force control. These units, on the inside of the hand, signal information related to the mechanical status of the skin to the central nervous system through fast myelinated fibers. Their sensitivity to skin deformation changes and their location close to the points of contact with manipulated objects make them efficient sensors. His talk specifically addressed how tactile afferent units innervating the skin of the fingers actually respond during manipulative movements, and the significance of those responses for the control of the manipulation. Johansson described a series of studies involving manipulating an object with the thumb and an opposing finger (Johansson 1989). The experiments produced a clearer understanding of how mechanoreceptive afferent units in the glabrous skin are utilized in adapting the motor commands. The experiments also demonstrate the relationships among the weight of the object, its frictional characteristics, slip, grip force, and load force. These data have clear implications for the design of improved robotic sensors and control strategies for dexterous handling and precision gripping, and some of Johansson's findings already have been implemented in the robotics laboratory at Stanford University.

**Robot Sensing.** These presentations on human sensing were followed by lectures on robotic sensing presented by Mark Cutkosky, Stanford University; Danilo De Rossi, University of Pisa, Italy; Ron Fearing, University of California, Berkeley; and Hugh Durrant-Whyte, Oxford University, U.K.

Cutkosky described his research on sensing of skin accelerations and stress rates for slip detection and texture perception. He described strategies for sensing the contact status with a combination of conventional tactile arrays and dynamic sensors that are activated by motion of the hand. The dynamic sensors include piezoelectric strips that measure the rate of change of stress in the skin and small accelerometers that measure skin accelerations and can detect the onset of slipping. The skin acceleration sensor is mounted on a finger end effector within a flexible skin which decouples the sensor from the robot structure. Data of the sensors' response were presented, together with experimental results for textured surfaces. A long-term goal of this research is to develop a low-level, high-bandwidth "reflex" control loop around the contacts using force and tactile information.

Fearing described his work on extracting local shape information, in the form of local curvatures, from a cylindrical tactile sensing finger tip. This local shape information can be used to predict the orientation of an unknown grasped object. Three tactile curvature measurements with a capacitive sensor on a solid surface of revolution were shown to be sufficient for determining the axis, except for certain singular configurations with error

bounds in the vector position of .05 inches and 4.9 degrees in direction.

Durrant-Whyte presented his work on the development of a tactile sensor utilizing a layer of photoelastic material. A force pattern impinging on the surface of this photoelastic material ("tactile skin") results in a characteristic optical stress pattern that can be imaged by a CCD array. This stress pattern reveals not only normal forces, but also enables shears and torques to be identified. Several experimental prototypes have been fabricated and the investigators are evaluating image-processing algorithms to interpret the tactile data.

De Rossi's lecture focused on tissue-analog polymer sensors with mechanoelectrical transduction properties. The sensor is composed of two subsystems made of different materials and functionally separated. An uppermost "pseudo-epidermal layer" contains an array of sensors made of a combination of piezoelectric polymer elements capable of resolving six independent components of the stress tensor field. The "pseudo-dermal layer" determines the mechanical properties of the integrated sensor structure. The sensing pad is made of a polyelectrolyte gel with transduction properties that can be exploited to sense strain rate and dilation. Its skin-like mechanical properties may offer a method to implement human-like contact modalities in terms of pressure adaptation, progressive object coverage in nonconformal contact to secure stable grasp, and tissue compliance. This very interesting and promising line of research includes analytical studies using an inverse problem approach to tactile sensing.

### Dexterous Hand and Arm Control

This session covered investigations involving psychophysical and perceptual experiments, computer simulations, mathematical modeling, and control algorithm developments dealing with grasping, object exploration, and hand control.

**Human Hand Control.** Nat Durlach, MIT, was the lead speaker for the psychophysical and perceptual studies, and he addressed the resolving power of the hand with respect to resolution of object length, force, and compliance (the inverse of stiffness). He first reported on length resolution in experiments involving forefinger and thumb spanning a reference length under different conditions of finger separation and handedness (Durlach et al., 1989). The results show that the just-noticeable difference (JND) for length resolution is in the 5-10 percent range, and is degraded by 20 percent when the nondominant hand is used. Results on the identification of length showed that it was much poorer than discrimination as indicated by the JND; this result is roughly similar to those found for other dimensions and modalities. Preliminary results were next presented on the resolution of force  $F$ , under conditions of different initial

finger pad separation  $S$  and the amount of movement  $D$  during squeezing of the apparatus's axes. The JND was approximately 7 percent independent of  $D$  and  $S$ . Finally, preliminary results were presented on the resolution of compliance, which were around 30 percent. These results are much worse than those for force and length resolution. For the compliance experiments, there is a strong tendency to overestimate stiffness when the displacement  $D$  is large, and to underestimate stiffness when  $D$  is small. The conclusion was that work (force times displacement) plays a central role in the discrimination of compliance or stiffness.

Susan Lederman, Queen's University, Canada, reported her recent findings in haptics research. Haptics builds on the tactual system and incorporates information from cutaneous sensors in the skin and kinesthetic sensors in muscles, tendons, and joints. Haptics' sensory primitives include pressure, vibration, position, and thermal properties. Her research focuses on models of sensori-motor behavioral patterns underlying haptic perception, specifically exploratory arm and hand strategies and procedures that are used to determine an object's substance (e.g., texture, hardness) and structure (planar and three-dimensional [3-D] shape and size). Her findings, summarized in Klatzky & Lederman (1989), clearly demonstrated relationships between prototypical exploratory patterns and object features relevant to the identification of texture, hardness, thermal properties, weight, volume, contour, and global shape. Current research is investigating the intriguing questions of higher-level processing and integration of haptically encoded information for complex tasks such as assembly and disassembly of physical structures.

**Human Arm Control.** Ian Hunter, McGill University, Canada, described research on the human operator transfer function in the context of telerobotics and medical microrobotics; this work was performed in collaboration with Lynett Jones of the same institution. In the past, the human operator had been modeled as a single system that is approximately linear. However, this model failed to generalize across experimental conditions and to reflect the existence of nonlinearities and short-term time variations. Jones' and Hunter's work instead decomposed the human operator tracking task into contributions made by four critical subsystems.

1. Visual processing where information about the mismatch between the actual and desired target position is provided
2. Cognitive processing where this target error is used to generate new corrective muscle commands to the arm
3. Excitation to force dynamics where nerve input to the muscle is converted to contractile force
4. Muscle-limb mechanics where muscle force generates limb movement.

Each subsystem has its own dynamics, which may always be constant or vary under different conditions, which contribute differing delays to the overall human operator transfer function, and which exhibit strong individual differences. Hunter described novel instrumentation and nonlinear system identification techniques to infer the dynamics of each subsystem separately. One important result is that muscle-limb mechanics change substantially depending on the amount of force of contraction. In particular, muscle stiffness and viscosity increase substantially with force level. This is in stark contrast to the linearity assumptions of the past. Another result shows the importance of the mechanical properties of the interface device (master) on the human operator performance. High stiffness levels of the manipulandum decreased tracking delay, although accuracy was optimized at moderate stiffness. Jones' and Hunter's studies have strong implications for designing human operator interfaces that are adapted to each individual, and is discussed later.

Marc Jeannerod, INSERM, Lyon, France, reported on his work concerning a model of visually-guided reaching and grasping. The act of prehension requires coordinated control of arm and fingers and is composed of two motor control components: a transport component and a grasping component. These components correspond to identified channels for the processing of visual information, one for the location of objects in space and one for processing the size or shape of objects. Jeannerod described the results of experiments designed to investigate unanswered questions concerning the level of coupling between the transport and grasp components. Preliminary data indicate that the two components are time coupled but each visual-motor channel appears to be effected independently.

**Robot Hand Control.** Mark Cutkosky discussed the importance of skin mechanics in grasping. Although much of the literature idealizes finger contact as a point with sliding friction, in actuality a more realistic model emphasizes rolling and sliding of fingers during contact, the geometry of the fingertip, and the indentation of the finger covering or skin. When substantial deformation of the skin occurs, plastic deformation models may be useful. Models and experiments show that the behavior of the grasp is quite sensitive to the finger/object contact condition. An intriguing possibility therefore is to provide robotic hands with fingertips where the firmness can be dynamically controlled in order to control the grasp stability and the rate of energy dissipation in the grasp. An example was presented of a robotic fingertip filled with an electrorheological fluid. This talk makes clear that skin must serve two functions: as a medium containing tactile sensors and as a covering enhancing grasp stability.

Ron Fearing showed how controlled slip could play an important role in grasping 2- and 3-D polygonal objects. In two dimensions, when fingertips are modeled as point force sources with Coulomb friction, objects will automatically align themselves in a grasp caused by a beneficial interaction of friction and geometry (called accidental compliance by some investigators). This strategy can be extended to manipulating objects in a grasp; e.g., twirling a pencil. Fearing then showed how this strategy could be extended to 3-D polyhedral objects. He showed that when an object is rotated about a line passing through the soft contacts of two fingers, the fingers slip in a simple, predictable trajectory. This strategy is appealing because of its simplicity and robustness.

**Robot Arm Control.** Joris de Schutter reviewed the major force control strategies that had been developed for robot force control. He contrasted two methods--external force control where a force control loop is closed about a position control system; and joint torque control where force is directly controlled open loop by torque commands to joint actuators. He stressed the advantages of external force control for most manipulators, including commercial manipulators, because good robot dynamic models and accurate torque control are not required and because one can simply incorporate existing position control systems. External force control has successfully been applied to contour tracking, palletizing, and peg-in-hole assembly. Joint torque control requires newer manipulator designs where joint torque can be accurately controlled; it represents a major trend in robot control. For both methods, contact instability must be avoided. This can be achieved through passive contact compliance, link or joint flexibility, or filtering external force sensor input. De Schutter's discussion is directly relevant to force control for both robotic and teleoperation applications.

## Novel Actuators

There is general agreement within the robotics research community that significant performance improvements in actuators are urgently needed. The principal shortcomings are the need for lightweight, compact actuators (higher power to weight ratios, and lower volume to weight ratios). The purpose of the lectures in this session was to review selected research programs directed at innovative actuator properties and design. The speakers included: Ian Hunter, McGill University; Danilo De Rossi, University of Pisa; Paul Taylor, Hull University, U.K.; and Paolo Dario, Scuola Superiore S. Anna, Italy.

Ian Hunter got the session underway with a tutorial on the properties and performance capabilities of biological muscles with the view that biological muscles might serve as a models for robotic actuators. That theme was explored by other speakers in the session with references to the capabilities of skeletal muscles as a benchmark for



evaluating progress towards the goal of achieving acceptable contraction times and force densities.

Danilo De Rossi presented the findings of his research on electrically activated polymer actuators using a new class of composite materials made of interpenetrated networks of polyelectrolytes and extrinsic electron-conducting polymers. These materials show both mechanoc-chemical and electromechanochemical response with force densities of the order of 10-15 Kg/cm<sup>2</sup> and contraction time constants of the order of a second, when in thin-fiber form (20 microns diameter). This class of materials is thought to be potentially useful in the development of muscle-like soft actuators. There are still important problems related to durability, low conversion efficiency, and precision of control.

Paolo Dario presented his research on a linear shape memory alloy (SMA) as a direct drive actuator. Dario's research is aimed at predicting the thermo-mechanical behavior of SMA active elements, developing methods for cooling SMA elements, and protecting against external overload. An experimental SMA push-pull actuator for controlling an interphalangeal joint was developed and tested. The most significant result relates to the frequency cut-off values, which were between 1.0 and 2.0 Hz, values higher than the previous values reported, which are attributed to the water cooling system. The data on the active elements for the coil spring the force exerted was about 9.0 N with an axial displacement of 22 mm. The results were in good agreement with theoretical data in literature.

### Applications of Teleoperated Systems

There were three presentations on applications of teleoperated systems--one focused on space applications and the other two described underwater teleoperated systems.

**Space Applications.** Gerd Hirzinger, Institute for Flight Systems Dynamics, the German Aerospace Research Establishment, Federal Republic of Germany, presented a description of Germany's first step into space robotics, referred to as the ROTEX (Robotics Technology Experiment) project. A schematic representation of ROTEX is shown in Figure 3.

The principal equipment consists of a modular spacecraft control station, and a six-axis robot manipulator with force-torque wrist sensors, a tactile array on each side of the gripper, an array of laser-range finders, and a small stereo camera to provide an image out of the gripper. In addition, a fixed pair of cameras will provide a stereo image of the robot's working area. Three modes of operation are envisioned--direct teleoperated control from the spacecraft, autonomous preprogrammed operation, and teleoperation from a ground-control station. Proposed tasks for the teleoperated system are assembly of structures in space, accomplishment of modular connec-

tions, and extra vehicular activity. Supervisory control concepts are being developed to deal with time delays up to 4-5 seconds under ground-control conditions. Some of the innovative and elegant features of the system are: precise performance of very small laser range finders; a tactile array of 4 x 8 sensing elements in each finger; a stiff six-axis, force-torque sensor based on strain-gauge measurements and a compliant optical sensor; a pair of miniature CCD cameras; and electrical drive systems for rotational joint control and rotational-translational gripper control. The ROTEX-teleoperated system is scheduled to fly with the German spacelab mission in 1991.

**Underwater Teleoperated Systems.** Doug Murphy, Naval Ocean Systems Center (NOSC), San Diego, described two research and development projects at NOSC, the Navy's lead laboratory for the development of underwater work systems (vehicles, sensors, remote manipulators, and tools). One major project is the Teleoperator-Presence System, a telerobotic undersea work system that blends the capabilities of the human operator with those afforded by robotic technologies. The goal of these systems is to give the operator the subjective experience of being at a remote worksite while he is in fact at a control station well removed from the potentially hazardous underwater work area. Systems of this type are said to exhibit telepresence, which is accomplished through the use of spatially correspondent controls and high fidelity sensory feedback systems; this configuration permits direct use of the operator's cognitive and sensory capabilities. The project is developing a dexterous remote manipulator with nine degrees of freedom (DOF) in the mechanical hand and 7 DOF in the arm, a force reflecting exoskeletal master controller, and a helmet-mounted stereo display system with 70 degrees FOV, 1023 line resolution.

The second system described by Murphy was the NOSC Advanced Tethered Vehicle system which is designed for a range of underwater work missions; e.g., underwater inspection, construction, and component assembly. The system consists of a remotely operated submersible controlled from a surface station; the control link includes a tether with optical fibers and digital telemetry. The work vehicle is equipped with two 7 DOF manipulators, a suite of interchangeable tools, stereo television, and zoom color cameras. Dexterous remote manipulation is an important design goal.

Dana Yoerger, Woods Hole Oceanographic Institution, Massachusetts, gave a presentation on the ARGO/JASON underwater search and inspection system comprised of two remotely controlled submersible vehicles. Figure 4 illustrates the ARGO/JASON system being controlled from the surface control ship RV KNORR.

A prototype model of this system was used to help locate the wreck of the R.M.S. TITANIC in 1985. The

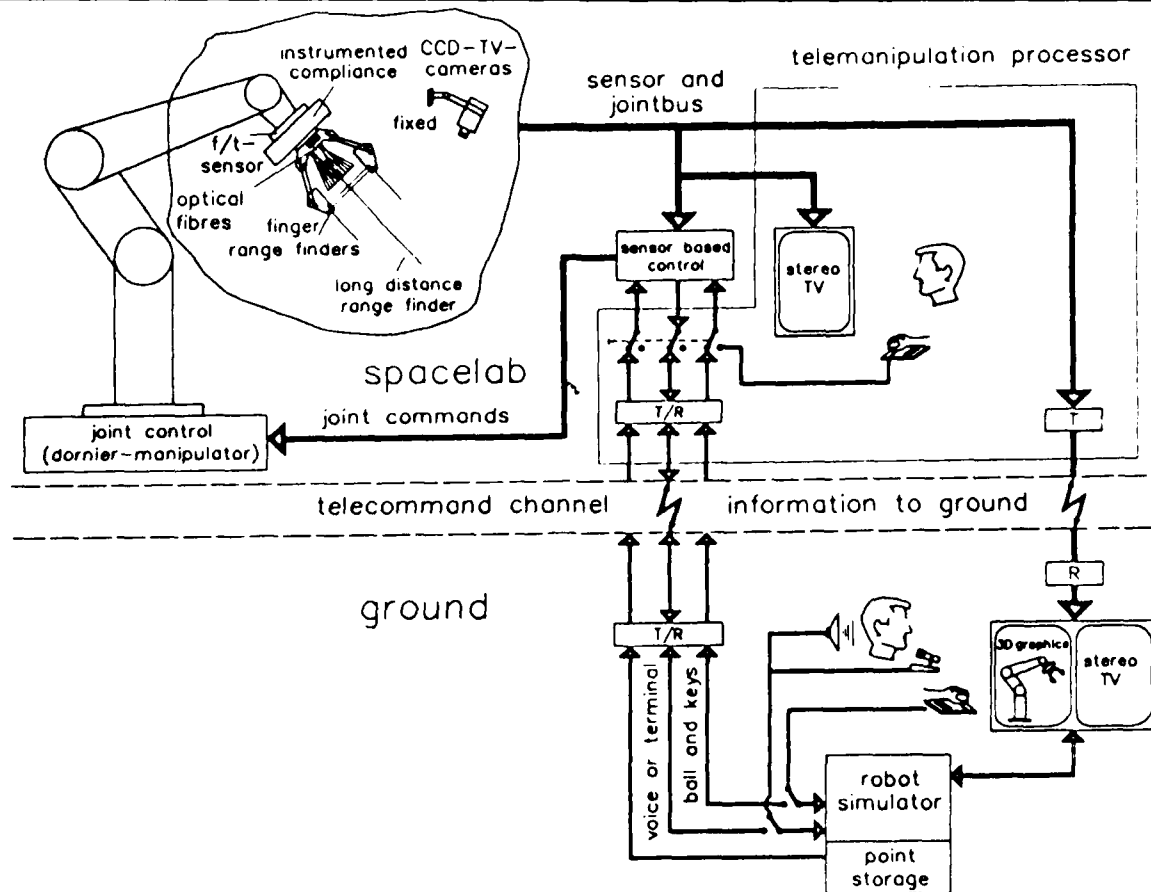


Figure 3. Schematic Representation of Germany's Space Robotics Technology Experiment (ROTEX)

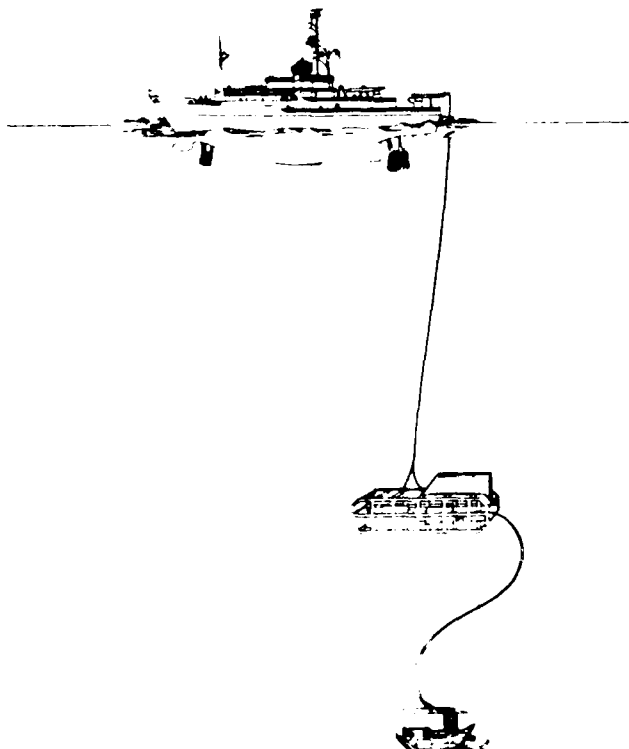


Figure 4. ARGO/JASON Underwater Search and Inspection System

ARGO, equipped with high-resolution sonars, wide-angle film and television cameras, is the reconnaissance and search vehicle. The JASON vehicle operates on a tether out of ARGO's garage and performs close-in inspection and exploration functions. Subsystems on JASON include position sensors, navigation systems, seven thrusters, and side-scan sonar for precision maneuvering. Articulated manipulator arms capable of lifting and grasping can be installed singly or as a pair, depending on mission requirements. The principal technical advances being developed for the JASON vehicle are:

- Supervisory control concepts for semiautonomous maneuvering and remote manipulation
- High-level control languages for command inputs
- Nonlinear adaptive vehicle control
- Compliant manipulator control
- Closed-loop control for heading, depth, and translation
- Models for concurrent control of the JASON vehicle and manipulators.

## Discussion

This section presents a discussion of selected workshop topics, namely, tactile sensors, tactile displays, actuators, and perceptual-motor research. The discussion highlights important recent research findings and explores research opportunities that have the potential for contributing to improved biological models and robotic devices.

**Tactile Sensors.** Finding compact, rugged tactile sensors with adequate sensitivity and discriminability that can be mounted on robot hands remains a stubborn problem. Although some progress is being made and several sensing technologies are being explored, few are currently suitable for multi-fingered hands. Most robot tactile sensors respond to normal force or indentation only; whereas, sensors capable of both normal and shear forces are a goal (a capability similar to human mechanoreceptors). In the long run, a multi-dimensional stress sensor would be desirable. De Rossi presented a six-dimensional tactile sensor that utilized different stress-strain properties of materials. This idea was implemented to a simpler degree by Cutkosky, who embedded polyvinyl fluoride (PVF<sub>2</sub>) materials at two different orientations in rubber to sense both normal force and shear force. A six-dimensional microelectromechanical (MEMS) sensor has also been proposed by Jacobsen at Utah University. Here an armature is embedded in rubber, and its position and orientation are sensed by special microcircuitry.

Development of tactile sensors for robotics still has far to go, with basic issues of function and design yet to be worked out. These include multi-axis stress sensors, possible multiple tactile sensors with different detection characteristics, and the choice of skin medium. Nevertheless, this workshop highlighted several promising developments in those directions.

**Tactile Display Issues For Teleoperation.** Ken Johnson, Johns Hopkins University, presented the following assessment of the relative state of tactile display. He observed that the field of tactile sensing is making slow-but-steady progress and is creating the basis for effective feedback to an operator. A larger problem is the lack of comparable development towards effective methods of tactile display. For use with teleoperated systems, the development of a high-quality display for the tactile sense must take into account the size, weight, and power restrictions imposed by a master glove or other controller. The design should meet or exceed the physiological specifications of the tactile sense over a significant skin region, including at least 1-2 square cm on the glabrous surface of a fingertip. In order to match or exceed the known properties of the tactile system at the fingerpad, the following spatial and temporal specifications are required: probe spacing = < 0.9 mm, indenta-

tion range > 2 mm, frequency range DC - 500 Hz (with declining amplitude requirements as frequency increases), and precision = < 1 micron. In order to meet those specifications over a significant skin region, a large number of probes are required; e.g., 250 probes for a 2.0 cm<sup>2</sup> area of fingerpad. Current progress towards such a device is described in Schneider (1988).

A strategy for developing high-fidelity tactile display within a flexible glove involves a distribution of the high spatial and temporal frequency requirements into two separate delivery systems--one having high spatial but low temporal bandwidth, and one having high temporal but low spatial bandwidth. The rationale can be seen by considering the act of grasping and working with a tool. The primary sensory information comes from deformation of the skin to conform to the tool and from the transient mechanical events and vibrations that are transmitted through the tool. The deformation pattern involves low temporal frequencies even when the tool is being manipulated. The mechanical transients involve high temporal frequencies and are appreciated primarily by the Pacinian receptor systems, which have low spatial acuity. The deformation patterns with high spatial bandwidth might be effectively displayed to the skin through a dense array of probes, each driven by a very small, low-power motor with low temporal bandwidth. The stimulus component with high temporal frequencies would be delivered by larger, powerful motors at much more coarse spacings. Perhaps only one such motor per digital phalanx is required.

**Actuators.** As mentioned earlier, significant advancements in robotics will depend on the development of more effective actuators. Actuators must have higher force densities, be more compact, and use more convenient power sources. Unless room-temperature superconductivity is developed, electric motors cannot produce much higher torques that they currently do because of limitations in generating magnetic fields either with magnets or with windings. Pneumatic actuators provide higher force densities than electric motors, and in fact are incorporated into the Utah/MIT Dexterous Hand. Their strength, however, is limited by air pressure (much more than 100 psi is not safe or convenient). Hydraulic actuators involve much higher fluid pressures (2000 psi), and are promising if control problems can be solved. However, neither hydraulics nor pneumatics are convenient power sources, and design and control problems are severe.

Dexterous hands and hand masters pose particularly stringent requirements in actuation. Hands have many more degrees of freedom than arms and are much smaller; they require sufficiently strong actuators that are not too bulky or heavy. Even more severe are requirements for a tactile stimulator, where many miniature actuators are required to generate a tactile pattern. Although the tactile stimulator presented by Ken Johnson is a step in

that direction, the stimulator is far too large to be incorporated into a master glove.

This workshop included three presentations on new actuators that hold promise for the future. Shape memory alloy (SMA), discussed by Paolo Dario, has a high-force density ( $40\text{Kg/cm}^2$ ), but so far is too slow for most uses. Although SMA contracts rapidly when heated, the cooling process takes too long. If a convenient and fast cooling method could be found, then SMA would be an extremely attractive possibility. Several groups are working on this problem, and SMAs definitely bear tracking.

Polymeric actuators were discussed by Danilo de Rossi and Paul Taylor. Again, the force density is quite high ( $15\text{Kg/cm}^2$ ), but current polymeric actuators are too slow. New architectures involving interpenetrated networks of polyelectrolytes and extrinsic electron-conducting polymers look to be promising developments for the future. In De Rossi's opinion, in next that 3-5 years, these actuators could be made useful if sufficient effort were devoted to them.

Tactile stimulators offer special design constraints that current polymeric and SMA actuators do not meet, namely, the requirement for miniaturization. However, electrostatic actuators look promising as miniature actuators. The field of MEMS is relatively new and quite active, and electrostatic sensors and actuators are beginning to appear. Electrostatics is quite favorable at the micron level, because for small electrode separations, the breakdown voltage of air is substantially increased. Thus, higher electric fields can be generated and maintained without arcing, and very high forces can be produced. The MEMS has been facilitated by developments in microelectronic technology and silicon machining. Leaders in this field include the University of Utah, MIT, University of California Berkeley, AT&T Bell Laboratories, and various Japanese laboratories. The MEMS appears to hold great promise for robotics.

**Perceptual-Motor Research.** Knowledge of the human haptics, reaching and grasping capabilities, and the tactile resolving power of the hand contribute importantly to our understanding of the sensing and manipulating capabilities of the human hand. This knowledge also provides a benchmark to which the resolving power of a teleoperated hand can be compared and helps in determining the resolution that should be strived for in designing human-machine interfaces for the hand. An equally important adjunct is an understanding of how multiple sensory inputs are integrated to produce coordinated motor performance.

The research reported on the human operator transfer function appears to offer two interesting aspects:

- Instrumentation and general modeling approaches provide the possibilities for deriving efficiently (during one experiment) very precise descriptive data for a range of human and system parameters

- Modeling approach includes a method for decomposing human responses to relevant anatomical subsystems and psychological functions; e.g., visual processing, neuro-muscular mechanics and positioning, and cognitive processing.

Both of these characteristics offer the potential for formulating more precise quantitative human transfer functions and providing a basis for developing explanatory theories of motor control.

## Concluding Observations

The workshop lectures by the participating scientists were first rate and the discussions were enlightening and stimulating. Overall, the workshop transactions provided an excellent overview of the most recent research findings in biological motor control and robotics related to dexterous manipulation. There was clear evidence of convergence in those two lines of scientific inquiry towards the development of new models for sensing, grasping, and manipulation. Beyond that, there were strong cases of active interdisciplinary and international collaboration and cooperation. In addition, there were examples of models and data independently produced by physiologists and psychologists being used by robotics engineers in the development of prototype hardware, and cases where engineering and computer science models have provided paradigms for perceptual-motor research. There were opportunities for scientists and engineers working on the central themes of dexterous manipulation and teleoperation at different levels of analyses, from basic neural investigations to engineering implementation of robotic hands, to stimulate each other's perspective. Importantly, there were positive signs that this forum has served as a seminal mechanism for future international research collaboration.

In closing, Office of Naval Research would like to thank all the participants for contributing to a lively and interesting scientific exchange, and to express our appreciation to Mike Brady for cochairing the workshop and graciously hosting our meetings in the hallowed halls of Keble College and the Sherrington Lecture Room, Department of Physiology, Oxford University.

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## NEWS, NOTES, AND ABSTRACTS

### Europe in the 1990s: An ONREUR Perspective on the European Community, It's Scientific Programs, and 1992

by James E. Andrews

In the next issue of *ESNIB*, the ONREUR liaison scientists will present a set of articles that discuss the future of European Science and Technology in light of the programs of the European Community (EC), the Single European Act, and the potential of a Europe without frontiers by the end of 1992.

Strictly speaking, 1992 and the Single European Act have nothing to do with R&D, being focused on commercial and trade barriers, the development of common or interchangeable licensing rules, and the easing of cross-border movement of people, goods, and ideas. However, this process, with it's design goal of December 1992, is having a major philosophical effect on scientific planning, and through the growing leverage of EC-funded R&D programs, is moving European science towards stronger internal ties and internally focused growth. The ONREUR Liaison Scientists are witness to these developments as they affect their particular disciplines, and will be following the evolution of European science as 1992 approaches.

### Conference on Tire/Road Noise

by David Feit

On August 8-10, 1990, the International Conference on Tire/Road Noise will be held in Göteborg, Sweden.

Conference themes:

- General effects of tire/road noise

- Noise generation mechanisms and their modeling
- Measurement methods and instrumentation
- Public perception of tire/road noise
- Road surface design for reducing traffic noise
- Tire design for reducing traffic noise
- Influence of other factors on noise
- Research or abatement programs
- Legal limits and international agreements
- Tire/road noise inside vehicles

For further information, contact:

International Tire/Road Conference  
c/o U. Sandberg  
Swedish Road and Traffic Research Institute  
S-581 01 Linköping, Sweden  
Telephone: (46) 13 20 41 31  
Telefax: (46) 13 14 14 36

### Euromech Colloquium on Composites

by David Feit

The Office of Naval Research European Office has received the first announcement of a call for papers for a colloquium on the experimental identification of the mechanical characteristics of composite materials and structures. The venue for the colloquium will be the Ecole des Mines de Saint-Etienne, Saint-Etienne, France and will be held December 3-6, 1990. This meeting will provide an occasion for the discussion of problems related to the experimental analysis and identification of composite material mechanical behavior and the methods used in such analyses. Both static and dynamic testing procedures would be appropriate for discussion at this meeting. The official language is English and, as is usual for Euromech Colloquia, participation is by invitation.

only and the attendance will be limited to approximately 60 participants. The Chairmen for the meeting are Professor Hugo Sol, Vrije Universiteit Brussel, Belgium, and Professor Alan Vautrin, Ecole des Mines de Saint-Etienne, France; the latter will also serve as Conference Secretary. For further information, contact A. Vautrin, Department Mecanique et Materiaux, Ecole des Mines de Saint-Etienne, 158, cours Fauriel, 42023 Saint-Etienne CEDEX 2, France.

### British Acoustician Joins Scripps Institute

by David Feit

Dr. M. Buckingham (see *ESNIB* 88-10) will join the Scripps Institute of Oceanography, La Jolla, California, starting in January 1990. An Individual Merit Senior Principal Officer, Buckingham has been with the Royal Aerospace Establishment (RAE) since 1974 and is currently head of the Theoretical Acoustics Group. At Scripps, he will have a joint appointment--Professor in Department A-008 and Research Scientist in the Marine Physical Laboratory where he will continue his activities in ocean ambient noise, Arctic Ocean acoustics, and 3-D propagation modeling.

### The "Best" of Physics in the United Kingdom

by Dean L. Mitchell

The Universities Funding Committee (UFC), successor to the University Grants Committee (UGC) in the U.K., has announced the results of its selectivity ranking for 53 departments of astronomy and physics in the U.K. based on an evaluation of research capabilities. The departmental rankings, together with the recommendations of the Edwards report on the future of university physics, are expected to factor heavily in the allocation of educational funds to individual institutions.

This comes at a critical time since the present national policy is to encourage universities to take a more independent role in attracting students and generating alternative funding modes which, in many cases, means increased fees. This policy is consistent with the national moves to "privatise" many of the services previously supported by the public sector. In effect, the tangible expression of governmental *encouragement* is expressed in the form of reduced budgets.

In 1986, UGC executed a selectivity exercise that was criticized for the lack of consistency in treating different disciplines and for the way that the evaluation parameters were defined and used. Since, the UFC has carefully gathered community input before and during the exercise to assure that assessment methods are well-understood and that the results are fairly based. Criticism is still expected; the degree will likely depend on the depth of the reductions.

Rankings were provided for 47 physics departments, 6 astronomy departments, and 1 particle theory group.

Cost centers were used as assessment units which, in physics and astronomy, coincided with the departmental units except for the Durham theory group. The rankings were on a scale of 1 to 5 with 5 considered to be "research quality that equates to attainable levels of international excellence in some subareas of activity and to attainable levels of national excellence in virtually all others." The 1 ranking corresponds to "research quality that equates to national excellence in none, or virtually none, of the subareas of activity."

As might be expected, Oxford, Cambridge, and Imperial College all achieved top ranking; they were joined by Birmingham, Bristol, Liverpool, Manchester, and Nottingham for a total of eight. Longborough and Aberdeen were the lonely two at the bottom with rankings of 1. In between, 12 departments were ranked 2, 15 were ranked 3, and 10 were ranked 4. No departments with recognized programs in solid-state and condensed matter physics ranked lower than 3. A complete list is available in the September 1989 issue of *Physics World*, the monthly magazine for the Institute of Physics.

### United Kingdom Ministry of Defence Revamps Research Establishments

By Dean L. Mitchell

The Ministry of Defence (MoD) of the U.K. is revamping the structure and modes of funding for its research and development (R&D) enterprise in order to get more "bang-for-the-buck," or rather, more "rounds-for-the-pounds." Under the government's "next step" policy, the main MoD R&D establishments will be combined in a single "Defense Research Agency" (DRA) which will negotiate with its customers in MoD and elsewhere for programs and budgets. The DRA will include: the Admiralty Research Establishment (ARE), which is the R&D house for undersea and surface naval applications; the Royal Aerospace Establishment (RAE), which is the center for airframes and aeronautical R&D; the Royal Armament Research and Development Establishment (RARDE); and, the Royal Signals and Radar Establishment (RSRE), which is an all-service laboratory specializing in electronic systems and components. Nigel Hughes, former Director of RSRE, has recently been appointed to head the DRA which is expected to be fully operational in early 1991.

The four components of the DRA (air, earth, fire, and water) will be expected to compete more actively for funds and programs than in the past. Each laboratory has its own areas of special competence so that duplication of effort within the MoD is not a major problem. The changes in research procurement procedures to give more control to the "customers" within MoD will bring the MoD practices closer to those in the U.S. Department of Defense.

## The Leslie Fox Prize in Numerical Analysis

by Richard Franke

### Introduction

The Leslie Fox Prize in Numerical Analysis was established to honor Professor Leslie Fox on his retirement from Oxford University. Professor Fox is a former Director of the Computing Laboratory at Oxford, and was Professor of Numerical Analysis there. He is the author of several books on numerical solutions of ordinary differential equations and numerical analysis in general, has published numerous scientific papers, and was previously the editor of the Journal of the Institute of Mathematics and its Applications. The first Fox prize was awarded in August 1985, with successive competitions in September 1986 and March 1987. The competition for the prize is open to researchers under age 31 (as of a particular date, depending on the solicitation for entrants; this may be waived for "late starters"). The entry consists of a paper in numerical analysis describing some of the candidate's research that is suitable for a 40-minute lecture to a general numerical analysis audience. An adjudicating committee selects several entries for oral presentation and, based on the paper as well as the lecture, one or more first and second prizes may be awarded. Part of the prize is a monetary award.

### Competition Finalists--1989

The fourth competition was resolved at Cambridge University on September 4, 1989. Seven candidates each presented a 40-minute lecture. Brief descriptions of these lectures are given here.

**Eigenvalues and Condition Numbers of Random Matrices,** A. Edelman, Massachusetts Institute of Technology and Thinking Machines, U.S.

Edelman considered the problem of solving the rectangular system  $Ax = b$  when the elements of  $A$  are random values with a given distribution. The condition number determines how accurately the system can be solved and this number depends on the eigenvalues of the matrix  $AA^t$ . He reviewed the history of random eigenvalues in numerical analysis, noting studies by Von Neumann, Birkhoff, Smale, among others. Previous results have tended to be vague.

Edelman proved that if the entries in an  $n \times n$  matrix  $A$  are normally distributed with mean zero, the expected value of the condition number  $\kappa$  of  $AA^t$  is given by  $\log(\kappa) = \log(n) + C$ , where  $C \approx 1.537$  is a known constant. These results were related to the question of the probability that a numerical analysis problem is difficult to solve. Some results were also given for nonsquare matrices. The final very interesting result mentioned by Edelman concerned the average (or expected) characteristic polynomial of a matrix whose entries are from a given probability distribution. If the probability distribu-

tion is  $w(x)$ , then the average characteristic polynomial is the orthogonal polynomial for the weight function  $w(x)$ , of degree equal to the size of the matrix.

**Multivariable Cardinal Interpolation with Radial Basis Functions,** M. Buhmann, Cambridge University, U.K.

Buhmann discussed his results concerning reproduction of polynomials by radial basis function approximations and his derivation of cardinal functions (see ESNIB 89-05:38).

**The Restricted Singular Value Decomposition: Properties and Applications,** B.L.R. De Moor, Stanford University, U.S., and Katholieke Universiteit, Leuven, Belgium

The singular value decomposition (SVD) is a powerful technique for solving computational matrix problems, including linear equations, least squares, system identification, adaptive control, and others. In the following,  $A$ ,  $B$ , and  $C$  are rectangular matrices;  $P$ ,  $Q$ ,  $U$ , and  $V$  are orthogonal matrices; and  $S$  is a diagonal matrix. These matrices may appear with subscripts; superscript  $*$  denotes the conjugate transpose, and superscript  $-*$  the inverse conjugate transpose. The singular value decomposition of a matrix is given by  $A = USV^*$ . Sometimes it is desirable to decompose more than one matrix (of compatible, but not necessarily the same dimensions) as  $A = P^* S_a V_a^*$ , and  $B = P S_b V_b^*$ . Then  $A^* B = V_a (S_a S_b) V_b^*$ . This is called the Product SVD. A similar decomposition is called the Quotient SVD.

The Restricted SVD is a decomposition of three matrices, as  $A = P^* S_a Q^{-1}$ ,  $B = P^* S_b V_b^*$ , and  $C = U_c S_c Q^{-1}$ . De Moor showed that the Restricted SVD is two Quotient SVD's, and has given a general classification to this type of decomposition, which is extendible to SVD-like decompositions of any number of matrices. One example application noted was to fitting problems simultaneously involving linear constraints, exact data, and noisy data.

**Highly Continuous Runge-Kutta Interpolants,** D.J. Higham, University of Toronto, Canada, and Manchester University, U.K.

Runge-Kutta methods are frequently used to obtain numerical solutions of systems of ordinary differential equations. Sometimes it is desirable to interpolate to intermediate points; e.g., to determine the exact time at which a variable becomes zero. Cubic spline interpolation could be used, but is only  $O(h^4)$  accurate and is a global scheme. Derivative values are readily available, and Shampine used a Hermite  $C^1$  approximation for the explicit Dormand-Prince Runge-Kutta scheme known as RK5(4)7FM that maintained  $O(h^5)$  accuracy and had the same form as the Runge-Kutta approximation.

Higham suggested a Hermite scheme that has  $C^k$  smoothness, and that is still local although information from the two adjacent intervals is required at each grid point. Left side derivative information is obtained from

the  $C^1$  Hermite approximation on the previous interval, which preserves stability of the scheme. Again, the approximation can be expressed in a Runge-Kutta form, but now involving derivative values over the two intervals. When interval sizes change rapidly, Higham suggests the use of internal information obtained from another derivative evaluation at an interior point, a ploy also suggested by Shampine.

Finally, Higham noted that using a  $C^2$  scheme compared to the  $C^1$  makes very little difference in the interpolated values, but will be useful when the additional smoothness is required.

#### **Circulant Preconditioners for Hermitian Toeplitz Systems, R.H. Chan, Hong Kong University**

Hermitian Toeplitz systems of equations occur regularly in signal processing and other applications. Algorithms have been given by Levinson, Trench, and Zohar that require  $O(n^2)$  operations, and more recently by Gragg and Ammar that require only  $O(n \log^2 n)$  operations. Strang previously suggested using a preconditioned conjugate gradient method requiring  $O(n \log n)$  operations per iteration. Chan developed, under slightly stronger than usual conditions (but that commonly occur in applications), a preconditioner that leads to a superlinearly convergent conjugate gradient iteration. More importantly as a practical matter, the method converges to a specified accuracy in a few iterations, the number being independent of the size of the system.

#### **Linear Instability Implies Spurious Periodic Solutions, A. M. Stuart, University of Bath**

Stuart considered the stability of explicit finite difference methods for the solution of reaction-diffusion-convection equations of the form  $w_t = w_{xx} + h(w, w_x)$ , with boundary and initial conditions of the form  $w(0, t) = w(1, t) = 0$ ;  $w(x, 0) = w_0(x)$ . The assumption is that the function  $h$  is smooth and that the finite difference approximation is consistent, but may be centered or upwind, as appropriate. The finite difference equations are considered for values of  $\Delta t$  close to that which makes the scheme linearly unstable.

Using techniques from bifurcation theory, Stuart showed the existence of a period two (in the time subscript) solution. These solutions are spurious and a product of the discretization. Even though they bifurcate at a value of  $\Delta t$  near the linear stability limit, they can seriously degrade the numerical approximation. Further, because they may be bounded and of moderate relative scale for nonlinear problems, the usual manifestation of unbounded growth as occurs in linear problems may not occur here.

#### **An Asymptotically Exact A-posteriori Error Estimator for the Finite Element Approximation of Problems with Singular Solutions, M. Ainsworth, Durham University and Lancaster University, U.K.**

Engineers want easily computable and accurate error estimates for finite element calculations, both for the purpose itself and to guide refinement algorithms in adaptive methods. Existing estimators are either for smooth problems; e.g., Babuska and Rheinbolt schemes, and nontrivial to calculate, or are quite heuristic and not accurate under a wide range of conditions. Ainsworth described methods based on estimation of derivatives where the estimates take advantage of the superconvergence at certain points possessed by finite element methods. These methods do not work well in the presence of singularities arising from, e.g., re-entrant corners. Here the term singularity means that derivatives of the solution do not exist, rather than a blow-up of the solution itself. A factor correcting the estimated error (generalizing a suggestion by Zienkiewicz) in terms of the type of singularity, the location, and the mesh ratio was derived. Examples showed the corrected estimator to be very good, leading to the possibility of a single mesh refinement, in turn, leading to a solution with the desired accuracy.

#### **Final Comments**

The Adjudicating Committee announced that one criterion for selection to the short list was that the paper was capable of winning a first prize. This was evident from the presentations, which were all superb. When the final announcement of prizes was made, Buhmann, De Moor, and Stuart received first prizes, with Edelman, Higham, Chan, and Ainsworth receiving second prizes. The quality of the research put in evidence here augurs well for the future of numerical analysis.

### **Parallel Architectures and Languages Europe**

by William J. Dally. Professor William Dally is a member of the Laboratory for Computer Science and the Artificial Intelligence Laboratory at MIT, in Cambridge, MA.

#### **Introduction**

The Parallel Architectures and Languages Europe (PARLE) conference was held in Eindhoven, the Netherlands. The papers at PARLE were varied. Much of the European architectural community is very theoretical; i.e. they do paper designs, but do not prove theorems. Most of the few experimentalists are religiously committed to a particular model of parallel computation. Functional programming, concurrent logic programming, and data-flow (and various combinations) are all popular.

My talk on "Universal Mechanisms for Concurrency" was very well received. Many people were very excited about the idea of standard mechanisms for concurrency while a few people were justifiably skeptical. I did learn from Tony Hey, Southampton University, that Les Valiant at Harvard is working on some similar ideas although from a very theoretical point of view.



## Presentation Summaries

**Data Diffusion Machine - Seif Haridi.** Seif Haridi is part of a group at the Swedish Institute of Computer Science that is working on a shared-memory, MIMD parallel computer intended to run a concurrent form of PROLOG. The paper describes a cache coherency protocol based on a tree of buses where a directory is associated with each bus (except the root). The protocol will support any shared-memory model as they do not take advantage of the fact that logic programming is single assignment. A distinguishing feature of their protocol is that there is no "main memory." Each datum is held in one or more caches; data diffuse to where they are needed via the protocol.

**Flagship - Brian Proctor, ICL.** Flagship is a big parallel computing project in the U.K. (many companies, many universities) that appears to consist of many disconnected parts. The project is intended to support functional programming and includes several levels of software as well as some prototype hardware. The hardware they have built so far consists of 16 processors (each a SUN 3/120) connected by a 4-ary, 2-fly network. One novel feature is that their network supports load balancing via a mechanism that allows a message to be sent to the least busy processor.

**DOOM-TROPICS-POOL - Bronnenberg, Philips.** A group at Philips Research Laboratories in Eindhoven has built a machine for parallel object-oriented programming. Called DOOM, the machine currently consists of 100 nodes. Each node contains four boards that hold a 68020 processor, some memory, and a router built from standard logic parts. The router is store-and-forward and table-driven so it can handle arbitrary topologies. The router handles fixed-size packets (256 bit) and runs at 20Mbits/sec. The machine runs POOL which is a static (Simula-like) object-oriented language with synchronous (CSP-like) communication tacked on.

**Fuzzy Barriers - Epstein, Philips, NY.** A group at Philips Briarcliff New York Laboratories has some ideas on how to make barrier synchronization less costly by separating the point where a process enables others to proceed from the point where it cannot proceed without waiting for other processes to reach the first point. A similar paper appeared at ASPLOS.

**GRIP - Peyton-Jones.** Simon's group at University College, London, has built a machine from graph reduction although it does not seem too specialized for that purpose. The machine consists of up to 20 boards each of which contains four 68020 processors and one micro-coded processor that controls the functions of an "intelligent" memory.

**Bounding Box Routing - Mooij.** This paper describes a method of performing adaptive routing in two-dimensional meshes. Unfortunately, it is prone to deadlock, but it can probably be modified so that does not happen.

**WSI Routing-Edge Following - Anderson.** This is a paper design of a wafer-scale machine for functional programming. One interesting point is an adaptive routing algorithm developed for routing around failed processors on the wafer.

**Dataflow (systolic) - Gunzinger.** A group at ETH in Zurich has built a "Synchronous Dataflow" machine for image processing; it is, in fact, a programmable systolic array. While very specialized for the application, the machine is interesting for its communication strategy and the fact that it contains no ALU. All operations are by table lookup.

**MIMD Parallel Computing - Tony Hey.** Mr. Hey discussed the experience his group at Southampton has had with transputers. The most interesting part was his description of Les Valiant's ideas on universal mechanisms for parallelism--the "Bulk Synchronous Parallel" model.

**Cambridge - Needham.** Needham's group has been doing a lot of work on networking (local area and wide area, not multicomputer networks). He described some of their recent projects including a WAN using satellite communication, a 600 Mb/s ring that is in progress, and some work on authentication. One interesting thing that came out of this discussion was their methodology for building prototype hardware. While many of their designs are done the standard way via an industrial partner (Olivetti), some designs are done by a local firm called QDOS that buys standard gate array blanks; e.g., from TI, and customizes them in short order (a few days) using an E-beam machine of their own design.

I described the J-Machine project to Needham and he seemed fairly interested and asked several questions about possible uses for such a machine. There does not seem to be any parallel computing research going on at Cambridge.

**INMOS - David May.** At Inmos Ltd., Bristol, the discussion was about current and future transputers and about how ideas in the J-Machine might be used in future transputers. Inmos seems to already feel constrained in their parallel computer development by the millstone of compatibility. They are very strongly committed to the static model of computation represented by OCCAM--static process structure and static communication channels. We discussed at some length the J-Machine approach of asynchronous communication and process creation on message arrival. While Mr. May admitted it had advantages and could even simulate synchronous communication fairly effectively, he felt compelled by compatibility to stick with the OCCAM model. One reason for this is that there is a lot of OCCAM micro-coded into the current transputers. They also do not feel that they can radically change their communication structure; e.g., go to wider parallel channels because this would prevent customers from tying new to old transputers.

## Third International Symposium on Protection Against Chemical Warfare Agents

by Victor R. Deitz, a research chemist at the Naval Research Laboratory, Washington, D.C.

**Introduction.** The symposium was held in Umeå, Sweden, June 10-16, 1989. As in the two previous symposia (1983 and 1986), the objective was a mutual exchange of information among different countries for protection against chemical warfare (CW) agents. Of the 30 countries represented (500 attendees), the home country, Sweden, had most attendees followed in sequence by the U.S., Israel, Great Britain, France, Federal Republic of Germany, Finland, and the Netherlands. The symposium language was English. There were no parallel sessions and the presentation of papers was limited to 15 minutes.

After the opening welcome of His Majesty, King Carl XVI Gustaf, the keynote address was made by A.J.J. Ooms, Delft, Netherlands, under the title "Chemical Weapons, What To Do About Them?" Dr. Ooms pointed out that recent events in the area of the Persian Gulf have created a public awareness of what chemical weapons can do. He proposed three options to the threat of chemical warfare: (1) deter by threatening retaliation, (2) protect military and civilian against the chemicals, and (3) eliminate by completely banning chemical weapons. Of these, the protection option was considered good. He also concluded, "If there ever will be a convention prohibiting the possession of chemical weapons, it will be because there is a reasonable protection available."

The seven papers to be presented by the Chinese Institute of Chemical Defense, Beijing, were cancelled at the last moment, leaving gaps in the already-printed program. Delegates from the U.S.S.R. were quiet. "Principles of Chemical Warfare Protection in G.D.R.", a paper by M. Schindler of the German Democratic Republic was carefully read by a colleague.

An interesting and sobering addition to the presentation of papers was the exhibit of the military equipment that is being offered to realize the desired protection. The civilian aspects of the problem were not neglected. The chemical and biological weapons systems present an even more insidious danger and its civilian aspects have been neglected in the U.S.

**Agents.** In addition to the classical chemical warfare agents, there are now new materials of chemical and biological composition. The rapid detection of these agents was the subject of some concern. The application of two or more agents simultaneously calls for special means to detect and to protect an individual or group.

Dr. G.S. Pearson, Chemical Defence Establishment (CDE), Porton Down, U.K. (the first group concerned with chemical defense, 1916), discussed the chemical biological warfare (CBW) spectrum of agents now available. His assessment of the hazards were: (1) what is the

nature of the agent, (2) how toxic is the material, (3) could delivery be made by an aggressor in sufficient quantity? Dr. Pearson concluded on an optimistic note that effective protective measures will be developed.

Perfluorobutene (PFIB) was discussed by investigators at the CDE. The PFIB produces pulmonary edema in men and animals at very low concentrations. Evidence showed that lung thiol levels have a strong influence on the toxicity of PFIB; no protection devices and/or procedures were presented.

**Detection.** More than a dozen papers were concerned with detection in which the chemist carried the initiative. The concentrations are extremely low and there are many interferents. The microsensor, capable of a signal amplification, is being exploited as well as less specific systems of equal complexity. Several optical, chromatographic, and sampling devices were presented. Finland has been developing analytical methods since 1972 and the presentation by Marjatta Rautio, University of Helsinki, of these research activities was very well received. Dr. Rautio stated that at the moment the most reliable identification methods are mass spectrometry, nuclear magnetic resonance spectrometry, and infrared spectroscopy.

The detection devices could be divided according to the objectives. The infrared detector, using backscattering from vapor clouds, divides the 8-12 micron band into segments and with improved detection enabled the U.S. Army to determine the chemical vapors (M.L.G. Althouse, Chemical Research, Development, and Engineering Center, Aberdeen, Maryland). The receptor-based biosensor, ionization techniques for mustard and nerve agents, a detection paper for S-mustard, and chromatographic determinations of the degradation products of the nerve agents were studied under laboratory conditions. The paper by Yongxin and Yuzheng, Peoples Republic of China (not presented), proposed reactions for a fiber optical chemical sensor in which the indicator reagent was fixed on the sensor. The measurement may be the change of visible absorbance, fluorescence, or luminescence. Sample handling and transportation to the laboratory after a field analysis indicated the presence of agents was proposed (J.A. Tornes and B.A. Johnson, Norway) in order to verify alleged use of CW agents.

**Protection.** On a second and more detailed review of the symposium agenda, one is impressed with the large number of items required to realize protection. From the top of the head (mask) to the bottom of the feet (boots), there are designs fitted for many variations. The possible use of a carbonaceous granular absorbent made from a Rohn & Haas Co. polymer was proposed (S.G. Maroldo, Rohn & Haas Co., PA) as a new class of carbon adsorbents. They can be made with varying porosity.

The PBI Saratoga protective textiles incorporate small carbon adsorbent spheres of 0.2-0.4 nm diameter. The

activated carbon spheres have been tested before and after contact with sweat, bleach, and salt water. The adsorbent spheres are derived from coal and the primary source is not given.

Protective fabrics have been studied for aerosol penetration (W. Bergman, Livermore, California, for relief of heat stress (M.G. Katz, Israel), carbon-adsorbent cloth with several variations, and for laundering properties. Activated carbon was the mainstay for filter operations in shelters. All of these studies employ dilute concentrations of toxic vapors relative to the pure agent. One can appreciate the predicament of a combatant who stumbles into a heavy vapor concentration of agent for which there is no protection.

The gas mask for respiratory protection continues to receive considerable attention because of the lack of comfort, poor seal, and psychological problems. Training and education, especially in civilian defense, are current problems. The Swedish government has decided that the entire civilian population must have access to equipment for protection against radioactive dust as well as CBW agents. Israel is also prepared to protect its population against nuclear biological chemical (NBC). A chemical agent monitor developed by the Ministry of Defence, U.K., was exhibited for military, civilian, and civil defense use.

**Medical Protection.** Protection against CW agents is a major concern of the medical profession of armed forces throughout the world. About 20 papers were concerned with toxicological studies, treatments of the organophosphorus agents, and viscous sulfur mustard, the latter having been detected in Iranian chemical warfare casualties. The determination of breakdown products from field exercises will be needed when alleged use of nerve agents are questioned.

**Conclusions.** There is a wide-spread interest in protection against chemical warfare agents among the European and Near Eastern countries. A wide gap exists between the toxic chemicals of industry and the toxic agents of chemical biological warfare, but both categories now require and are receiving increasing technical studies. These can have a reciprocal result in the sense that one group can help the other. An industrial accident; e.g., Bhopal, India, with a moderately toxic chemical demonstrates the kind of event that can be expected in all heavily industrialized locations.

Chemical warfare weapons, sometimes termed the poor man's nuclear bomb, may be relatively easy to fabricate, but the weapons still require expensive delivery systems. However, all countries need protection against chemical agents in the hands of the terrorists.

In June 1989, the Proceedings were issued by the Swedish Defence Research Establishment (FOA Report C40266-4,6,4,7; item 5146103); project name: "Chemical

Protection Symposium," Department of NBC Defence, S-90182, UMEA, Sweden.

## Second International Symposium on Polymer Electrolytes

by Gregory C. Farrington, Department of Materials Science and Engineering, University of Pennsylvania

On June 14-16, 1989, the Second International Symposium on Polymer Electrolytes was held in Siena, Italy, under the auspices of the International Society of Electrochemistry and the Electrochemistry Division of the Italian Chemical Society. Financial assistance was provided by the University of Siena, Consiglio Nazionale delle Ricerche (CNR), Eniricerche, U.S. Army Research European Office, and Mead Imaging, U.S. Forty-eight contributions were presented, and their full texts appear in a special volume published by Elsevier Science Publisher Ltd., England. The symposium attracted over 120 participants from the U.S., Canada, Japan, and most of the countries of Western Europe (about twice the number expected). Eastern Europe was represented by six participants from Poland and one from Bulgaria. The attendees voted unanimously to hold a third symposium in Grenoble, France, in 1991, with Michel Armand as Chairman.

Session topics included theory and physical properties; new syntheses; new electrolytes; polyvalent, protonic, and composite electrolytes; interfaces and electrodes; batteries and electrochromic displays. The conference was unusually lively, and the final two sessions on batteries and electrochromic displays were particularly interesting.

From developmental work underway in Canada, England, France, Denmark, Japan, and the U.S., it is clear that polymer electrolytes are likely to assume an important role in advanced electrochemical technology. The most likely first applications will be as electrolytes in high-energy density, rechargeable batteries. Two different laboratories, ERL Laboratories in Denmark and Harwell Laboratories in England, demonstrated working prototypes of room temperature rechargeable polymer electrolyte batteries. Though developed independently, they both represent significant breakthroughs in the development of high-conductivity polymer electrolytes for room temperature operation. A diagram of the Li/PEO/V<sub>6</sub>O<sub>13</sub> battery design presented is shown in Figure 1.

The ERL technology consists of lithium foil anode, polymer electrolyte, and a composite cathode based on V<sub>6</sub>O<sub>13</sub>. The polymer electrolyte is the key element of the battery and is one of the major breakthroughs in the battery concept. The Harwell battery design is similar but uses a TiS<sub>2</sub> cathode. Both groups demonstrated polymer electrolytes that operate at temperatures as low as -20°C

and have room temperature conductivities of about  $10^{-3}$  S/cm, comparable to that of liquid nonaqueous electrolytes and several orders of magnitude higher than previous materials. These materials are a major advance in the field and may make it possible to develop solid polymer electrolyte batteries for a wide variety of applications previously served by NiCd technology (see Table 1).

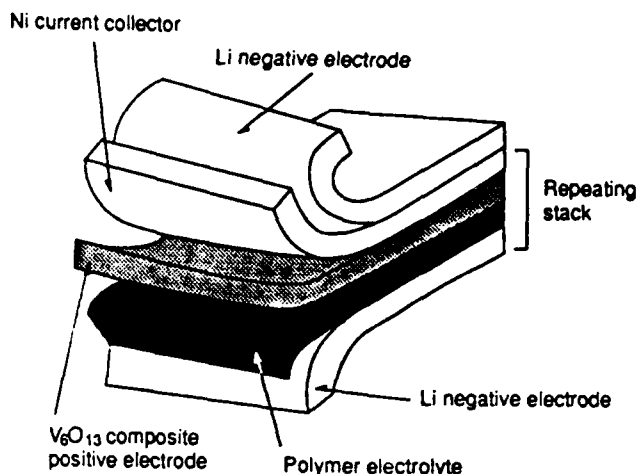


Figure 1. Li/PEO/V<sub>6</sub>O<sub>13</sub> Battery

Table 1. Characteristics of ERL Technology

Cell thickness	200 microns
Voltage	2.4V
Voltage Range	1.8-3.0V
Energy Density	2.5 mAh/cm <sup>2</sup> 300 Wh/l 150 Wh/kg
Power Density (max)	200 W/l 400 W/kg
Impedance	200 ohm/cm <sup>2</sup>
Charge Time (typical)	4 hours
Service Life (80% depth of discharge)	100-300 cycles
Shelf Life	1 year
Temperature Range	-20 to 120°C

Both ERL and Harwell researchers demonstrated that working prototypes of their systems had the power capability to drive a portable electric drill and a portable television. Both designs were described as very safe; puncturing, compressing, or heating above 200°C did not produce any dangerous exotherm.

Questions arose concerning the relative advantages of the polymer electrolyte battery designs over more conventional rechargeable lithium batteries using non-aqueous electrolytes. According to the presenters, the polymer batteries have the following advantages:

- High power without sacrifice of energy density, because of the thin-film design

- Enhanced stability and cycle life because of the limited mobility of the "solvent" in the polymer electrolyte
- Manufacturing advantage since batteries can be produced in a continuous process that produces battery laminate of consistent properties
- Major safety advantages since the design has been demonstrated to be inherently forgiving of mechanical and thermal abuse.

Both Harwell and ERL are currently developing manufacturing technology for producing polymer batteries continuously; in particular, ERL appears to be quite advanced in this area. Also, ERL is currently working on a 2nd and 3rd generation automated pilot facility for continuously producing battery laminate in one step.

Discussions of more fundamental developments included the presentation of several papers on new polymer electrolyte hosts, electrolytes for cations other than Li<sup>+</sup>, and the understanding of the mechanisms of ion motion in polymer electrolytes. However, it is obvious that much more research is needed. The chemical characteristics essential for high-conductivity polymer electrolyte solvents are not yet well understood nor are the key issues that determine ion mobility and transport number in polymer electrolytes. The advances in technology could stimulate more intensive efforts to understand the fundamental physical chemistry and electrochemistry of solid polymer electrolytes, which appear to be a unique family of electrochemical media.

## The Second International Union of Theoretical and Applied Mechanics Symposium on Structure of Turbulence and Drag Reduction

by Chih-Ming Ho and Ron F. Blackwelder, Department of Aerospace Engineering, University of Southern California, Los Angeles, California

**Symposium Overview - Ho.** The Second International Union of Theoretical and Applied Mechanics (IUTAM) Symposium on Structure of Turbulence and Drag Reduction was held at the Federal Institute of Technology, Zurich, Switzerland, July 25-28, 1989. Professor A. Gyrthe chaired the scientific committee. There were about 100 participants representing 10 countries.

Most of the papers discussed the structures in boundary layer flow and the methods of reducing the viscous drag. A handful of papers investigated the vortical structures in the free shear layer or other types of flows. Three types of presentations were organized--regular talks including invited speeches, panel discussions, and poster sessions with 2 minutes of oral presentations.

The meeting started with fundamental studies of coherent structures followed by investigations about various control techniques in drag reduction during the next 3 days.

Robinson and Kline, Stanford University, gave the first review talk. They provided an extensive review about the experimental and numerical results of horseshoe-shaped vortices. Smith, Walker, and Haji-Haidari presented a well-controlled experiment on generating hairpin vortices in a laminar boundary layer. They proposed a synthesized model of the turbulent boundary layer based on the evolution process, birth of secondary vortices, and the pairing of the legs of the vortices.

On the first day, two papers were presented that discussed the control of free shear layers. Nikitopoulos and Liu applied the stability approach to model the vortex merging process. Inoue used the point vortex method to simulate the flow under forced situations. Both works indicated that the subharmonic forcing is important in controlling the merging of vortices. This result confirmed the experimental findings.

The effects of polymer additives on the drag reduction was the main thrust of the second day's discussion. Tiederman summarized the velocity measurements by hot film and by laser Doppler velocimeter during the last decade. The thicker buffer region and the different wavelength of the streaks are the two well-known distinct features in the modified boundary layer. Mizunuma, Kato, and Kurita reported on the increase of the spanwise wavelength of the shaped vortices in the transitional flow.

Landahl used the stability analysis to model the vortical structures near the wall. The results especially brought out the importance of the asymmetric structures. Kim and Moin demonstrated an interesting feedback control numerical experiment. When a velocity fluctuation was detected between  $5y^+$ , the signal was used to impose an out-of-phase disturbance on the wall. A maximum of 20 percent of drag reduction was obtained.

The manipulation of the wall-bounded flow with passive means was the topic of the last day of the conference. Wark and Nagib examined the structures under the influence of a plate placed in the boundary layer. The relaxation region depends on the distance between the plate and the wall as well as the size of the structures. When the separation distance is large, the large structures are modified. The relaxation region is longer for larger structures. The function of large eddy breakup devices (LEBU) at high Reynolds number was investigated by Anders. He found that the LEBU altered the outer structures but had no effect on wall stress when the Reynolds number based on the momentum thickness was above 10,000. Based on existing experiments, Bechert and Hoppe concluded that the upper limit of the drag reduction of two-dimensional riblets was about 7 percent. They suggested that three-dimensional riblets could have better results, but the present test models did not yet exceed the 7 percent.

This conference provided a complete and concise summary of the drag reduction researches during the past

decade. One significant progress was the introduction of the control concept to the flow structures. The techniques for applying the control are not quite developed, but the direction is clear and bright.

**Laboratory Visitations - Blackwelder.** In conjunction with participation in the Symposium on Structure of Turbulence and Drag Reduction, I visited two different laboratories at the Federal Institute of Technology in Zurich. Professor Hans Thomann's group at the main campus has studied a variety of basic fluid mechanic problems and novel ideas in instrumentation. They have measured the drag in 6-inch pipe flows with many different Large Eddy Breakup devices and have found no consistent evidence of drag reduction. Other problems studied include separation within diffusers and another using a drag balance in a separating flow.

One of the research highlights of the trip was a visit to Professor Dracos' turbulence laboratory and data processing facility. Dimitris Papantoniou, a post-doctoral fellow, has taken data in the wall region of an open channel flow that has been seeded by small particles. He records the particles by using laser illumination and three simultaneous and synchronized video cameras. The frames are digitized and stored in a Sun IV computer and processed by programs written by Papantoniou. He has developed algorithms to correctly identify the particles in all three frames and track them in time, thus yielding all velocity components in three-dimensional space. At present, he can track approximately 500 particles simultaneously but believes that he can further increase it with other hardware. In 1987, I observed similar efforts at several Japanese laboratories, but they were not as far developed as Papantoniou's. Very little developmental effort of this type is going on in the U.S.

## Institute of Scientific Interchange Workshop on Noise and Chaos in Nonlinear Dynamical Systems

by Professor Frank Moss, University of Missouri; Professor L.A. Lugiatto, Polytechnic Institute of Turin, Italy; and W. Schleich, Max Planck Institute for Quantum Optics, Federal Republic of Germany

The workshop on Noise and Chaos in Nonlinear Dynamical Systems was held on March 7-11, 1989, at the Institute for Scientific Interchange in Turin, Italy. The central theme--quantum measurement--was set forth in a keynote lecture by W. Lamb, Jr., on an operational approach to the quantum measurement theory.

**Scientific Content.** During the past decade, a great deal of research interest has centered on problems of classical stochastic effects, or noise, on nonlinear dynamical systems. This field, in both theoretical and experimental aspects, has now grown toward maturity. The one outstanding theoretical problem, how to adequately

approximate the effects of time correlated noise, has largely been solved; and a number of definitive experiments and simulations have been published. At the same time, we have witnessed the explosive growth of interest in classical and quantum chaos which, while stemming from entirely different sources, often affect the physical world in similar ways. For example, each limits our ability to predict the future evolution of a physical system. In other words, both are closely linked with the ultimate precision that can be expected from physical measurements.

Significant developments in our understanding and realization of squeezed states in both optical (chiefly laser) devices and parametric (Josephson junction) amplifiers have recently made feasible measurements below the limits set by quantum noise. Noise and chaos can also trigger, establish, and sustain pattern formation in both optical and fluid dynamic, and turbulent systems. Finally, Hamiltonian chaos excited by weak external periodic perturbations, with its exquisite webs, sometimes displaying unexpected symmetries, formed in the phase space and the newly discovered cycles of remarkable stability buried within strange attractors, are expected to show an underlying nontrivial susceptibility to noise. While fluid dynamics and chaos have been intimately connected for several years, and separately laser chaos has developed as a particularly clean example of low dimensional dynamical behavior, these two fields seem not to have enjoyed a large degree of mutual stimulation. Likewise, pattern formation has been studied separately in laser systems with nonlinear dielectrics and in fluid dynamics. Appropriately, a workshop was designed that would gather major contributors in each of these areas. The underlying theme is noise--classical and quantum--and its effect on the physical systems represented.

The central theme--quantum measurement--was set forth in a keynote lecture by W. Lamb, Jr., on an operational approach to the quantum measurement theory. This was followed by reports on the latest achievements of squeezed-state technology in quantum noise suppression in both optical and parametric amplifier devices. Presentations on pattern formation in both optical and fluid dynamic systems followed, wherein the property of external noise to sustain certain structures in the general Ginzberg-Landau equation was illustrated by a computer-generated cinema. A review of progress on calculating the spectrum of velocity fluctuations in fully developed turbulence (based on the Navier-Stokes equation) demonstrated the robustness of this long-standing challenge in statistical mechanics. Laser chaos was highlighted by the presentation of two very different experimental realizations of S'hilnikov chaos. A laser device was presented whose output signal-to-noise ratio is actually improved with increasing input noise intensity. Finally, two laser experiments were discussed that can

detect small numbers, or even a fraction of one, external photon. The workshop closed with two lectures on classical chaos. The final topics were the web-forming properties of weakly but periodically perturbed conservative systems, illustrated by a series of color slides, and the remarkable stability of buried cycles within chaos.

The *Proceedings* volume will be approximately 320-350 pages long which will result in an attractive price. Only the featured, or key, speakers will be published in the volume. We expect the papers to be substantial communications of new results combined with a tutorial aspect. Each paper is a self-contained item that can be read alone or in concert with some or all of the others. To obtain copies, contact Cambridge University Press, Cambridge, U.K.

Excerpted from NATO International Scientific Exchange Programmes, Advanced Research Workshop, Scientific Affairs Division, 8-1110 Brussels, Belgium.

### Advisory Group for Aerospace Research and Development Activities

by Dr. Spyridon G. Lekoudis, Fluid Dynamics Department, Office of Naval Research, Arlington, Virginia

**Introduction.** Representing the U.S. Navy, I attended the following Advisory Group for Aerospace Research and Development (AGARD) activities: A Specialists Meeting on Computational Methods for Aerodynamic Design and Optimization (May 22-23), a Specialists Meeting on Applications of Mesh Generation to Complex 3-D Configurations (May 24-25), and the Spring 1989 Business Meeting of the Fluid Dynamics Panel (May 26). All the activities took place at the Alexandria Hotel in Loen, Norway.

Both specialists meetings were directly related to the design of aerospace vehicles. The topics are important to the Navy's ship and submarine design activities and those related to Defense Advanced Research Projects Agency's submarine technology program. However, the work on mesh generation involves new efforts on adaptation that are described in this report. Works from the U.S., U.K., Federal Republic of Germany (FRG), France, Italy, Belgium, Sweden, Portugal, and the Netherlands was presented, and the weakness was evident of the southern flank countries (Greece, Turkey, Portugal, and Spain) in these areas of research and development.

The work on inverse design and optimization involves using prescribed constraints; e.g., aircraft lift, on computational fluid dynamics (CFD) software. The software generates geometries that satisfy the constraints. Three conclusions from the work are that:

1. Capabilities of the U.K., FRG, France, and the Netherlands was lagging behind that of the U.S.

2. Use of the Reynolds-Averaged-Navier-Stokes as an inverse design tool is emerging (paper presented by John Malone, Bell Helicopter Textron Inc.).
3. Availability of supercomputers in the U.S. is a major reason for its leadership on the subject.

The work on mesh generation involves ways of dividing the space around complex geometries so that discrete representations of the equations on fluid dynamics can be accurately and efficiently solved by CFD. Some impressive achievements of the state of the art in this area include mesh generation around complete aircraft configurations and around the separation of the solid rockets from the shuttle orbiter during ascent. The most advanced topic on the subject involves dynamic reconfiguration of the grid as the solution evolves. One of the best papers was presented by Professor R. Lohner, George Washington University, a leading researcher in the area. Again, the U.S. is leading in this area, because of using methodology of finite elements. The methodology was developed primarily by research in structures, to mesh generation problems in fluid dynamics. Some of the work (circa early 1980's, Princeton University, Professor A. Jameson) was funded by Office of Naval Research.

#### Personal Assessment

- DARPA's submarine technology program includes plans to develop a design center. The purpose will be to integrate software and include, for the first time, advanced hydrodynamic codes so that unconventional concepts can be analyzed. With the increasing sophistication of such software, like the ones presented in the meetings, success in this effort will greatly enhance the Navy's existing capabilities for submarine design.
- No information was presented about relations of artificial intelligence (AI) and sophisticated design. Hydrodynamic software is extremely complex, and major developers are discipline-oriented researchers with in-depth knowledge of fluid dynamics. However, it seems appropriate to increase research efforts that will take AI closer to the development of such software. Success in such efforts could take advantage of the emerging multiprocessor computers, where the U.S. is leading.
- Turbulence is becoming a more important issue than previously. The reason is that the availability of computer power and smart algorithms is no longer the pacing item. In the past, good designs relied on potential flow methods, simpler geometries, and flow events that did not crucially depend on turbulence. However, new designs depend on our ability to predict complex flows and the behavior of vehicles immersed in such flows, and knowledge about turbulence is crucial.

## International Workshop on Biotechnology and Biodegradation

by Dr. Robert W. Newburgh, Biological Sciences Division  
Director, Office of Naval Research, Arlington, Virginia.

**Introduction.** The International Workshop on Biotechnology and Biodegradation was held on June 18-24, 1989, at Valle de Lobos, Portugal. The purpose of the workshop was to assess the state of biodegradation of hazardous wastes. The topics included basic research as well as field studies.

Diverse capabilities exist in nature for the degradation of hazardous wastes by micro-organisms. A problem is that many of these organisms grow slowly and the final products are often not the smaller nontoxic compounds that are desired. Nevertheless, it is becoming clear that many of the nonbiological approaches such as incineration or landfills used in the past are no longer available or will not be in the near future. Therefore, using biological systems for remediation is becoming a serious alternative approach. The approaches are either to isolate naturally occurring organisms, concentrate mutants, or design new organisms using biotechnology approaches. The pathways organisms used to degrade hazardous chemicals were more complex than anticipated. Often, more than one organism is required for the degradation of hazardous wastes; e.g., chlorinated phenols to nontoxic products.

There are basic science requirements. One of the first needs is to isolate and characterize the organisms involved from mixed cultures. Once this is accomplished, it is then necessary to characterize the metabolic pathways, to determine in which organism all or part of these pathways exist, to isolate and characterize the proteins and genes required and to construct a biological system that is stable, reasonably efficient, and (if engineered) acceptable for release into the environment. After this basic research at the laboratory level, it is then necessary to field test the system--first in a greenhouse situation, then under the actual field conditions.

**Workshop Sessions.** The first workshop sessions covered the basic science of biodegradation. The promising research is essentially in two areas--use of mixed cultures and the development of engineered organisms. Often, in the case of mixed cultures, they consist of an anaerobic and aerobic organism. Usually, the aerobe executes the initial steps in the reactions such as dehalogenation and ring fission, while the anaerobe then converts the products to smaller compounds such as methane or CO<sub>2</sub>.

Clearly, it is necessary not only to consider variables such as temperature, aeration, nutrients, and pH for pure cultures but also for mixed cultures. This is a difficult problem for mixed cultures since the requirements for one of the organisms are not necessarily the same for the



other organisms. The need is to establish optimal conditions for the mixed culture, which is an area of research that is only in its infancy. There is a need to find what the contribution to the degradative process is from each organism even in the case of the degradation of TNT, nitroglycerine, and other nitro compounds that have been well studied but the mechanisms are not understood. One interesting finding is that phospho-inositol seems to be involved in the biodegradation of some of the fluoroaromatics.

The selection and development of mutants and genetically engineered organisms and components has been one of the more active research areas. Two approaches are being pursued in the area of selection. The first is called relaxed evolution. This means that there exists an enzymatic system for a naturally occurring compound that is chemically similar to a synthetic toxic substance. The organism, when exposed to the synthetic compound, makes a new gene. This new gene has a great deal of sequence homology with the parent gene particularly at the active site; e.g., catechol. An organism exists that degrades naturally occurring catechols. When exposed to chlorinated catechol, a new gene is produced that is similar to the parent gene and codes a protein active against the chlorinated catechol. The second strategy is called directed evolution. In this case, the organism is grown in a chemostat in the presence of plasmids and a toxic chemical, e.g., 2,4,5-T. After several months, one obtains a pure culture that now degrades this compound and other chlorophenols. This change in the organism often involves a transposon. In the area of genetic engineering, the approach is to create proteins with a broad specificity. This is done either by restructuring an existing pathway or creating a new route. The approach is to take a biological system that does not completely degrade a particular compound. One then looks for the block in metabolism which is usually the lack of a particular enzyme. The gene for this enzyme(s) is then inserted into the organism using molecular biological techniques. Anaerobes are used in many of the studies particularly for the biodegradation of ethers and surfactant. The reactions involved are an ATP-independent decarboxylation followed by carbonylation.

The next sessions were a transition from basic to applied research ending with field studies; the early sessions dealt with lignin degradation. One of the problems in this area is that many of the compounds are bound to sediment, thus anaerobic and not readily accessible to microorganisms. In this area, the most promising organisms are the fungi (white and brown rot) that grow naturally on dead trees. In general, the enzymes involved in the earlier stages are peroxidases. Thus, there exists a need for hydrogen peroxide. In biodegradation, this creates a problem in terms of *in situ* systems, since metal ions are often present, resulting in a nonbiological degradation of

peroxide. There have been a few successes with *in situ* biodegradation involving bioreactors. This involves moving soil to the site of the bioreactor and after treatment moving it back. Not only is this costly, but new laws will prohibit this.

In the final session, it was emphasized that of critical importance is the detection, identification, and enumeration of organisms involved in bioremediation. Improved sampling techniques, culture techniques, and using biological markers are required. The latter can be fulfilled by using immunological techniques and genetic analysis, such as restriction mapping and DNA probes, which is not unlike the problem in biofouling.

One interesting study for the degradation of toluene was presented. This involves several initial hydroxylations where oxygen is required for the hydroxylation step but not as the final electron acceptor as is the case in many organisms. Instead, the final electron acceptor is nitrate or sulfate.

## Neural Network Research in the Federal Republic of Germany

by Dr. Steven F. Zornetzer, Life Sciences Directorate, Office of Naval Research, Arlington, Virginia.

During a trip to the Federal Republic of Germany (FRG), I met with several distinguished researchers leading the German neural network effort. A summary of these meetings follows:

Dr. Rolf Eckmiller, University of Düsseldorf, is probably the leading figure in all of Germany, if not Western Europe, in terms of spearheading a basic research effort into neural networks. Our meeting dealt with a thorough overview of his own research dealing with visually guided control of eye movements in primates, but also a frank discussion of Eckmiller's view of the European effort in neural networks, cooperation versus competition among the various European research communities, and the opportunities for neural networks to alter conventional computer science and artificial intelligence research in the future.

Dr. Wolfgang Dahnicht, University of Düsseldorf, is a leader in research dealing with neural generation and control of limb movements in space. Biological joints perform movements in space under a variety of conditions using a redundant set of oblique compliant muscles. Dahnicht is investigating neural network approaches to the active control of mechano-sensory signals responsible for ensuring uniqueness of motor commands while taking the geometry of joint and other external conditions into account. We discussed the likelihood that his research and other research along similar themes would impact the more traditional robotics research communities. Dahnicht believes that within 5 years robotics research will be



dramatically transformed resulting from biological insights with joint control.

Dr. Gunther Palm, Max Planck Institute for Biological Cybernetics, is investigating the theoretical limits of neural network storage capacities. He has developed an analysis of the economics of associative memories and their asymptotic information storage capacity. His research to date suggests that the simple Hebb rule is optimal in terms of storage capacity.

Dr. Hanspeter Mallot, Johannes Gutenberg University, studies neural networks in visual processing in the vertebrate visual cortex. His work couples neurophysiological, architectural, computational, and psychophysical analyses of various aspects of information processing in early vision. He has recently shown that cellular lamination, average axonal and dendritic domains, and intrinsic feedback determine the spatiotemporal interactions in cortical processing. Possible applications of the resulting filters include continuous motion perception and the direct measurement of high-level parameters of image flow. His research in the visual system is as a model for others regarding the power of neural computational approaches in analyzing brain information processing.

Dr. Wolf Singer, Max Planck Institute for Brain Research, is studying the properties of striate cortex networks involved in processing information critical for the analysis of the speed and direction of motion. His work suggests that two parallel streams of information flow through these networks--a continuous and a discontinuous system. Singer is studying the interactions between these two data streams and the information contained in the discrepancies between them.

## Sixth Taylor-Vortex Flow Working Party

by Dr. Richard J. Wiener, Department of Physics, University of Oregon.

The Sixth Taylor-Vortex Flow Working Party took place May 29-31, 1989, at the Université Libre de Bruxelles in Brussels, Belgium. The meeting is held every 2 years alternating between a site in Europe and the U.S. At this year's conference, approximately 45 papers were presented to the 70 attendees. All papers were given in plenary sessions.

Although the emphasis of the meeting was the Taylor-Couette system, which consists of fluid flow between rotating concentric cylinders, a wide range of topics in basic fluid dynamics was addressed. Roughly speaking, papers fell into four categories: Taylor-Vortex flow in non-ideal conditions (e.g., complex fluids, temporally modulated flow, external fields, alternative geometries, and the Taylor-Dean problem); Taylor-Vortex flow beyond the first transition (including chaos); the spiral vortex mode; and the comparative studies of complex flows and instabilities. In this article, I will discuss briefly sev-

eral presentations which are representative of these categories.

Two examples of complex fluids examined, either theoretically or experimentally, in the Taylor-Couette system, are liquid Helium II and non-Newtonian polymer solutions. Professor K.G. Roesner, Technische Hochschule, Darmstadt, Federal Republic of Germany (FRG), talked on the linear stability analysis of Taylor-Couette flow of polymer solutions. To carry out the analysis, Roesner used an exact solution (which he derived) to a set of constitutive equations developed by Lhuillier and Ouibrahim, Université Curie, Paris, to model the viscoelastic character of long chained molecules. The exciting implication is that Taylor-Couette flow offers a testing ground for the modeling of the behavior of polymers.

Similarly, the Taylor-Couette system provides an opportunity for examining the scope of the semiclassical two-fluid model for the quantum mechanical properties of liquid Helium II (the Hall-Vinen-Bekharevich-Khalatnikov equations). Dr. Carlo Bharenghi, University of Newcastle Upon Tyne, U.K., talked on the linear stability of the HVBK equations in the infinite cylinder approximation of Taylor-Couette flow.

Michael R. Smith (substituting for Chris Swanson) University of Oregon, Eugene, presented experimental results for the onset of quantized vortices in Helium II undergoing Taylor-Couette flow. These results support the theory developed by Charles E. Swanson and Russell J. Donnelly, University of Oregon, for the onset of such vortices, using free energy arguments despite the dissipative character of Taylor-Couette flow.

A topic of considerable interest in fluid dynamics in recent years is flows with periodically modulated boundary conditions. Solutions to the Navier-Stokes equation for these flows, or their numerical simulation, are becoming more feasible with increased computing power and progress in theory. Dr. Chris Jones, University of Newcastle Upon Tyne, presented theoretical results on the onset of instability and the subsequent nonlinear development of modulated Taylor-Couette flow. He used a numerical implementation of Floquet theory to determine the critical mean Reynolds number for the onset of instability. Dr. Jones found good agreement between theory and previous experimental work by G. Ahlers, University of California, Santa Barbara, and T.J. Walsh and R.J. Donnelly, University of Oregon. H. Kuhlmann, Universität des Saarlandes, FRG, gave an excellent talk on the analogy between low frequency modulation of Taylor-Vortex flow and similar modulation of Rayleigh-Bénard convection. Through the use of Galerkin methods, Kuhlmann has reduced the equations for these systems to a single common form: an equation for a nonlinear, second-order, driven oscillator.

Coriolis force and magnetic fields are two examples of external fields of widespread interest in the study of fluid dynamical systems. I presented experimental results on the stability of Taylor-Couette flow subject to an external Coriolis force. I found that the stability behavior of this system exhibits qualitative and quantitative similarity to the behavior of Rayleigh-Bénard convection subject to rotation, Taylor-Couette flow under the influence of a coaxial magnetic field, and Rayleigh-Bénard convection subject to a magnetic field. M. Lücke, Universität des Saarlandes, spoke on the flow of ferrofluids in the Taylor-Couette system and the effects induced by magnetic fields.

Another type of nonideal Taylor-Couette flow involves alternative geometries. Dr. Manfred Wimmer, Universität Karlsruhe, FRG, spoke on experimental results concerning Taylor vortices between conical surfaces, and M. Abboud, University of Stuttgart, FRG, discussed the numerical investigation of this geometrical arrangement. Koichi Nakabayashi and Yoichi Tsuchida, Nagoya Institute of Technology, Japan, each talked on flow regimes in a spherical Couette system.

Chaos theory is a major intellectual movement encompassing many fields of study that has emerged in the last few years. Through the work of Swinney and Gollub and their colleagues, the Taylor-Couette system has been used as an example of chaos ideas applied to fluid dynamics. The investigation of chaos in Taylor-Couette flow continues. C. Stern, University of Houston, presented experimental work on a chaotic flow regime in counter-rotating Taylor-Couette flow. The chaotic flows have broadband spectra, low dimension ( $< 6$ ) and the largest Lyapunov exponent is positive. P. Chossat, Université de Nice, France, compared theoretical studies to Stern's experimental work on the counter-rotating Taylor-Couette system and found good qualitative agreement. S. Ciliberto, Istituto Nazionale Ottica, Italy, gave a special lecture on chaos concerning chaos and order in Rayleigh-Bénard convection. This talk continued a theme that ran throughout the conference on the close analogy between the thermal instability in the Rayleigh-Bénard system and the shear instability in Taylor-Couette flow.

The Taylor-Dean problem involves flow between two horizontal coaxial cylinders with a partially filled gap. Innocent Mutabazi, Laboratoire d'Hydrodynamique et Mécanique Physique, Paris, talked on theoretical results on the onset of instabilities in Taylor-Dean flow; and J.E. Wesfreid, Laboratoire d'Hydrodynamique et Mécanique Physique, Paris, presented theoretical results on spatio-temporal chaos in the Taylor-Dean problem.

One of the most dramatic patterns that occurs in the flow between concentric cylinders is spiral vortex flow. Spiral vortex flow has been observed in the flow between counter-rotating cylinders, flow with rotating inner cylinder and a through-flux, flow in the Taylor-Dean system, and flow in a stationary situation for a conducting fluid subject to a coaxial magnetic field and a radial electric current. Quite a few papers, experimental and theoretical, were presented on spiral vortex flow. John Hegseth, Ohio State University, discussed observations and measurements for the first time of nonuniform pitch in spiral turbulence, a remarkable phenomenon in which turbulent and laminar domains coexist in a spiral pattern. He explained these results in the framework of phase dynamics. Helmut Brand, Universität Essen, FRG, also applied phase dynamics to spiral flow and interpenetrating spirals.

Dr. Hermann Riecke, University of California, San Diego, presented theoretical results on spiral vortex flow in the Taylor-Couette system with counter-rotating cylinders and in the Taylor-Dean system. He investigated the influence of a temporal modulation of the Reynolds number with a modulation frequency which is resonant with a Hopf frequency. For a Hopf bifurcation, which leads to stable supercritical travelling waves (and unstable standing waves), modulation of a control parameter at twice the Hopf frequency has been shown to excite stable standing waves. Dr. Riecke discussed the role of symmetry breaking for the temporal modulation to be effective in these systems. His results predict that resonant temporal modulation of supercritical spirals will excite ribbons, which correspond to standing waves. This talk was particularly interesting in that it brought together many major topics of the conference, including temporal modulation, Taylor-Dean flow, higher instabilities, chaos theory, and spiral vortex flow.

Several papers on related issues in hydrodynamics were presented. P. Huerre, University of Southern California, discussed open flow instabilities, including Görtler vortices, which occur in the flow past a concave wall boundary. P. Lallemand, Ecole Normale Supérieure, France, gave a lecture on lattice gases and hydrodynamic simulations.

The above discussions is meant to give a flavor of the scope of the conference. The wide range of presentations and their relevance to many areas in fluid dynamics was very exciting. Taken as a whole, the Sixth Taylor-Vortex Flow Working Party was highly educational and successful.

## ONREUR REPORTS AND MAS BULLETINS

### Reports

To request reports, indicate the report number on the self-addressed mailer and return it to ONREUR.

### Communications

*The RACE Program: A 1989 Update*, by J.F. Blackburn. (9-13-R) Early plans for the program called Research and Development in Advanced Communications Technologies for Europe (RACE) were reported in ESN 39-3:122-123 (1985), a comprehensive description of the work of the definition phases carried out in 1986 was given in ONRL Report No. 8-014-R (August 1988), and the RACE Program in 1988 was described in ONREUR Report 9-7-C (March 1989). This report will go into a little more depth in some areas of the work and will describe several projects started since the Report No. 9-7-C was written; that report briefly described projects 1001 through 1048.

Nearly all of European Community (EC) and European Free Trade Association Telecommunications and Telematics Equipment Manufacturers, as well as major users of telecommunications, are participating in the framework of the RACE Program. The program is addressing the matter of providing Europe in a timely manner with advanced telecommunications services, required for continued economic and political strength and for completion of the Internal Market in 1992.

Joint teams of technical experts are collaborating in producing common functional specifications for Integrated Broadband Communications (IBC) and in the development of the technologies required for the application of advanced technologies in an economic fashion. Throughput, cost effectiveness, and technical performance are all important in arriving at the best solution.

The management and transport of information throughout the world has a turnover of over 500 billion European Currency Units (ECU). The world market for telecommunications equipment alone is well over 80 billion ECU and that for services is more than three times as large and is growing rapidly. By 2000, the EC will have invested an additional 500 billion ECU in telecommunications and the sector will account for about seven percent of Gross Domestic Product, compared with two percent in 1984. Inevitably, employment and the conti-

nued prosperity of Europe will be affected in a major way by the developments in telecommunications. Probably 60 million jobs in Europe will depend on the international competitiveness of Europe's information infrastructure and services in 2000.

The work in RACE addresses the technical and economic options for the development of an advanced information infrastructure. However, strategic analyses of demand for powerful and cost-effective services determines the orientation of the technical work.

The first strategic audit of RACE was carried out in 1988 by independent specialists familiar with key political and technical developments. The audit concentrated on global objectives and priorities, taking into account political, social, economic, technical, and industrial developments and the evolution of demand for advanced telecommunications. As of this writing, its conclusions were generally favorable and a second strategic audit is underway.

Within the EC, 11 telecommunications administrations, 89 universities and research establishments, and over 230 companies are now involved in RACE consortia. Organizations from 11 of the 12 European countries are represented. Also, 32 organizations from Austria, Finland, Norway, Sweden, and Switzerland participate in 39 consortia.

### Computer Science

*ESPRIT II*, by J.F. Blackburn. (90-1-R) The second 5-year phase of the European Strategic Program for Research and Development in Information Technology (ESPRIT II) began at the start of 1989. (For information on the first phase, see ESNIB 89-03:13-17.) This report will provide more detail on ESPRIT II, which is funded at 3.2 billion European Currency Units; half will come from participating companies.

This report includes a list of all approved projects in: Information Processing Systems, Office and Business Systems, Computer Integrated Manufacturing, Information Exchange System, and Basic Research. A brief description of each of the 47 projects currently supported within the Information Processing Systems area is included.

## REPORTS ON EUROPEAN SCIENCE AND TECHNOLOGY FROM OTHER COMMANDS

### Reports

Information on each of the reports listed below was furnished by the following activity. Address requests to:

**EOARD** - European Office of Aerospace Research and Development, Box 14, FPO New York 09510

*Soreq Nuclear Research Center*, by Dr. Vince Donlan, EOARD. (28pp) [EOARD-LR-89-062]

This report describes some of the current research programs in materials, optics, and energy systems at the Soreq Nuclear Research Center. Topics covered are: narrow bandgap semiconductors, atomic oxygen erosion simulation, diamond-like coatings, nonlinear index of refraction glasses, hardened aluminum surfaces, phase conjugate mirrors, optical switches, optical signal amplification, statistical treatment of material damage, laser simulation of hypervelocity impacts, ultracapacitors, and hybrid chemical/electrothermal hypervelocity guns.

*Heavy Cation Research at the Manne Siegbahn Institute of Physics in Stockholm*, by LTC Chet Dymek, EOARD. (14pp) [EOARD-LR-89-064]

The Manne Siegbahn Institute (MSI), formerly the Research Institute of Physics (AFI), Stockholm, was founded in 1937 to continue the Nobel Prize-winning work of Dr. Manne Siegbahn in high-energy particle physics. The MSI has since shifted its emphasis to relatively low energy beams and collisions of atomic and molecular ions and are now constructing a heavy ion storage ring. The CRYRING (costing about \$15 million) will enhance MSI's ability to study highly charged ions, including molecular di-cations. The MSI compares its experimental results with complete active space SCF theoretical calculations. The MSI also plans to study the one-dimensional crystallinity of cooled flows of ions completely stripped of electrons.

*Multifunctional Materials Research in Stockholm*, by LTC Chet Dymek, EOARD. (15 pp) [EOARD-LR-89-066]

Polymer chemists and material scientists at the Royal Institute of Technology (RIT) and the National Defense Research Establishment of Sweden (FOA) have active programs in the area of functional materials. The RIT is the focal point of a project to exploit its capability to prepare ordered polymer films with anisotropic electrical, magnetic, and optical properties. The essential expertise in the efficient creation of such films at RIT is in the preparation of macromers containing the functionally

active organic molecules followed by their photo-initiated cationic polymerization into films. The FOA group does research and development aimed at incorporating functionality into structural materials, especially composites with thermoplastic matrices and oriented polyethylene fibers. Their main focuses are on IR and radar signature reduction and effects of processing parameters on fiber-matrix interfacial behavior.

*Physical Chemistry at the University of Oslo*, by LTC Chet Dymek, EOARD. (17 pp) [EOARD-LR-89-067]

The Chemistry Department at the University of Oslo has a wide range of high quality research programs. They include basic research such as Professor Haaland's gas electron diffusion studies on molecules with group IVA-VIA dimetal bonds; e.g.,  $R_3Sn-SnR_3$  or  $R_3Ge-SbR_2$ . More applied projects include Professor Kofstad's high temperature corrosion work on defect structures in oxide scales on superalloy metals and Dr. Norby's work on ion conduction in ceramics. Their recent results shed new light on the role of water vapor in corrosion processes on steel at 900°C. Dr. Fraegi's group has considerable expertise in single SCF calculations and is developing techniques for relativistic quantum effects. Professor Klæboe uses Raman and IR spectroscopy to do kinetic studies of upper atmosphere chemistry and is a prolific contributor to azide chemistry. Some results suggest formation of azide polymers.

*Technion - Israel Institute of Technology*, by Dr. Vince Donlan, EOARD. (12 pp) [EOARD-LR-89-068]

This report describes research programs in aeronautical engineering, solid-state physics, and materials science currently under way at Technion. Topics covered are: advanced rocket propellants, hypervelocity impacts at glancing angles, thin-shell composite structures, thrust-vectored jet engines, vibration mode analysis of aeroelastic structures, ion implantation and annealing of HgCdTe, reduction of 1/f noise in elevated temperature HgCdTe detectors, intersubband infrared absorption in undoped III-V quantum well structures, strained layer InGaAs lasers, thin-film sputtering of ternary alloys, and ceramics and cermets.

*The 13th International Congress on Instrumentation in Aerospace Simulation Facilities*, by LTC Fred Gilliam, EOARD. (11 pp) [EOARD-LR-89-069]

The technical program of the 13th International Congress on Instrumentation in Aerospace Simulation Facilities (ICIASF) is summarized. This conference was held on September 18-21, 1989, at the German Aerospace

Research Center (DLR), Gottingen, Germany. The report briefly describes important developments in instrumentation application, instrumentation system enhancements, and new systems being developed. Specific instrumentation systems discussed include laser doppler velocimetry, particle image velocimetry, laser-induced fluorescence, liquid crystals, infrared imaging, and several other techniques.

*HOTOL Structures and Materials*, by LTC James G.R. Hansen, EOARD. (15 pp) [EOARD-LR-90-001]

HOTOL is British Aerospace's concept for a single-stage-to-orbit, "horizontal takeoff and landing" aerospace plane. This report summarizes categories of advanced structural materials for HOTOL and shows where on the structure these materials would be utilized.

*International Meeting on Modeling of Molecular Structure and Properties*, by LTC Chet Dymek, EOARD. (19 pp) [EOARD-LR-89-070]

The progress in computer modeling of macromolecular structure and properties is like a wave that, while it changes little in shape, continues to gather momentum, giving the appearance that it will inevitably crash onto the shore and crush the rocks of ignorance. This meeting in Nancy, France, was an attempt to keep the wave intact by bringing together some of the best physicists, biochemists, molecular biologists, and theoretical chemists working this field. Issues stressed were how to best treat intermolecular forces (receptor-substrate and solvent-macromolecule) and intramolecular interactions (secondary protein structure and channel formation). Supercomputer architecture and "jumping cucumbers" also made appearances. Molecular mechanics and dynamics, and the ways to get good potentials for these methods were the main interests for theoretical chemists.

## THE EMBASSIES: TECHNOLOGY ROUNDUP

### Federal Republic of Germany

*For further information on FRG items, contact Mr. Edward M. Malloy, Science Counselor, American Embassy, Bonn, APO New York 09080-7400.*

#### Federal Republic of Germany Court Prohibits Producing Genetically Manipulated Human Insulin

The Administrative Court (Court), State of Hesse, Federal Republic of Germany (FRG), prohibited the Hoechst AG chemical company from using genetically manipulated organisms to produce human insulin. The decision appears to extend to all kinds of genetechnology manufacturing plants. Because there is no legal regulation, the Court decided that the risks for man and his environment of industrial use of genetechnology cannot be assessed. In the Court's view, the existing laws on precautionary measures for a limitation and reduction of genetechnology risks do not justify a licensing of genetechnology processes and production plants. In 1985 and 1987, despite numerous objections from citizens, the district government head in Darmstadt, State of Hesse, had issued construction licenses for the Hoechst AG test facility for the large-scale genetechnology production of human insulin. The recent decision was against Hoechst because it had delayed the provision of the indispensable legal ordinances on genetechnology.

The new Court decision was a total surprise for Hoechst AG. Immediately after the publication of the decision, the Hoechst AG announced the discontinuation of the work on the nearly completed test production plant. According to a Hoechst spokesman, the company follows the further development with great concern because of the rising uncertainty on the use of genetechnology in the FRG.

### Italy

*For further information on Italian items, contact Gerald Whitman, Office of Science Counselor, American Embassy, Rome, APO New York 09794-9500.*

#### Italian National Research Council Committed to Strengthening Southern Italian Research and Development

**Research Institute Financing.** The President of the Italian National Research Council (CNR) announced an investment of 740 billion lire (about \$548 million) to strengthen research and development (R&D) in southern Italy. The financing will allow the creation of 36 new research institutes, 1,579 researcher and technician positions, 92 Ph.D. positions in southern universities, and 1,239 fellowships for southern graduates. The effort will focus on food and agriculture technologies, biotechno-

logies, environmental sciences, informatics, archaeology, and art preservation.

**Venice's Center for Marine Technology.** The University of Venice, with the support and participation of public and private industry and CNR, is creating a marine technologies study and research center. The center will cost 40 billion lire (about \$30 million) in 8 years with an operating expenditure estimated at 8.5 billion lire per year and about 100 full-time employees. The center will support research on marine environmental protection, exploiting marine resources, building oil platforms, and offshore devices for automated submarine exploration, and studying safeguarding the Venice Lagoon.

**Trento's Institute for Artificial Intelligence.** Located in Trento, the Institute for Science and Technological Research (IRST), is one of the most advanced organizations in Italy for research on artificial intelligence and materials science. The IRST was created in 1985; since 1986, Professor Luigi Stringa has been manager and is responsible for its remarkable development. The IRST presently employs 139 researchers—69 for artificial intelligence, 34 for materials sciences, and 36 for structure of matter. By the end of 1989, IRST will employ 170 researchers, 28 percent of whom are foreigners. Operating costs of IRST for 1989 will be 21 billion lire (about \$15.5 million) and for 1990 and 1991 are expected to reach 24 billion lire per year. In 1990, IRST will exchange scientists with the MIT Vision Laboratory. The IRST conducts advanced research on robots that interact with human intelligence and behavior, and conducts research on hyperthermic therapies in oncology and medical biophysics. In materials science, IRST is especially advanced on surface microanalysis of metallic and nonmetallic materials and integrated optical sensors for vision.

**Pisa's Space Center.** In cooperation with the CNR and the National Institute for Nuclear Physics, The University of Pisa has inaugurated a space center to conduct research on advanced propulsion systems such as magneto-plasma-dynamics propulsors and field emission propulsors. The facilities will also allow research in thermodynamics, several other research activities carried out in vacuum, and theoretical and experimental studies to acquire skill and knowledge on remote-controlled space robotic systems.

**EUREKA Approves Shipbuilding Automation Project.** During the recent Vienna EUREKA Conference, a project on flexible automation in ship prefabrication was approved costing 130 billion lire (about \$96 million) with IRI-FINCANTIERI as prime contractor. Industry from the Federal Republic of Germany (FRG), Sweden, and Spain will also participate in the project with a 30 percent share. The project is aimed at reducing the cost of shipbuilding by decreasing working hours by 25 percent. Shipbuilding is probably the only industry where auto-

mation has not been attempted because of the difficulties of handling construction parts weighing as much as 200 tons, and for the nonrecurrent and nonstandardized manufacturing processes.

**Telespazio Monitoring the Tyrrhenian Sea.** Telespazio started a program named *TEMPO* (Italian acronym for Tyrrhenian Eddy Multi-Platform Observations) in cooperation with CNR, National Agency for Nuclear and Renewable Energies, and support from research institutes in the U.K. and the FRG. The program will monitor the dynamics of the Tyrrhenian Sea, its environmental characteristics, temperature variations, and sea currents. Telespazio will supply remote-sensing information obtained by the GEOSAT and NOAA satellites, which will be supplemented by the European Satellite ERS 1 to be launched in 1991. The program is also supported by research and observations carried out by CNR oceanographic ship *MINERVA* and by airplanes.

**CAVI Pirelli Research Laboratories Manufactures Advanced Optical Amplifier.** In 1987, CAVI Pirelli laboratories began a program of advanced research in the area of telecommunications; it recently manufactured an optical amplifier made with a special fiber containing trivalent erbium ions, which is considered a key component of future optical transmission systems. The CAVI Pirelli laboratories used their amplifiers in a cooperative experiment with the U.S. Bell Communication Research Laboratories, and obtained an enormous increase of the signal entering the optical fiber for data transmission. By employing one fiber only, a speed was achieved of 11 gbit per second (equal to more than 100,000 simultaneous telephone conversations) at a distance of 260 kilometers. The CAVI Pirelli laboratories aim to proceed to the rapid industrialization of its research which is likely to find broad use in the aerospace sector.

**Aeritalia Studies Cancer Hyperthermic Treatment.** In cooperation with the Institute of Radiology of the University of Turin, Aeritalia has invested several billion lire and over 10 years of research to produce a device for the hyperthermic treatment of cancer. Aeritalia used technologies acquired in manufacturing satellite antennas to heat deeply-imbedded tissues and tumors. Expertise derived from electromagnetic research has permitted the monitoring of induced temperatures in heated tissues. The therapy has proved especially successful in treating breast cancer.

**The Florence Institute of Interplanetary Physics Carries Out Theoretical Studies on the Tethered Satellite Project.** In preparation for the Tethered Satellite Project to be launched in 1991, the Florence Institute of Interplanetary Physics is studying the effect of the flow of electrons caused by the tether crossing the magnetic field in space. The electron flow thus formed on the tether is collected by the core equipment on the shuttle and from there is launched into space through a modulator which

causes electric current variations in the tether. The tether then acts as a large antenna, sending out low-frequency long waves allowing communications with submarines and submarine bases. This new transmission technology will be tested during the 36-hour tethered satellite experiments during the 1991 shuttle flight. The signals from the tether will be captured and tested by three stations located in the Antilles, Canary Islands, and the Island of Tino in the Gulf of Genoa.

**FIDIA Pharmaceutical Company.** The FIDIA Pharmaceutical Company has its headquarters in Abano Terme near Padua in an area of 250,000 square meters. The company employs over 1,000 individuals including 278 researchers in Italy and 30 abroad. The company's business turnover is over 300 billion lire (about \$223 million), making it the fourth largest in the Italian pharmaceutical market and among the first 100 pharmaceutical companies in the world. The company has branches in the U.S., U.K., FRG, France, Spain, and Belgium, and recently concluded cooperation agreements with the U.S.S.R. and the Peoples Republic of China for establishing joint research institutes. The company produces only six drugs; the best known is Cronassial, responsible for 55 percent of the company's business turnover. Based on the discovery of the nerve growth factor by Italian Nobel Laureate Rita Levi Montalcini, Cronassial stimulates the regeneration of the nervous system and is used in peripheral neuropathy therapy. The company is now expanding by building an animal breeding test center and a research center in Syracuse, Sicily, and is also building a new 500,000-square meter factory in San Giorgio Nogaro. The company invests 20 percent of its business turnover in research which is centered mainly on ageing, innovation in biotechnologies with special focus on polysaccharides, and new plastic materials for surgery and artificial skin. In 20 years of activity, the company increased 500 times its original value.

#### AIDS Update

**Research Developments.** The Department of Informatics of the University of Milan, with the support of the Italian National Research Council (CNR), is initiating an informatic system for research on AIDS. Through a work station based at the University of Milan, it will be possible to access data bank, bibliography, statistics, and research descriptions concerning AIDS, which will be constantly updated.

Professor Fernando Aiuti, Immunology Institute, University of Rome, has tested the Italian drug Fluimcil on AIDS serum positive patients affected by opportunistic bronchitis. The experiment is inspired by the test being conducted at Stanford University with NAC (N-Acetylcysteine) corresponding to Fluimcil. Professor Aiuti said that so far the treatment did not show significant modifications or improvement on AIDS or related

syndromes; nevertheless, testing of Fluimcil will continue, introducing variation in the therapy length and dosage.

**Government Actions.** The new Minister of Health, Francesco De Lorenzo, (formerly President of the Italian National Association for the Fight Against AIDS) has announced a national plan against the disease. The Ministry of Health has 2,100 billion lire (about \$1.5 billion) to spend through 1991. During this period, 12,380 new beds will be created in hospitals to be added to 3,750 beds presently existing in infectious disease hospitals. They will hire 775 physicians, together with 2,830 AIDS specialty nurses. Community houses with health safety facilities will be built to lodge AIDS patients, and courses to update physicians and medical personnel will be held regularly.

Twenty-four billion lire (about \$17 million) will be used for research and 20 billion lire (about \$14 million) for a new information campaign through newspapers, TV, and schools. The trend of the new information campaign will be to sponsor and recommend using the condom as suggested by the World Health Organization. The new campaign will carry more information and fewer admonitions, but will not support the project of free distribution of condoms and syringes nor the proposal by some Parliament members for government-controlled heroin distribution to limit the increase of the disease among drug addicts.

**New and Proposed AIDS-Related Laws.** The Defense Committee of the Italian Senate approved a law that exempts AIDS serum positive individuals from military service. A bipartisan Parliament group has presented a draft law requesting to extend to AIDS patients the rules, legislation, and social security norms approved about 70 years ago for tuberculosis (TB) patients, who were discriminated against at the turn of the century. The draft law provides also for the transfer of the unused TB funds to assist AIDS patients.

**Other AIDS-Related News.** A committee of the U.S. magazine "Archives of AIDS Research" has named the Italian publication "AIDS - Atlante Di Clinica E Laboratorio" the 1989 AIDS Book of the Year. The book was written by a team of scientists coordinated by Professor Elio Guido Rondanelli, Director of the Clinic of Infectious Diseases of the University of Pavia.

The Court of Turin sentenced the director of a hospital and the manufacturer of a testing device to 6 months in jail for negligence that in 1987 caused a nurse to become serum positive after receiving on her face and hands infected blood from the defective testing device. The nurse received one million lire indemnity but meanwhile developed a full case of AIDS.

**Statistics.** As of September 30, 1989, the number of AIDS cases in Italy stood at 4,663, up 12 percent from the 4,158 cases reported on June 30, 1989; the number of



deaths totaled 2,274. On September 30, 1988, the number of AIDS cases stood at 2,556.

The Italian Institute of Health Centro Operativo AIDS (AIDS Operation Center [COA]) states that although the number of AIDS cases notified for statistical purposes by September 30 is 4,663, the diagnosed cases not yet notified and registered by COA are estimated to be 5,386. However, on September 30, the percent increase of new cases is the lowest registered quarterly since statistical data began to be collected.

The Lombardy Region has the highest number of AIDS cases in Italy (1,536) with an average incidence of 17.29 cases for 100,000 inhabitants. The Milan Hospital for Infectious Diseases (SACCO) has registered an average of three AIDS-related deaths every 24 hours. Milan is second only to New York for number of children with developed AIDS. The Lombardy regional administration has approved the financial support of 90 billion lire (about \$64 million) to fight the disease.

In Italy, out of 10 persons with AIDS, 8 are men and 2 are women, while the average in other countries is 9 men and 1 woman. The number of homosexuals developing AIDS in Italy is slowly decreasing, while the number of drug addicts developing the disease is climbing.

## The Netherlands

*For further information on Netherlands items, contact the American Embassy, Science Office, Economic Section, the Hague, APO NY 09159.*

### The Netherlands Science Policy

**Background.** The Netherlands government differentiates between science and technology, and divides policy responsibility accordingly. Responsibility for science research is therefore given to the Ministry of Education and Science, which funds both the public university system and research institutes. The Ministry of Economic Affairs (MEA) controls technology policy, and funds more applied research both by research institutes and private industry. The MEA's implementing agency for technology policy, STIPT, provides development subsidies for small- and medium-size businesses, and innovation centers that are information clearinghouses on science- and technology-related matters. All ministries fund research and development (R&D) related to their own functions.

**Environment, University Research System Emphasized.** Since Dutch science policy for the 1990s will have a stronger orientation to the social consequences of science, the 1990 science budget is different than its predecessors in that politically relevant issues are treated separately. Both long-term environmental research and the university research system are emphasized.

The Netherlands perceives itself as having fallen behind the research curve from 1975 until 1985, based on the proportion of people employed in research and on

expenditures as a percentage of GNP. An increase in private sector research expenditure after 1985 improved the Dutch position. Since 1987, Dutch spending on science research stabilized at roughly 2.3 percent of GNP, still behind the U.S., the Federal Republic of Germany (FRG), and Japan but roughly equal to French and U.S. percentages.

**Dutch Strong on Basic Research, Weak on Patents.** The Dutch public sector performs a relatively high proportion of basic research. The Netherlands government actively seeks to promote business funding of applied university research. Output of dissertations in science and scientific publications at Dutch universities increased from 15 percent in 1980 to 23 percent in 1987.

Less promising are the statistics related to per capita output of patents. The semipublic technology institutes such as Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (TNO) rarely publish the results of their contract research or apply for patent rights. According to the 1990 Dutch science budget study, the Netherlands ranks above FRG and Japan on publications but below on patents. Sweden outscores the Netherlands in both areas.

Overall, the Netherlands government judges that the position of the Netherlands is adequate on basic scientific research, regarding quantity as well as quality. On a sectoral basis, some weaknesses appear--the most glaring is that the Netherlands makes too little use of research results. As early as 1982, the prestigious Dekker Commission already recognized this problem, which it defined as a lack of communication between the academic community and business.

**See Need to Assess Social Consequences of Science and Technology Advances.** The Netherlands also sees a need for an extension of research in the society, with more emphasis on soft and social sciences. The Netherlands government sees technological advances as a necessary but insufficient prerequisite for balanced economic development and the maintenance of its competitive position. Increased learning in behavioral and social sciences is necessary to support economic development and the optimal implementation of new technology into society. The budget policy statement argues that an extension of science policy to include behavioral and social sciences also will be expected to result in greater insight and contributions to resolving questions of social welfare. Long-term environmental research is needed to contribute to sustainable development which must be translated into new economic and technological possibilities. On the environmental front, the Netherlands government not only sees the need for greater international cooperation but also for institutional changes.



# Office of Naval Research European Office

TELEPHONE: 44-1-409 + ext.

TELEX: (900) 7402119 ONRE UC

OMNET: ONR.LONDON

FAX: 44-1-724-7030

ARPANET: onr@uk.ac.ucl.cs.ess

## Office of the Commanding Officer and Scientific Director

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### U.S. Mail Address

Box 39

FPO New York 09510-0700

### U.K. Address

223/231 Old Marylebone Road

London NW1 5TH