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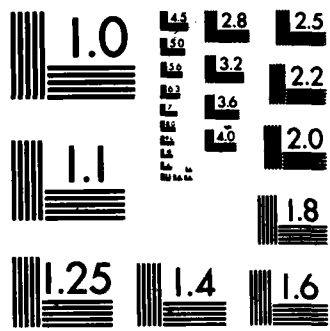
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OFFICE OF NAVAL RESEARCH  
LONDON

EUROPEAN SCIENTIFIC NOTES

ESN 38-1

January 1984



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**EUROPEAN SCIENTIFIC NOTES  
OFFICE OF NAVAL RESEARCH  
LONDON**

Edited by Larry E. Shaffer

January 1984  
Vol 38, No. 1

**BEHAVIORAL  
SCIENCES**

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~~Gender-Mixed Crews on Dutch Combat Ships~~, ..... Richard E. Snow 1

The Royal Netherlands Navy is examining whether women are being accepted in combat positions aboard ships.

The Max-Planck-Institute for Psycholinguistics, ..... Richard E. Snow 1

A world center for research in psycholinguistics, this new institute is principally interested in language production, comprehension, acquisition, and disorders.

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~~Cancer Therapy With Magnetism~~, *9th*, ..... Thomas C. Rozzell 3

Neuroblastoma, a rare and often fatal type of cancer in children, is now being fought with magnetic antibodies developed by Dr. John Kemshead of the Institute of Child Health in London.

Ninth European Underwater Biomedical Society Convention, ..... A.R. Manalaysay 3

The conference dealt with deep diving and decompression sickness, hyperbaric oxygen therapy, dysbaric osteonecrosis and general aspects of diving, lung barotrauma, and the cardiopulmonary physiology of diving.

The International Center for Genetic Engineering and Biotechnology, ..... Thomas C. Rozzell 5

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- Physical Chemistry of the Solid State-- Metals and Alloys ..... R.W. Armstrong 30

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A German scientist invites readers to submit military problems for solution by his system.



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James W. Daniel  
Scientific Director

  
M.A. Howard  
Captain, USN  
Commanding Officer

## BEHAVIORAL SCIENCES

### GENDER-MIXED CREWS ON DUTCH COMBAT SHIPS

by Richard E. Snow. Dr. Snow is the Liaison Scientist for Psychology in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until September 1985 from Stanford University, where he is Professor of Education and Psychology.

Women are now serving at sea in four Western navies--those of the US, Canada, Denmark, and The Netherlands. In most cases, the proportion of women included in the crews has been relatively small, and the ships involved have been noncombatant. Now the Royal Netherlands Navy has taken a major new step in a lengthy experiment aboard HNLMS *Zuiderkruis*, a combat-support ship with sailing programs and areas corresponding to those of frigates; all positions in such a ship are combat positions.

A 1-year experiment began in 1981, with women representing about 15 percent of the crew (two officers, three senior ratings, and 17 junior ratings). Questionnaires and private interviews were used to collect attitudes and the concrete experiences of all crew members. Extensive performance records and other behavioral data were also kept. Following this first year, a 4-month sea trip to North America was added. The ship served as part of a task force, but part of the crew was new. Here, ship's management reports and post interviews provided the data.

Results of the experiment suggested that men generally accepted the women as equal crew members, and the women felt generally accepted, except with respect to heavy physical work. The ship's operational readiness met prescribed standards, though extra effort was occasionally needed from the men to compensate for training and strength differences. On the long follow-up trip, however, some problems involving sexual harassment, interpersonal conflict, and breaches of discipline were observed. Differences between the experimental and follow-up periods in crew, ship's management, and sailing conditions seemed to underlie these problems; recommendations for future improvements were developed.

The Royal Netherlands Navy is now extending the program to a similar ship, HNLMS *Poolster*, and planning a similar experiment aboard a frigate. Details

are available in a report, in English, entitled "Sailing With Women," from the Project Group on Women, Department of Social Research of the Royal Netherlands Navy, P.O. Box 20702, 2500ES, Den Haag, The Netherlands.

10/28/83

### THE MAX-PLANCK-INSTITUTE FOR PSYCHOLINGUISTICS

by Richard E. Snow.

The Max-Planck-Institute for Psycholinguistics, Nijmegen, The Netherlands, is the first such institute created outside of West Germany for research in any area of psychology. It began as a project group in 1976 and was established as a full-blown institute in 1980. Its directors are W.J.M. Levelt and W. Klein. There are now about 100 staff members, including 18 scientists, 23 technical and administrative staff, and 25 students. Though presently housed in what was a Jesuit school and seminary, the institute is to move to a new building in the University of Nijmegen, close to the departments of psychology, linguistics, and neurology. The building will also house the university's interfaculty research unit for language and speech.

Thus, the institute has already become a world center for psycholinguistics research and may well become the world center in time. It already can boast an impressive list of visiting scholars, working conferences, and activities in association with other major research centers. In addition to its four primary research programs, outlined below, some of its senior staff members have also participated in major studies supported by the European Science Foundation to build a comprehensive inventory of child language research in Europe, to establish an archive of such research at the institute, and to launch a major longitudinal study of second-language acquisition by adult immigrants throughout Europe. This last activity affords a unique opportunity to make paired comparisons in which learners of one particular second language come from structurally different source languages, and in which learners of different second, or target, languages come from the same source language. The pairings being studied are shown in Figure 1.

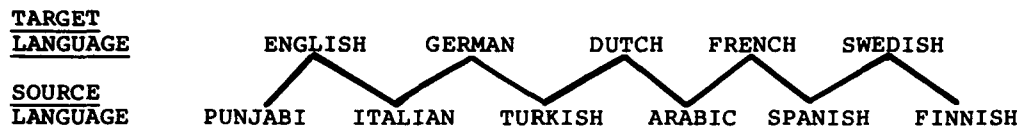


Figure 1. Language pairings.

The study is running for 5 years (Perdue, 1982).

The institute's primary areas of research are in language production, comprehension, acquisition, and disorders. Work on language production is investigating the ways in which a speaker uses conceptual, linguistic, and articulatory components to express intentions in different contexts. One line of experiments here concerns speech repairs--self-made changes that occur on-line to correct errors in speech--to determine the rules speakers follow to leave listener comprehension undisturbed. Another line of work analyzes the context dependency of intonation rules. In another series, gestures and expressions are studied to determine how speakers convey spatial and temporal positions of objects and events effectively. Computer models of language production are also a focus in this area.

Research on language comprehension ranges across studies of form/meaning relations, lexical processing, text comprehension, and language universals. A central concern is "cohort" theory, in which it is hypothesized that word recognition is mediated by parallel processing of all other words that begin with the same sound sequence. The parallel processing is activated at the beginning of the word and reduces the cohort of possible words on-line as the target word unfolds in speech; the target is recognized as soon as it is uniquely distinguishable from all others in the cohort (i.e., with which it shares initial segments). Auditory lexical decision tasks with reaction time as the measure have been developed to test this theory, and preliminary results using target words processed in isolation are quite promising. Further experiments are examining the interaction of sentence context and word recognition; the recognition point should move forward in a word if context helps reduce the cohort but could move back beyond the word in some contexts. In text processing research, the ways in which

listeners integrate incoming utterances with their mental representation of preceding context is studied. A particular concern here is the interaction of syntactic and semantic sources of information in on-line processing. Finally, a new project aims at developing explanatory theories for the extensive collection of language universals now in hand from research around the world.

In the language acquisition area, in addition to the immigrant second-language project noted above and some related studies, there are also studies of first-language acquisition. These examine language development as a continuum of reorganizational processes rather than as a series of stages, and suggest that learners gradually systematize semantic and linguistic development spontaneously, even though such systematization may not strictly be required for adequate communication. The role of "linguistic awareness" in both first- and second-language acquisition, is also studied. Other related studies analyze the development of cognitive and linguistic skills that underlie cohesive discourse, narration, communicative competence, and spatial reference.

Research on language disorders has concentrated so far on adult aphasia. One objective is to determine whether several different types of aphasias can be attributed to the same or similar deficits. Another is whether deficits result from specific system impairments or from impairments of the interaction among unimpaired systems. Still another is the degree to which certain pragmatic abilities in conversation are preserved in aphasics. The work with aphasics is planned to contribute both to the understanding of the condition and to special kinds of tests of hypotheses about normal functioning.

The institute distributes an annual report, which contains a comprehensive list of its publications (the mailing address is Berg En Dalseweg 79, Nijmegen, The Netherlands). It does not produce technical or other interim reports.

**Reference**

Perdue, C., ed., *Second Language Acquisition by Adult Immigrants: A Field Manual* (Strasbourg, France: European Science Foundation, 1982).

11/3/83

## BIOLOGICAL SCIENCES

### CANCER THERAPY WITH MAGNETISM

by Thomas C. Rozzell. Dr. Rozzell is the Liaison Scientist for Biological Sciences in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on reassignment until August 1985 from the Office of Naval Research, Arlington, VA, where he is Group Leader for Cellular Biosystems.

A rare and often fatal type of cancer in children, neuroblastoma, is now being fought with magnetic antibodies developed by Dr. John Kemshead of the Institute of Child Health in London.

A neuroblastoma is a solid tumor of primitive nerve cells that forms on the outer surface of the brain. The disease almost always strikes children (only one case has ever been recorded in a person over 20 years old). The tumor soon spreads to other parts of the body, especially to the bone marrow. Normal therapy for this type of cancer involves the administration of low doses of potent antitumor drugs coupled with radiation and surgical removal of the primary tumor. This is then followed by a second phase of treatment with higher doses of drugs.

The drugs and chemicals used to kill the tumor cells are also toxic to normal cells and especially to bone marrow cells (BMCs). Killing BMCs, the basis for the body's immune system, leaves the individual highly susceptible to infection. One way around the dilemma is to remove the bone marrow before the high dose treatment. Once the tumor cells are killed, the bone marrow can be returned to the patient.

In order for this technique to be effective, all tumor cells must be removed from the bone marrow before the normal BMCs are returned to the patient--otherwise the tumor cells will continue growing and spreading. Here is where the new technique comes into play.

First, Kemshead prepares monoclonal antibodies against neuroblastoma cells. When mixed with bone marrow cells, the antibodies attach themselves to any tumor cells that are present. The next stage uses 2- $\mu$  polystyrene beads developed by Dr. John Ugelstad of Trondheim University in Norway. The core of each bead contains a small amount of magnetite. These small spherical beads are coated with a second antibody that is specially made to recognize the first. These microspheres, with magnetite and antibodies, are then mixed with the BMCs that already contain the original monoclonal antibodies now attached to the tumor cells. The first antibody and the second antibody (or anti antibody) now merge, holding the tumor cells to the magnetic microspheres. In other words, the tumor cells adhere to the first monoclonal antibody, the first antibody to the second anti antibody, and the second antibody to the bead.

The entire complex--normal BMCs, tumor cells, antibodies, and antibodies, and magnetic microspheres--are now passed through a glass column surrounded by electromagnets that hold the tumor cells and magnetic beads against the sides while the normal marrow cells pass through. Several passes are made through the column to finally obtain a pure collection of normal BMCs that is then returned to the patient.

Kemshead is conducting clinical trials at the Hospital for Sick Children in London and currently has about seven children under treatment. If this method proves successful for neuroblastoma, it will surely be adapted for other types of cancer.

10/12/83

### NINTH EUROPEAN UNDERWATER BIOMEDICAL SOCIETY CONVENTION

by A.R. Manalaysay. CDR Manalaysay is Exchange Officer for Underwater Medicine at the Institute of Naval Medicine, Alverstoke, UK.

The ninth European Undersea Biomedical Society (EUBS) annual convention was held from 23 through 25 September in Barcelona, Spain. The conference was sponsored by EUBS, Centre de Recuperacio' i d'Investigacions Submarines

(CRIS), Generalitat de Catalunya Departament de Sanitat i Seguretat Social, Excellentism Ajuntament de Barcelona, Academia de Ciències Mèdiques de Catalunya i de Balears, Associació de Medicina Aeroespacial Subaquàtica i Ambiental, Federació Catalana d'Activitats Subaquàtiques, Nemrod-Metzeler S.A., and Boehringuer Ingelheim S.A. Most of the background work and organization was done by Dr. Jordi Desola, with the support of CRIS.

The EUBS was started some time ago by members of the Undersea Medical Society (UMS); they intended to have a European chapter of the UMS. The EUBS evolved into an independent organization which is an affiliate of the UMS. The EUBS has members from all over the globe, but most come from Europe. Despite the disparate backgrounds and languages of the society's members, the EUBS remains the one unifying forum in Europe for scientific exchange and collaboration in the undersea field and its allied disciplines. The mix at the latest conference attested to this: there were about 150 participants, and less than 10 percent of these were from the host nation.

The EUBS conventions tend to have an element of surprise, more so than other scientific societies--perhaps because the selection criteria for papers are not as stringent as at other conferences. This is intentional and is meant to allow less conventional ideas to be aired and discussed. For example, can atmospheric ionization have a significant influence on the occurrence of a decompression accident and on its subsequent evolution? Dr. R. Battestini noted that positive ions are found in greater numbers in dry fronts, in cold fronts, at dawn, and during the full moon. Among other things, these positive ions can speed the metabolism, increase oxygen consumption, and provoke vessel spasms. Negative ions cause opposite effects on the organism. Battestini went on to explain that we should consider such factors when planning and carrying out diving operations and treatments.

The scientific program was varied and consisted of 49 presentations during four sessions. Four of the 49 presentations were filmed sequences from experimental dives conducted on both sides of the Atlantic. Session I was opened by Dr. X. Fructus (Marseille, France); he presented a lecture titled "New Developments in Diagnosis and Treatment of Decompression Sickness." Papers at this session dealt with experiments and observations on the pathophysiology of deep diving, and diagnosis and treatment

of decompression sickness. Here, deep diving loosely refers to depths in excess of 1500 feet. At these depths, the high pressure nervous syndrome becomes a problem, especially if the diver is expected to perform useful work requiring cognition and fine motor control. The increased density of the gas at these depths also causes physiological alterations which affect man's usual homeostatic mechanisms.

Other presentations in this first session highlighted the fact that when decompression sickness occurs, it is not a simple case of bubbles forming in the tissues or vascular bed. Bubbles and the resulting gas-liquid interfaces cause secondary vascular effects, which may then become important in the eventual outcome of the case. Therefore, simply applying pressure to abolish the bubbles does not adequately deal with the etiology of the disease. Many approaches have been proposed, and properly conducted studies should lead to better treatment schemes.

Session II was called "Clinical Applications of Hyperbaric Oxygen; Past, Present, and Future Indications." Hyperbaric oxygen (HBO) therapy has gotten bad press in the past because unscrupulous practitioners used it in ignorance. But the medical community is coming to realize that some conditions improve if HBO is applied rationally. One must hasten to add that there are also contraindications to the use of HBO, since it is not entirely innocuous. Obviously there are points of contention in this area, as in other fields of medicine--cancer chemotherapy, for example. In both instances, the user is seeking to cure a malady; in both instances, the definition of a cure is not always easy to obtain. It is in these shadowy areas that more information is needed; it is also in these areas that continued rational investigations may eventually provide some answers.

The third session dealt with dysbaric osteonecrosis and general aspects of diving. Dr. R.I. McCallum (University of Newcastle, UK) gave the first lecture. He reviewed the topic of dysbaric osteonecrosis, which has been recognized for some time as an occupational hazard for divers and compressed-air workers. Current investigation continues to try to define the contributing factors and predict resulting hazards. Newer, less hazardous screening and follow-up procedures are being investigated as an alternative to repeated x-ray studies.

The papers on the general aspects of diving did not fall into any one

category. For example, can a prior back ailment predispose a diver to spinal cord decompression sickness involving the same segment of the spine? One paper presented two cases in which just such an association was noted. What kind of bacterial contamination may one expect in a hyperbaric chamber which is routinely used to treat hospital patients? Results from one study showed that the bacterial flora would be the usual hospital type, and that currently instituted antiseptics measures were adequate to prevent unusual contamination problems.

The last session was devoted to lung barotrauma and the cardiopulmonary physiology of diving. Lung barotrauma may cause a simple pneumothorax, or may result in arterial gas embolism with disastrous consequences. There is controversy about the best single approach to treating the cases which turn into disasters. This is not surprising because such a complex sequence of events may involve different causal factors. In fact, there may be more than one preferred method, depending on the precise evolutionary sequence. One paper that was expected to be quite controversial turned out to be quite conventional. The authors reviewed the recommendations for dealing with arterial gas emboli secondary to lung barotrauma. As mentioned earlier, some of these cases resolve quickly; others do not, and result in serious neurological deficits. Why this happens is not entirely clear, and various theories abound. This is another area which could profit from proper investigation.

The proceedings of the conference will be published soon. For more information, write to Dr. P.B. James, Wolfson Institute of Occupational Medicine, Ninewells Hospital, Dundee, Scotland.

10/11/83

THE INTERNATIONAL CENTER FOR GENETIC ENGINEERING AND BIOTECHNOLOGY

by Thomas C. Rozzell.

At the recent Biotechnology Symposium, held as part of the much larger Synergium-83 in Liège, Belgium, Dr. David McConnell (Trinity College, Dublin, Ireland) described the concept and foundation of the International Center for Genetic Engineering and Biotechnology (ICGEB).

The idea for the ICGEB was conceived by a group of molecular biologists at a meeting convened by the United Nations Industrial Development Organization in Vienna in February 1981. The group included four scientists born in India, Pakistan, or China, but now conducting research in North America; Dr. Herb Boyer, founder of Genentech, the first genetic engineering company; and Dr. Carl G. Heden, a Swedish microbiologist who has been involved in many international projects for cooperation with the Third World in science and technology. The group was aware of the potential impact of the new biotechnology on health, industry, and agriculture, and believed it posed a new set of problems for developing countries. It was felt that unless these countries acquired the science and technology of genetic engineering and biotechnology, they would only experience the deleterious effects of the changes that are bound to occur, and would not be able to apply biotechnology for their own purposes.

The ICGEB was envisioned as serving as a relatively small but dynamic center of excellence in research and training, and as a source of information and advice in genetic engineering and biotechnology dedicated to the specific objectives and needs of the less-developed countries. It was expected that the ICGEB would play a major role in coordinating the independent efforts of these countries, assisting affiliated centers (either regional or national), and cooperating closely with institutions with related research programs. It would set standards to be followed and maintained in this field throughout the less-developed countries, to whom it would belong as an independent institution--unlike any other organization.

As the new biotechnology owes much to the highly complex technology of genetic engineering, the ICGEB was seen as a center in which the main emphasis would be on research using genetic engineering, which is on one hand the key technology and on the other the aspect of biotechnology with which the less-developed countries have the least experience.

The ICGEB was endorsed in a long series of consultations in developed countries and in less-developed countries during 1981 and 1982, and by a high-level meeting of interested countries held in Belgrade, Yugoslavia, in December 1982. At this meeting, a committee was selected to determine potential locations for the ICGEB. Offers were made by Belgium, Cuba, Italy, Pakistan, India, and Thailand.

The committee reported these offers for consideration at a ministerial meeting held in Madrid, Spain, in September 1983. The ICGEB was formally established at this meeting, and representatives of 25 countries signed the legal articles of establishment.

The location of the center was not decided upon at the Madrid meeting, nor did the representatives decide how the center would be financed. If the ICGEB is to be the center of excellence that its founders envisaged, it will have to attract a group of outstanding scientists to its staff; the location could thus be critical.

One disturbing note was the absence at Madrid of representatives from many western nations, including the US, France, the Federal Republic of Germany, and Japan. Perhaps it has not been fully realized that many of the most important applications of the new techniques being developed in the Western world will find their greatest markets in the less-developed countries. A global synergy is needed.

10/26/83

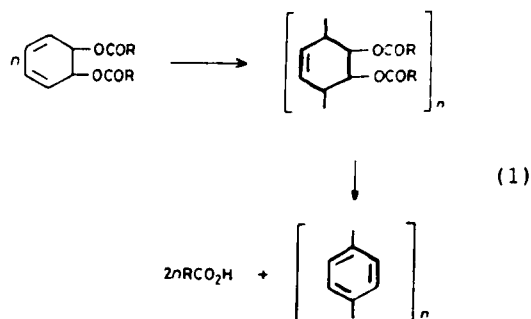
## CHEMISTRY

### A BIOTECHNOLOGICAL ROUTE TO POLYPHENYLENE

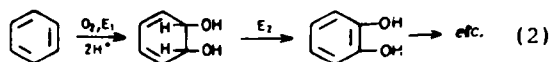
by Vivian T. Stannett and Thomas C. Rozzell. Dr. Stannett is the Liaison Scientist for Polymer Science and Dr. Rozzell is the Liaison Scientist for Biological Sciences in Europe and the Middle East for the Office of Naval Research's London Branch Office. Dr. Stannett is on leave until January 1984 from North Carolina State University, where he is Camille Dreyfus Professor in the Chemical Engineering Department. Dr. Rozzell is on reassignment until August 1985 from the Office of Naval Research, Arlington, VA, where he is Group Leader for Cellular Biosystems.

A new method of producing polyphenylene has been discovered by scientists at the Runcorn Laboratory of Imperial Chemical Industries (ICI) in Cheshire, UK. Until now, only oligomers of polyphenylene have ever been prepared, and even these may only be fabricated by sintering and compression at high temperatures.

The new method is based on the discovery that derivatives of 5,6 dihydroxycyclohexa 1,3 diene are readily polymerized using radical initiators to high molecular weight polymers. These are very soluble in simple organic solvents and can be used to cast films, coat substrates, or spin fibers. When the polymers are in this form, heating to 140° to 240°C smoothly converts them to polyphenylene, as shown in equation (1).



The ICI team has found that the simplest route to the dihydrodiol is the bacterial oxidation of benzene, as shown in equation (2).



Normally, the bacteria *Pseudomonas putida* uses benzene as a source for carbon by converting it into catechol using at least two of its enzymes, E<sub>1</sub> and E<sub>2</sub>. Genetic manipulation of the organism can render enzyme E<sub>2</sub> inactive, leaving the dihydrodiol as the only oxidation product. This is excreted by the cell, isolated by solvent extraction, and then can be purified by crystallization.

Simple bacteria are available from various sources and can be modified using chemical mutagens by well-established microbiological techniques. A preliminary report of this work, together with other details of the polymers and the synthesis, has been published by D.G.H. Ballard, A. Courtis, I.M. Shirley, and S.C. Taylor, *Journal of the Chemical Society, Chemical Communications* (1983), 954.

10/26/83



THE SECOND ROMANIA-US SEMINAR ON POLYMER CHEMISTRY

by Vivian T. Stannett.

The Second Romania-US Seminar on Polymer Chemistry was held in Bucharest from 10 through 15 September 1983. The first seminar was held in Jassy in 1976; the long lapse was due to a freeze in US-Romanian scientific cooperation, a situation that has now improved somewhat. The seminar was jointly sponsored by the US National Science Foundation and the National Council for Science and Technology of Romania. The chairmen were Prof. J.C. Salamone (University of Lowell, MA) and Dr. V. Dobrescu (Research Institute for Chemistry [ICECHIM], Romania).

Romanian Papers

The Romanian papers were interesting, not only in their own right but because they reflected the current areas of polymer research and development in Romania. The work itself was of a considerably higher quality than that presented at the first seminar, which the author also attended.

Three of the Romanian papers, all from the Chemical Research Institute in Bucharest, were concerned with elastomers. Dr. E. Badea discussed the modification of diene rubbers. Antioxidants were prepared which contained thiol groups. These were found to add readily to the double bonds of the diene rubbers. The resulting rubbers had good antioxidant properties, less than the equivalent of added material over the short term, but much better for long-term use due to the lack of volatility. Dr. R. Bordeianu reported work on the halogenation of polybutadiene with iodine chloride and bromine in tetrahydrofuran. The resulting glassy polymers were grafted with polystyryl lithium and a number of other reagents. Gels were formed in every case. Dr. V. Gruber described the modification of cis 1, 4 polyisoprene by the addition of the nitroso derivative Ph-NH-Ph-NO. The green strength was increased by a free radical modest crosslinking reaction. Natural rubber responded better than synthetic rubber to the treatment.

Three papers were essentially concerned with emulsion and suspension polymerization. Dr. M.M. Marinescu (Central Institute of Chemistry, Bucharest) presented some results concerned with the polymerization of acrylamide in an inverse emulsion system of water and white spirits. The molecular weights

were less than those obtained by solution polymerization. With seeded systems, however, molecular weights up to 20 million were claimed. The system is being studied for enzyme entrapment. Dr. M. Matescu (Central Institute of Chemistry, Bucharest) described the synthesis of beads of polyvinyl alcohol by suspension hydrolysis of polyvinyl acetate in paraffin oil. Their use for enzyme immobilization was also suggested. Dr. D. Donescu (Center for Plastic Materials, Bucharest) described some pilot plant experiments concerned with the semicontinuous emulsion copolymerization of vinyl acetate and dibutyl maleate. The various reaction parameters were investigated.

Ten papers on miscellaneous topics were also presented. Seven of these were from Jassy, five from the well-known Petru Poni Institute of Macromolecular Chemistry (PPIMC), and two from the Polytechnic Institute of Jassy (PIJ). Dr. A. Caraculacu (PPIMC) discussed the influence of dibenzyl structures derived from the 4, 4 diisocyanate on the properties of polyurethanes, polyureas, polyimides, and polyparabanic acid. The most interesting observation was that liquid crystal properties could be obtained with the polyurethanes when the crystalline block frequencies were suitably regulated. Dr. V. Barboiu (PPIME) described the preparation of copolymers of various acrylates and methacrylates which had donor and acceptor groups substituted into them. Examples were carbazole and anthracene as donors and dinitrophenol and dinitrobenzoate as acceptor groups. The intramolecular charge transfer complexes appear to induce a certain ordering in the copolymers, which also exhibit limited photoconductive properties.

Dr. A. Carpov (PPIMC) presented a summary of his well-known work on the synthesis of polymers containing quaternary ammonium groups. Methods of preparation included both substitution and addition reactions via chloromethylation and vinyl pyridine polymers and copolymers. Dr. I. Negulescu (PPIMC) reviewed the present state of knowledge of the isomerism of polyacetylene, polyphenyl acetylene and poly  $\beta$  ethynyl naphthalene, including the activation energies. Very few new results were presented. Dr. M. Bruma (PPIMC) presented some results of the synthesis of a number of heterocyclic polyimides. These contained oxadiazole, benzoxazinone and benzthiazole units. The thermal and hydrolytic stabilities of the various polyimides were studied. Both were often found to be superior to

the fully aromatic polyimides. Dr. V. Bulacocshi (PIJ) prepared a number of condensation polymers with cycloaliphatic units in the chain. Trans cyclopropane and cyclobutane dicarboxylic acids were used for the syntheses. Some gave an indication of having liquid crystal properties and were interesting as potentially thermostable and photoreactive polymers. Dr. B.G. Simionescu (PIJ) discussed plasma-induced polymerization and copolymerization. The method used, high frequency discharge in the gas phase with liquid monomer below, gave extremely high (about 80 million) molecular weights; an example is a methyl methacrylate-styrene copolymer. The polymers were all soluble; water-soluble polymers might be of interest for secondary oil recovery and the immobilization of enzymes.

The remaining four papers were all from the Chemical research Institute at Bucharest. Dr. M. Ionescu described some improved catalytic systems for the oxidative coupling of 2, 6 dimethyl phenol. These were based on the classical  $\text{CuCl}_2$ -aliphatic amine complexes with new ligands which weaken the metal halogen bond, using the principle of the so-called trans effect. The highest reaction rates were given by complexes having Cu-S bonds. Dr. O. Bufe discussed the development of some catalytic polymers based on the polycondensation of chloranil and piperazine, respectively, with benzidene. These could then be chelated with inorganic salts such as palladium and copper dichlorides. Their catalytic activity was tested for the hydrogenation of styrene to ethyl benzene. Good conversions were obtained; the activity was found to be a function of their thermal stability.

Dr. M. Dimonie spoke on the ring opening polymerization of the cycloolefins using the catalytic system epichlorhydrin-tungsten hexachloride,  $\text{WCl}_6$ . The ring was found to open next to the double bond, and olefin complexation with the transition metal had a decisive influence. The study was mainly devoted to the mechanism and has been extended to the tricomponent system  $\text{WCl}_6$ , aluminum triisobutyl and epichlorhydrin or chloranil. Dr. V. Dobrescu presented some new evidence for the liquid-liquid transition in polymers--polyethylene and polypropylene are being studied in detail. The viscosity-temperature curves showed clear evidence of such a transition; x-ray diffraction, heat capacity and melt density were also used to support the viscosity evidence. The

interpretation was based on changes in the molecular chain packing, and the transition was found to lower with increasing pressure.

#### US Papers

Twelve US scientists attended, all of whom presented papers. Prof. O. Vogl (Polytechnic Institute of New York) spoke on "New Polymeric Structures"; Prof. V. Stannett (US Office of Naval Research, London) on "Recent Work on Grafting to Cellulose"; Dr. E.J. Vandenberg (Arizona State University) on "Polyethers with Reactive Side Chains"; Prof. J.C. Salamone (University of Lowell, MA) on "Polymerization of Ion-Pair Comonomers"; Dr. P.F. Boettcher (Du Pont, Wilmington, DE) on "Recent Progress in the Preparation of Functional Methacrylate Polymers"; Prof. W.H. Daly (Louisiana State University) on the "Modification of Condensation Polymers"; Prof. J.A. Moore (Rensselaer Polytechnic Institute) on "Vinyllogous Nucleophilic Substitution--A Route to New Polymers"; Prof. S.C. Israel (University of Lowell, MA) on "The Characterization of Polymers by Direct Pyrolysis--Chemical Ionization Mass Spectrometry"; Prof. R.M. Ottenbrite (Virginia Commonwealth University) on the "Biological Activity of Polycarboxylic Acids"; Prof. T. St. Pierre (University Of Alabama, Birmingham) on the "Synthesis of Novel Polyamines and Some of Their Properties"; Dr. A.L. Brode (Union Carbide Corporation, Bound Brook, NJ) on "Phenolics--Non-classical Routes to Solid and Liquid Binders"; and Prof. C.L. McCormick (University of Southern Mississippi) on "Polymers for Enhanced Oil Recovery." The US papers were well received and engendered considerable discussion.

10/28/83

## CLIMATOLOGY

### STATISTICAL CLIMATOLOGY

by Bruce Hayden and D.R. Barr. Dr. Hayden is Professor of Environmental Sciences at the University of Virginia, Charlottesville. Dr. Barr is Professor of Statistics and Operations Research at the Naval Postgraduate School, Monterey, CA.

The Second International Meeting on Statistical Climatology was held near Lisbon, Portugal, from 26 to 30 September 1983. The purposes of the meeting were to bring together climatologists, meteorologists, statisticians, and other scientists involved in climatology; to discuss current research in these areas; and to review the nature of the problems of interest and statistical methods that might be useful in attacking them.

The program for the meeting was divided into 17 sessions on 14 different topics; a "lead paper" was given at the beginning of each session, followed by several contributed papers. About 80 papers were presented to over 100 attendees from about 30 countries. Primary sponsors of the meeting were the World Meteorological Organization, the US National Science Foundation, and the US Office of Naval Research; a number of scientific societies and academies were involved as cosponsors. Prof. Allan H. Murphy (Oregon State University) was chairman of the organizing committee.

Statistical methods have played an important role in climate research, in analyses of meteorological and climatological data, and in applications of climate information. Areas in which statistical methods are making significant contributions include:

- Analysis and modeling of climatological data
- Spatial and temporal variability in meteorological elements on climatological time scales
- Climate prediction
- Detection of changes in real or simulated climates
- Climate impacts and applications of climate information.

#### Climate Prediction

About half-way through the conference the statisticians asked the climatologists, "What is the fundamental scientific question you are trying to solve?" Allan Murphy responded, "The number-one problem is climate predictions." Within the context of climate prediction, most conference papers fell into one of three categories: climate predictability, successes and failures, and the value of predictions.

Climate Predictability. The theoretical basis for assessing the predictability of climate is the concept of the signal-to-noise ratio. Dr. Roland Madden of the National Center for Atmospheric Research (NCAR, Boulder, CO) reviewed the question of climate predictability in the lead paper for the first session on climate prediction.

Madden has estimated variances of January mean temperature ( $\sigma_a^2$ ) and the expected January climate noise ( $\sigma_n^2$ ) for the northern hemisphere north of 20°N. He suggested that the ratio  $\sigma_a^2/\sigma_n^2$  could serve as an index of January temperature predictability. As a general rule, this measure of predictability is greatest along coastal margins and least in the continental interiors. The regions of greatest predictability also coincide with dominant storm tracks of the middle and high latitudes. While Madden's paper was the only one that directly addressed the concept of predictability, conference participants quickly grasped the ideas and suggested that it might serve as a guide in funding proposed prediction research and in evaluating suggested prediction schemes.

The approach using the signal-to-noise ratio has been applied only to the monthly time scale. The lower climatic noise at seasonal and longer scales, however, suggests the potential for prediction at these scales. In contrast, the time scale between extended weather forecasts (up to 14 days) and the monthly forecast seems to offer the least prospect of detecting a climate signal amid the weather-related noise.

Successes and Failures. Nigel Nicholls (Australian Numerical Meteorology Research Center, Melbourne, Australia) reviewed the current state of the art of statistical climate prediction. While his review was largely restricted to work on the tropics and the southern hemisphere, his earlier papers attest to his generally pessimistic view of the success and value of existing prediction schemes.

Only three papers discussed prediction methods and evaluated the forecasts on independent data. It is noteworthy that one of these papers was offered by scientists from the National Meteorological Center of the People's Republic of China. They applied a threshold autoregressive model (TAR) to the problem of monthly precipitation prediction using past precipitation and northern hemisphere kinetic energy at 500 millibars (mb). Basically nonlinear time series were linearized in selected time segments, and extrapolations to the future were made. Tests for only 5 months were reported, so it is not possible to place statistical confidence in the reported success.

Bartholy and Kaba (Central Meteorological Institute, Hungary) reported on their operational model for monthly temperature and precipitation forecasts

based on persistences in a 500-mb height field. For above and below the mean types of forecasts from 1961 to 1970, they reported correct scores of 70 to 80 percent for temperature and 70 percent for precipitation. Given the verification sample size ( $N = 10$ ) and a  $p = 0.05$  significance level, further verification is needed before confidence in their method would be justified.

The third forecasting method was reported by Bruce Hayden (University of Virginia). Seasonal temperatures (October-November-December and January-February-March) were forecast and verified for the independent period 1960-80 for 18 stations in the eastern US. The forecasting method relies on reported season-to-season persistences in the first four empirical orthogonal functions of cyclone frequencies over eastern and western North America. Average autumn (77.8 percent) and winter (80.4) forecast skills were reported. With 21 years of forecast trials, a score of 71 percent would be significant at the 0.05 level.

While the monthly and seasonal forecasts issued by the US National Weather Service's Climate Analysis Center were not reported on, they also rely on 500-mb high anomalies and analog configurations. In the session on climate prediction, five papers focused on the variability of the 500-mb pressure surface and its correlations with surface monthly temperature and precipitation. It is generally believed that anomalies from the mean circulation at 500 mb evolve more slowly than the surface weather pattern and so may be a key to near-term climate prediction.

In the long-term (decades and longer) prediction problem, general circulation models (GCMs) are viewed with some optimism. These models attempt to use known physical principles with the planetary atmosphere divided vertically into several layers, and horizontally into  $10^\circ$  by  $10^\circ$  latitude and longitude grid cells. The quality of the product of these models was questioned during the conference.

In his lead paper for the session on detecting climate changes, Robert Livezey (Climate Analysis Center, National Weather Service, National Oceanographic and Atmospheric Administration [NOAA]) observed that "substantive climate signals in GCM experiments often will not be credibly detected--or worse, sampling fluctuations will be misrepresented as signals." The question of  $\text{CO}_2$  doubling, he noted, "is largely based on empirical- and model-related evidence that has not held up

well under critical post-examinations by [people] other than those who presented the evidence."

Hans von Storch and Erich Roeckner (University of Hamburg, Federal Republic of Germany) evaluated January simulations using their GCM and compared the results with observations. They concluded that "all zonally averaged model-generated quantities are significantly different from observations." It seems clear that current GCMs cannot predict climates with any skill. It is expected that model adjustments will permit the product to be not only realistic but accurate. Such an adjustment is a first step in the model calibration process. Once it can be shown that a GCM correctly "forecasts" current earth climates, a second point of calibration will be required before confidence can be placed in the products of GCM models that focus on future conditions.

GCMs produce hundreds of thousands of climate estimates or predictions; but the models are expensive, and they are run only a few times, so the sample sizes are small. Both Livezey and von Storch detailed this problem and suggested that the number of quantities forecast must be reduced and the number of GCM runs increased; otherwise, the climate signal will not be detected in the model's noise. Progress in this area is essential before GCM experiment results, such as those concerning  $\text{CO}_2$  doubling, can be important inputs for related public policy decisions.

Prediction Value. To date, climate prediction models of only modest skill have been achieved. The question is, then, what level of skill is needed if the prediction is to have value. Dr. Roman Krzysztofowicz (University of Virginia) presented the lead paper on the use and value of climate forecasts. Krzysztofowicz finds that a probabilistic forecast of even low but positive forecast skill may be of real value if the user makes many decisions, the forecaster quantifies his uncertainties, and the user optimizes decisions against a background of historical climatological distributions.

Zhurovsky (Agrophysical Research Institute, Leningrad, USSR) showed that in the absence of forecasts, climate information in a decision-theory context can optimize economic strategies by using climatological distributions rather than the simple mean statistics. Allan Murphy used a decision-analytic approach to the information-value problem and concluded that forecasts similar to the US National Weather Service long-range forecast may have real value if the user optimizes his

decision-making process with respect to the uncertainties of the forecast.

The papers relating to decision theoretic applications clearly showed that climatological distributions, based on either existing data or forecast data, are more important than just their low-order moments. There was substantial interest in models to fit rainfall distributions (12 papers) and wind direction and intensity data (three papers), reflecting the realization of the value of climatological data. Hydrologists preceded the climatologists in applying decision theoretic concepts in optimization of their products, and this was reflected in the number of papers on the topic which were presented by statistical hydrologists.

#### Statistical Applications

We mention here a few papers that had statistical emphasis and that were especially interesting. One instance of fruitful collaboration between a statistician and an oceanographer was reported by Professors Iognaid G.O Muircheartaigh and Edward C. Monahan (University College, Galway, Ireland) in their paper, "Aspects of Oceanic Whitecap Coverage Dependence on Wind Speed: Heteroscedasticity in the Data, and the Estimation of the Beaufort Velocity." There is a need for a precise expression relating the oceanic whitecap coverage,  $W$ , and the 10-m-elevation wind speed,  $U$ . Such a relationship would facilitate estimation of wind speed from remote measurement of whitecap coverage with satellite instruments, for example. Expressions for the  $U$ -dependence of  $W$  are almost always in the form of a simple power law, such as  $W = \alpha U^\lambda$ . But it is recognized there is a wind speed below which whitecapping does not occur, called the Beaufort velocity,  $U_\beta$ . There has been some controversy about the value of  $U_\beta$  (estimates range from about 3 m/s up to about 7 m/s). O Muircheartaigh and Monahan reported the results of their rather extensive efforts to fit the law  $W = \alpha U^\lambda - U_\beta$ , including estimation of  $U_\beta$ , using several available data sets. They found evidence of heteroscedasticity in these data, which they incorporated into their estimators. They ultimately used a weighted least squares approach to obtain estimates of  $U_\beta$  in the range 3.8 to 4.0 m/s.

The paper "High-resolution Frequency Analysis and Applications to the Prediction of Almost-Periodic Functions" was presented by Professors G.W. Brier,

M.M. Siddiqui, M.W. Haurwitz, and R. Biondini, all of Colorado State University. They described two new statistical methods for analyzing time series having characteristics of almost-periodic functions. The first method is a high-resolution frequency analysis (HRFA) which has been applied to series composed of known periodic signals with superposed random noise. It was reported that the technique provides information that would be missed by autocorrelation and fast Fourier transform methods. The second technique Brier and his colleagues reported was concerned with analysis and prediction of time series responding in a nonlinear fashion to multiple periodic forcings of specified periods (which might be known *a priori* or estimated using HRFA). Applications to real and simulated data suggest these methods are more robust than the usual autoregressive schemes, with less danger of over-fitting. Several examples of applications of the techniques to analyses and predictions of geophysical and climatic time series were reported.

Prof. George Tiao (University of Chicago) described models he has developed to investigate whether ozone in the upper atmosphere has decreased significantly since about 1970. He was concerned with ozone carried by chemical reactions with hydrofluorocarbons formerly used in aerosol and refrigerant applications. Tiao used time series models with a trend term; using variance components considerations, he tested the significance of the hypothesis that the trend was not negative. The conclusion was that there is not strong evidence of worldwide decreases in ozone levels, although with proper adjustment for other factors, such as volcanic dust, data from some locations suggest there has been some decrease.

#### Comments

A significant proportion of the papers concerned applications of well-known statistical methods to climatological data. Some of the analyses seemed to constitute trying numerous approaches in search of "statistical relationships." There were many reports of analyses of data sets using regression, correlation analyses, principal components, and various time series procedures. Even though there was a lot of talk about collaborative efforts between climatologists and statisticians, it was apparent that quite a few climatologists do their own statistical work. In a discipline as young as modern climatology, one can expect a period of

searching for, and developing, appropriate statistical methods. Indeed, just as in psychology and economics, it may well be that researchers will develop a set of statistical methods especially suited to climatology--Climato-metrics? Metstatistics? It certainly does appear that close collaboration between climatologists and statisticians will be beneficial to both groups--and, of course, ultimately to the population at large.

10/5/83

**COMPUTER SCIENCES**

A CODE FOR GENERATING DYNAMIC MODELS OF ROBOTS

by J.F. Blackburn. Dr. Blackburn is the Liaison Scientist for Computer Science in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until September 1984 from the National Academy of Sciences, where he is Executive Director, Computer Science Board.

The Dipartimento di Informatica e Sistemistica of the University of Rome has developed a program for generating a model of industrial robots in symbolic form (Cesareo et al., 1983). The code, called DYMIR, derives the equations of motion of robots, considered as a chain of rigid bodies connected by suitable single-degree-of-freedom joints. The code can be run on a variety of large computers, is transparent to the user, permits the calculation of dynamical models with up to 12 degrees of freedom, and takes into account elasticity and transmission losses at joints.

Systems for Symbolic and Algebraic Manipulation

The choice of a Lagrangian formalism and symbolic computation for generating the model led to an analysis of existing symbolic and algebraic manipulation systems. Among others, REDUCE and SCRATCHPAD were considered. Since SCRATCHPAD is an internal IBM language, is not portable, and requires more core memory and processing time than REDUCE, the preferred system which was implemented was REDUCE. It is based on LISP

and implemented in the same Algol-like procedural language used for access to the system. It permits integer and rational arithmetics with unlimited precision, manipulation of polynomials, rational and elementary functions, and differentiation. Also, "pattern matching" techniques proved useful for adding new rules for specific applications. REDUCE is available on many computers the size of the IBM 370/148.

Robot Kinematics

An industrial robot may be described as a chain of  $n+1$  links interconnected by  $n$  joints. Only joints with a single degree of freedom (rotational or translational) are considered, since a multi-degree-of-freedom joint can be split into a combination of rotational or prismatic (sliding) joints.

A coordinate frame  $R^i$  is attached to the end of link  $i$ , and the orientation is related to the type of joint at the end of the link and to the position and shape of the link. Where frames of reference are chosen arbitrarily, appropriate rules must be applied in order to simplify the automatic manipulation of DYMIR and to make the model less complex.

The displacement of link  $i$  relative to link  $i-1$  is given by the  $i$  joint variable  $q_i$ . In the case of translational joints,  $q_i$  is the perpendicular distance  $r_i$  between the X-axis of frames  $R^i$  and  $R^{i-1}$ . For rotational joints, it is the angle  $\theta_i$  between the X-axes of the same frames. Coordinates of two adjacent frames are related by: (1) the distance,  $a_i$ , between the Z-axes; (2) the angle,  $\alpha_i$ , between the projections of the Z-axes onto the plane perpendicular to the common normal; (3) the distance,  $r_i$ ; and (4) the angle,  $\theta_i$ . In order to perform transformations relating frame  $R^i$  to frame  $R^{i-1}$ , a  $4 \times 4$  matrix  $A^i$  is employed, where:

$$\begin{matrix} x_{i-1} & & x_i \\ y_{i-1} & & y_i \\ z_{i-1} & = A^i & z_i \end{matrix} \quad \text{and} \quad \begin{matrix} 1 & & 1 \end{matrix}$$

$$A^i = \begin{array}{ccc|c} \cos\theta_i & -\sin\theta_i \cos\alpha_i & \sin\theta_i \sin\alpha_i & a_i \cos\theta_i \\ \sin\theta_i & \cos\theta_i \cos\alpha_i & -\cos\theta_i \sin\alpha_i & a_i \sin\theta_i \\ \hline 0 & \sin\alpha_i & \cos\alpha_i & r_i \\ \hline 0 & 0 & 0 & 1 \end{array}$$

The transpose  $C^i$  of a  $3 \times 3$  submatrix of  $A^i$  gives the pure rotation from  $R^{i-1}$  to  $R^i$  and is useful when computing velocities of the chain in a recursive way.

A  $4 \times 4$  matrix  $W^i$  based on  $A^i$  performs the coordinate transformation between  $R^i$  and  $R^0$  frames so that

$$W^1 = A^1$$

$$W^i = W^{i-1} A^i \quad i=2,3,\dots,n.$$

Thus the position of the end point of the manipulator relative to the frame  $R^0$  is given by the first three rows of the last column of  $W^n$ .

The equation which gives the coordinates of the manipulator end-point relative to an inertial frame expressed in terms of generalized coordinates is usually called a kinematic model. The mathematics of determining dynamic models of rigid body chains is discussed by Cesareo et al. (1983).

The basic version of DYMER refers to a robot only as a simple kinematic chain considering rigid joints. The behavior of motor and gear boxes is not accounted for. However, the basic version is useful as a first approximation in the study of a robot for synthesis and control.

DYMER consists of 10 modules; each performs a particular computation needed in the dynamic model. In the basic DYMER, the inertia of the rotor is considered part of the inertia of the arm to which it is linked. In order to avoid taking into account the effect of the rotors in data input, a modified version of DYMER must be used. Kinematic data (and inertia) of the rotors are entered separately from those of the arm, and the gear ratio,  $n_i$ , of each gear box is inserted.

A new module of DYMER was designed to perform these computations; however, the use of the code with this improved version is the same as for the basic version.

The basic and rigid versions of DYMER discussed above are valid when elasticity may be neglected. Joint elasticity for certain types of gear boxes can be incorporated in the Lagrange equations as a set of conservative forces. Each joint is then split into the rotor of the motor and the output of the gear box, which is attached to the arm. This is the elastic version. If transmission losses at gear boxes cannot be neglected, the elastic model can be modified.

The input data differ for basic and rigid. In the basic version, only the mechanical data of the arms are considered; in the rigid version, the mechanical data of the actuators are also considered. In the elastic version of DYMER, mechanical input data are those in the rigid version plus the elastic constants. The output uses the same format and symbols as in the other two versions, but refers to the elastic model.

The DYMER program uses symbolic algebraic manipulation to compute the dynamical equations of open spatial mechanical chains. It allows the user to compute these dynamical equations for systems with up to 12 degrees of freedom, taking into account, if required, elasticity and transmission losses at joints.

Specifically, the equations of motion with elasticity of joints taken into account are given by

$$B_e(q_e)\ddot{q}_e + f_e(q_e, \dot{q}_e) + e_e(q_e) = m_e$$

where: the subscript  $e$  denotes that the terms are related to the case of elastic joints

$q_e$  is the vector of joint variables

$\dot{q}_e$  is the time derivative of  $q_e$

$\ddot{q}_e$  is the time derivative of  $\dot{q}_e$

$B_e(q_e)$  is the inertia matrix

$f_e(q_e, \dot{q}_e)$  is the vector containing centrifugal and coriolis terms

$e_e(q_e)$  is the vector defining potential terms (e.g., gravity)

$m_e$  is the vector of generalized applied forces.

The effect of elastic forces at each joint is taken into account by adding the elastic potential energy:

$$\frac{1}{2} K_e^i (q_{e,i+1} - q_{e,i}/n_i)^2 \quad \text{odd } i,$$

where  $K_e^i$  is the elastic constant computed at the output, and  $1/n_i$  is the transmission coefficient of the gear box in the joint  $i$ .

The DYMER program computes the nonzero components of the matrices  $e_e(q_e)$ ,  $B_e(q_e)$ , and  $f_e(q_e, \dot{q}_e)$  in terms of the symbols on which they depend through algebraic manipulation of those symbols. (An appendix with sample output is provided in Cesareo et al., 1983.) Thus the user has a model of the robot he wishes to control.

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10/31/83

JAPAN'S FIFTH GENERATION COMPUTER  
 PROJECT: PROGRESS AND ASSESSMENT

by J.F. Blackburn.

Society in the 1990s will expect improved performance from information technology and will require more advanced and higher-level functions than are available today. For example, there will be demands for use of more varied media, easy-to-use computers, and higher software productivity; in addition, information technology will have to be applied to new areas. To meet these needs, there must be a review and evaluation of the design philosophy of current computer technology. Conventional computers are relatively straightforward in hardware design, and they depend heavily on software to provide an efficient processing system. They are mainly designed for numerical processing carried out sequentially. The pursuit of high speed and large memory capacity has led to enormous computer systems.

Several factors now have to be considered:

1. Hardware costs have been substantially reduced through very large scale integration (VLSI), and computer systems can use as much hardware as required.

2. A new architecture for parallel processing is required because device speed has approached the limit for sequential processing.

3. Two-dimensional VLSI chips are designed today with the aid of super-computers. Three-dimensional chips would give a better ratio of price to performance but would require far greater computing power for design.

4. Current computer technology lacks the basic functions for non-numerical processing of speech, text, graphics, and patterns, and for artificial intelligence--including inference, association, and learning. Such functions should be developed.

These factors have motivated the Japanese to begin their Fifth Generation Computer project, which will include research and development in VLSI technology, distributed processing, software engineering, knowledge engineering, artificial intelligence, and pattern information processing.

Focus of the Japanese Project

During the 1983 Fifth Generation World Conference--held in London from 27 through 29 September--Kazuhiro Fuchi and Kunio Murakami of the Institute for New Generation Computer Technology (ICOT) gave a progress report on Japan's Fifth Generation Computer Project. During the same conference Edward Feigenbaum, Professor of Computer Science and Director of the Heuristic Programming Project at Stanford University, gave a personal assessment of the project.

According to Fuchi, the idea behind the Fifth Generation Computer Systems (FGCS) is to develop an expert system. The basic task for the 1990s will be knowledge information processing. The Japanese hope that this project will encourage other countries to undertake similar programs.

In hardware, it will be necessary to use natural communication capabilities, such as the use of natural language. Logic programming will need to be used (ESN 37-10/11:400 [1983]). A fundamental question is whether current machine designs with improvements will be able to meet these needs. The answer, in the opinion of the Japanese, is that a new approach is needed, including new devices and a different machine architecture. The key will be logic programming.

A further question to be considered is whether to use classical programming or relational data-base programming. However, in logic programming these two systems can be brought together. Logic programming is a kind of functional programming. If logic programming is adopted as the machine language of the new system, then a high-level architecture will be required. Fuchi said many Americans don't like logic programming.

It was emphasized that FGCS is not a VLSI project. Although progress is expected in this area, other projects in Japan will continue to carry on such research.

Software and Architecture

Murakami discussed the program to support software development and the architecture of the machines. The relational data-base machine will be called Delta; the sequential inference machine will be referred to as PSI.



It is expected that a language like Prolog will be directly executed on the PSI machine. Inferences will be performed based on stored information. These considerations will lead to the technology and design of the FGCS machines.

The parallel inference machine (PIM) and the knowledge-based machine are the nucleus of the FGCS hardware. During the initial stage of the software support system, an evaluation will be made of the basic inference module configuration, which includes the following:

1. A parallel-type inference basic mechanism to manage the parallel execution of inference operations.
2. A data flow mechanism to execute inference operations and rapidly determine solutions.
3. An abstract-data-type mechanism to consolidate detailed inference operations into several groups and control them by group.

The parallel-type inference basic mechanism, data flow mechanism, and abstract-data-type mechanism individually consist of functional submodules. Initially, prototypes of these submodules will be constructed and then combined to make a prototype module of the three functional mechanisms. Prototype simulators for experimental operation will be built to simulate module configurations, using different numbers and combinations of submodules. The simulators will be used to determine the optimum configuration of the modules for the three functional mechanisms, and of the inference basic module that will comprise these submodules.

Prototype software will be developed for evaluation and examination of the VLSI convertibility of the circuit composition of each submodule designed. It will be used for data gathering and evaluation for integrating in VLSIs.

Also during the initial stage of development, an evaluation will be made of the configuration of the knowledge-based module, which includes the following:

1. A basic knowledge-based mechanism to provide overall management of the execution of knowledge-based operations.
2. A parallel-type relation and knowledge operation mechanism to provide speedy knowledge accumulation, retrieval, updating, and data conversion.
3. A relational data-base mechanism to provide large capacity knowledge accumulation, storage, and management.

The basic software system will contain software modules for the following purposes: (1) problem solving and inference, (2) knowledge-based management, (3) intelligent interface, and (4) intelligent programming.

A pilot model prototype sequential inference machine (SIM) for development of software for the FGCS will be made. It will be produced by improving a selected language (probably Prolog) suitable for inference, and by modifying existing machine architecture.

Research in the initial stage of FGCS is based on version 0 kernel language, an extension of Prolog. Specification of this language was completed in 1982. Version 0 serves as the machine language of the SIM, and is tentatively used for program description in software development. Version 0 was developed for sequential processing, and another version--called version 1 kernel language--is for parallel processing. It is a logic programming language based on experience with version 0 and with new functions added.

Figure 1 shows how the SIM and the relational data base machine (RDBM) will be connected to each other and to their data bases. Figure 2 gives the functional distribution between the two.

As mentioned earlier, the relational data-base machine is called Delta. Its basic architecture consists of the following:

1. A dedicated engine based on a sorting-by-merging algorithm for "heavy" relational operations--such as Join, used to combine tables based on data value.
2. A stream interface between the dedicated engine and the hierarchical memory.
3. An internal scheme suitable for a dedicated engine and a stream interface.

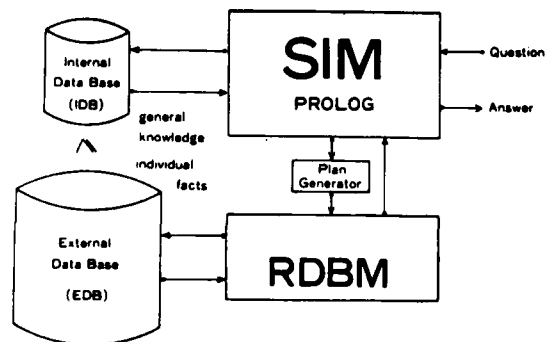


Figure 1. SIM and the RDBM.

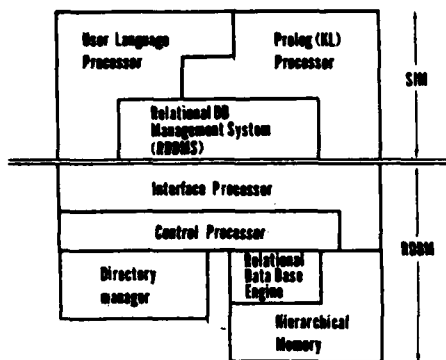


Figure 2. Functional distribution between SIM and RDBM.

4. A large-capacity hierarchical memory with nonvolatilized integrated circuit memory.

Figure 3 is a block diagram of Delta. The hierarchical memory will have a moving head disk of 10 to 20 gigabytes and a silicone disk of 16 to 128 megabytes. Its functions will include stream generation, data clustering, memory resource management, data recovery, and high-bandwidth data transfer.

Some architectural features of the Delta system are: (1) high level machine language (Prolog-like), (2) tagged data representation, (3) fast-stack access mechanism, (4) multiprocessing support, (5) compiling approach.

Figure 4 shows the hardware configuration of PSI, the sequential inference machine. PSI has a cycle time of 200 ns and a cache memory access time of 200 ns. Its performance is expected to be 20,000 to 100,000 logical inferences per second; its memory capacity will be 2 million to 16 million 40-bit words.

Assessment of the Japanese Program

Prof. Feigenbaum's assessment of Japan's FGCS was based on a trip made to Japan during July and August 1983. He found that progress at ICOT was steady. He rated the learning phase as better than usual; progress toward a knowledge-based machine was better than he had expected. He said that there was solid progress on sequential processing.

Four of the 40 ICOT people are working on parallel architecture and are concentrating on VLSI and software. No research is being done on applications, and very little is being done in expert systems at this stage.

It is expected that the budget for ICOT will hold steady. Mitsubishi has been chosen to build the first inference machine in 1984. Cooperation between participating Japanese companies and ICOT is close. The number of staff members devoted to FGCS within the companies is growing rapidly. There are 100 people working on FGCS in the two laboratories of the Electrical Communications Laboratory, the research arm of Nippon Telegraph and Telephone Public Corporation.

Relations between ICOT and the universities is weak but cordial;

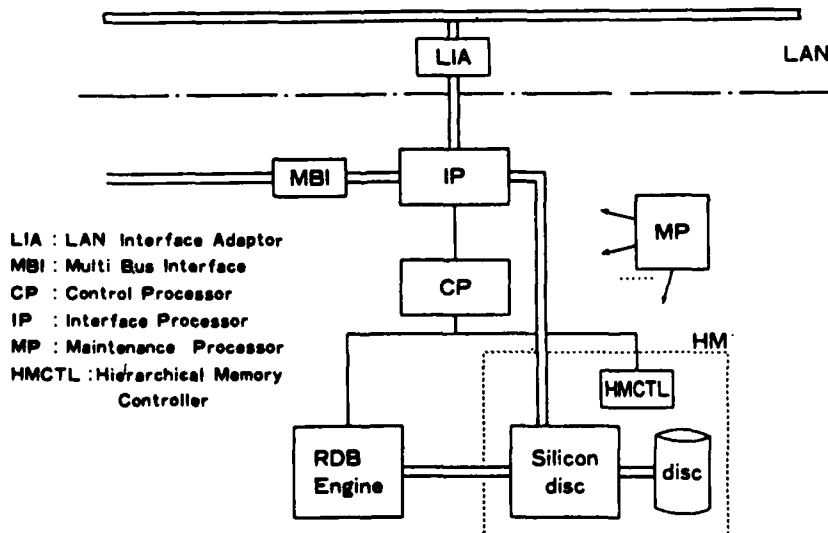


Figure 3. Delta, the relational data-base machine.

GERMAN PLANS FOR FIFTH GENERATION  
COMPUTING SYSTEMS

by J.F. Blackburn.

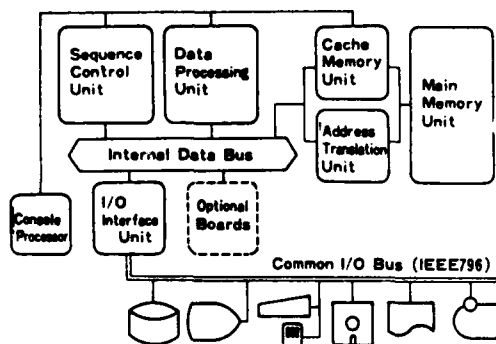


Figure 4. Hardware configuration of PSI.

research groups under the supervision of professors are working on FGCS. Also, the relation between ICOT and the Electrotechnology Laboratory--part of the Ministry of International Trade and Industry--is considered cordial but weak.

A second world conference on FGCS is scheduled for November 1984. The meeting will serve as a forum to review progress at ICOT and will include demonstrations and invited papers. It is expected to be a culmination of the first stage of the development process.

The prospects for international cooperation in the project depend on what is meant by the term "cooperation." The Japanese are issuing English language reports on their work and frequently invite foreign visitors to Japan. In addition, the Japanese occasionally visit American and other foreign laboratories for discussion. However, genuine collaboration is improbable, if not impossible, because of geographical distance, cultural differences, and language barriers. One purpose of the program is to teach Japanese technologists to innovate, but the program also represents intense economic competitiveness. So even though the problems are most challenging, international cooperation will not happen.

The Japanese people love technology; they view the FGCS project with great enthusiasm but with an element of skepticism as well--because there is some doubt about its total success.

At the first International Conference on Fifth-Generation Computer Systems held in Tokyo, 15 through 22 October 1981, Japanese computer scientists announced that they had designed a 10-year research plan for developing prototypes of new computer systems which will be appropriate for the society of the 1990s (see preceding article). These high-speed systems will be very easy to use and flexible in applications. Application programs using sophisticated techniques of artificial intelligence will enable natural language comprehension by the machine and automatic translation from one language to another. The architecture of the hardware will consist of communicating machines--each specializing in a particular function, such as handling relational databases and performing logical inference. Each machine will be a collection of processors working in parallel to perform a job very efficiently. Performance of up to 10,000 times that of today's fastest machines is envisioned.

At the Fifth Generation World Conference (London, 27 through 29 September 1983), Peter Vaulefs (University of Kaiserslautern) gave a report on German work dealing with fifth-generation computing systems. Even though there is no total plan corresponding directly to Japan's, Germany does have programs which are directly related to parts of the Japanese program.

Current Activities

Germany is doing work in a wide range of artificial intelligence areas, including expert systems, natural language, robotic vision, man-machine interface, deduction, programming environment, and machine architecture.

The program in expert systems is 2 years old. Projects are under way at the University of Kaiserslautern; Fraunhofer Gesellschaft at Karlsruhe, Stuttgart, and Berlin; and Battelle Institute at Frankfurt; four companies also have projects: Nixdorf, Siemens, Scientific Control Systems (SCS, Hamburg), and Krupp-Atlas.

Work in expert systems at Kaiserslautern includes knowledge-based program construction, diagnosis (medical and other), and computer aided design. Specifically, work is under way on

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integrating software development, theorem proving, machine architecture for distributed systems, and expert systems in medicine. Gesellschaft für Mathematik und Datenverarbeitung (GMD) is working with Kaiserslautern on the above projects. Battelle has a program in fault diagnosis in automobiles.

Several companies have started artificial intelligence groups for expert systems; the focus for the groups is on developing prototypes. Included are Siemens, Nixdorf, Triumph, SCS, and Krupp-Atlas.

Research work in natural languages is being done at the Universities of Hamburg and Berlin. At Hamburg the work concerns development of a system which will converse with the user. At Berlin, the work is on text understanding.

The universities of Hamburg and Karlsruhe are working on computer vision projects. The following institutes also are carrying on research in this field: Fraunhofer-Gesellschaft-Institut für Informationsverarbeitung in Technik und Biologie, Karlsruhe; Forschungsinstitut für Mustererkennung, Karlsruhe; and Deutsche Forschungs-Und Versuchsanstalt für Luft und Raumfahrt, Munich.

Hamburg University is concentrating on scene analysis using techniques for digitizing, edge detection, interpretation of parts, interpretation of objects, and reference models. The work also includes a study of the relation between vision and natural language.

Stuttgart University is working on a project called Inform; it deals with man-machine interfaces and uses knowledge-based editors and knowledge-based handling of documents. The university also has a project on office automation.

Two universities--Kaiserslautern and the Technical University of Berlin--have programs in deduction. Kaiserslautern is working on a program verification system to be used in nuclear power plants and railroad operation. It is based on the use of intelligent data bases.

The Technical University of Berlin is building a hardware system to use symbolic LISP language.

In the area of programming environments, the work at Siemens on Interlisp is significant. The work is an adaptation from the IBM 360/370 version developed at Uppsala University in Sweden.

The University of Kaiserslautern is carrying on research on LISP/PROLOG and other languages. Stuttgart University has a project called OB-TALK--similar to SMALLTALK in the US.

The Technical University of Berlin has a machine architecture program to develop by 1988 a fifth generation computer system expected to perform 100 million floating point operations per second.

#### Future Plans

Starting in 1984, the government's Department for Research and Industry will start a German research and development program on knowledge-based systems.

Also, the Universities of Karlsruhe and Saarbrücken, and Deutsche Forschungsgemeinschaft (DFG) will begin a long-range (10 to 15 year) research program in artificial intelligence. (DFG is the German equivalent of the National Science Foundation in the US). Areas to be covered are expert systems for diagnosis and interpretation in automobile factories, medicine, and possibly other areas, and for planning and construction in the building industry. Also included will be research in man-machine interface. For the starting phase of the long-range research program in 1984, the budget will be \$37.5 million and will increase as the major program gets under way in 1985. The expense will be equally divided between government and industry. There will be a relatively small number of projects (about six); universities and industry will cooperate on them. The plan is to concentrate on a few collaborators and to create a few centers of excellence.

The long-range programs at the Universities of Karlsruhe, Kaiserslautern, and Saarbrücken will involve as many as 100 scientists in expert systems, robotics vision, and artificial intelligence software.

As is true of the Alvey Program in the UK (ESN 37-12:447-450 [1983]), the German program in areas related to fifth generation computing systems will complement the European fifth generation program, ESPRIT.

10/21/83

#### IBM INSTITUTE '83 AT OXFORD UNIVERSITY

by J.F. Blackburn.

Each year for the last 6 years IBM has sponsored at Oxford University a week-long seminar giving current and future directions in their information

systems. Institute '83 was held from 12 through 16 September 1983; it was attended by more than 300 people and covered the following topics: information systems management, the end user, industry, large systems, intermediate systems, data systems, and communications.

This article concentrates on the sessions dealing with large systems, office systems, computer aided engineering, and communications.

#### Software Architecture for Large Systems

David Norris gave a very good lecture on software architecture for large systems. The trend is toward higher performance in millions of instructions per second (MIPS). Although IBM generally has not competed for the very largest systems in terms of MIPS, they have System 3084Q rated at 27 MIPS. The other two trends in large systems are toward corporate-wide integrated data bases and accommodation of users who are not data-processing professionals.

High performance is attained through the use of multiple central processing units (CPUs). Systems have shown an 18 percent per year increase in MIPS for many years, but customers' needs for large systems are growing at the rate of 30 to 40 percent.

Corporate-wide integrated data bases are possible because of addressable data and controlled sharing capability. The new IBM operating system called multiple virtual systems/extended architecture (MVS/XA) provides support for multiple CPUs and addressable data.

In the early days of the IBM System 360, introduced in 1964, the capability to address 4 million bytes (8 bits each) appeared adequate. However, the search for higher speed and bigger addressable memory led to the concept of virtual memory, introduced in the System 360/67 and continued in the System 370. This allowed 16 million bytes of directly addressable data and required 24 bits for the address part of an instruction.

Even 16 million bytes of directly addressable memory proved inadequate, and 31-bit addressing was made available in the 3000 series of processors (e.g., 3084). Thus, it became possible to directly address more than 2 gigabytes (2 billion bytes) of memory. This was supported by the multiple virtual system (MVS) programming system. Finally, MVS was extended by MVS/XA through implementing 32,768 virtual memories of 2 gigabytes each in a so-called horizontal system arrangement.

The extended MVS system permits very large networks of many thousands of

terminals; each user can have a large addressable memory. In fact, up to 32,000 users can have approximately 2 gigabytes of memory.

The question of a system's ease of use by people who are not data-processing professionals is becoming more and more important. A major problem is scheduling access to external data. In the past, the various job control languages and methods of assessing data presented difficulties for the nonprofessional. The user needed to track and locate external data, understand it, and be able to plan and predict its changes; this required an expert. However, the MVS has a resource management system which gives heuristic scheduling and greatly simplifies the data accessing procedures.

In an integrated data-base system, the question of authority to access and to update is an important consideration. In the past there were two states of authority: supervisor and program. These are adequate for batch processing systems. However, a hierarchy of authority is needed in an integrated system accessed from a variety of locations. There must be data-base management, telecommunications management, and other functions with different needs and hence requiring different access authorities. The MVS offers a hierarchy of authorities and controlled sharing access.

#### Relational Data Systems

J. Jones discussed relational data systems. In most enterprises today the majority of data processing systems are operational systems designed for:

- Stable applications that change very little over the years.
- High transaction rates, typically several thousand per day.
- Complex predefined data structures to provide the required performance.
- Current data, updated in real time.

An emerging need for timely and accurate information to support business decisions requires systems in which:

- Data requests are business-related.
- Specific problems are solved.
- Considerable flexibility is available for simple and changing data requirements.
- Summarized and historical data can be provided.

To meet these needs, a relational model of data, in which data are viewed

as tables, is most suitable. This tabular view is easy to understand. We are accustomed to a tabular view of data in telephone directories, timetables, and business reports. A user sees the data in two-dimensional tables consisting of rows and columns. As an example, an employee table might have four columns of data: employee number, name, department number, and salary. The actual manner of data storage is not relevant to the user. He simply asks for the data he wants, and the data-base management system selects the optimum path to the data.

Tables in a relational data base are related dynamically through the values of the information in them. Part of the power and flexibility of a relational data-base management system is this ability to relate information dynamically and not to have it pre-defined in the data structure. If, for example, we wish to know the department in which an employee named Sutton works, the system uses the employee table and the department table. First, the employee table gives the department number in which Sutton works. This number is matched with department number in the department table, thus providing the department's name.

A relational language provides operators which process sets of rows, rather than a single row at a time. A single relational request can be used to selectively retrieve, update, or delete multiple rows of a table. This is called set processing. For example, let us say that the user asks for details of all employees working in department D11. The system would present the result in the form of a table with all rows corresponding to D11, which contains information about the relevant employees.

A relational language called Structural Query Language (SQL) is used

by the relational data-base management systems SQL/DS and DB2, and by Query Management Facility (QMF), a query system for users. In SQL the user specifies what is wanted, not how to get it--it is nonprocedural. For example, to ask the system who is employee 60 and what does he earn, the user would enter:

```
Select Name, Salary
From Employee
Where Empnum = 60
```

The user would receive:

Name	Salary
Henderson	8000

SQL supports all functions expected in a relational language, including joining of tables and set processing. To give everyone in department D11 a 10-percent pay raise, the entry would be:

```
Update Employee
Set Salary = Salary * 1.1
Where Dept = "D11"
```

SQL has built-in functions and arithmetic operators, allowing the user to group or sort data, and to find the average, minimum, maximum, and total of a specific column. The same language is used to define, retrieve, and manipulate data.

Computer Aided Engineering

Douglas Brand gave a report on computer aided engineering. Typical problems faced in engineering today are listed in Table 1.

The total engineering cycle requires an integrated solution (Figure 1). The following are substantial issues that must be considered:

Table 1

Engineering Problem

- Critical skills shortage
- Design lead time
- Quality control/scrap/rework
- Accommodation of new technologies/materials
- Engineering changes
- Project management
- Excessive paperwork
- Distribution of drawings
- Up-to-date information
- Interaction/dialogue between designers/toolmaker/inspector
- Automatic drafting
- Modeling
- Design analysis and simulation
- Tracking and releasing systems
- Numerical control
- Robotics
- Project control
- Telecommunications
- Data management

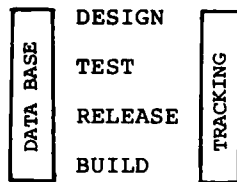


Figure 1. The engineering cycle.

1. Computer aided engineering is the life blood of manufacturing industries.
2. High-investment technology requires skillful initial judgments.
3. Strategies must minimize risk of obsolescence
4. Change requires extensive training and education.
5. There are substantial benefits to getting things right, minimal opportunity for recovery if you get them wrong.

The estimated obsolescence hierarchy of the tools and information is shown in Table 2. It is therefore necessary that the system architecture, system growth path, and application software structure be compatible, consistent, and serviceable.

The following are some key activities that the engineering department must carry out: (1) agree upon and establish the business flow, (2) identify critical improvements required, (3) appoint working parties to prepare an integrated plan, (4) handle business reconciliation, (5) provide organization/staffing, and (6) provide management, including accountability, monitoring, and delivering.

In the computer-aided-design department, objective monitoring should include the following:

1. Design validation
  - a. Reduced destructive testing
  - b. Newer prototypes
  - c. Shorter concept design phase
  - d. Reduced weight/material/cost

2. Design drafting
  - a. Use of work stations
  - b. Drafting productivity improvements
  - c. Fewer redesigns/manufacturing queries
  - d. Increased flexibility/responsibilities
  - e. High throughput on drafting machine changes
3. Data bases/manufacturing
  - a. Less load on print room
  - b. Less drawing storage areas
  - c. Reduced fitting/benchwork
  - d. Shorter floor-to-floor time
  - e. Fast access to design information
4. Equipment/software support
  - a. Availability
  - b. Reliability
  - c. Throughput

Objective monitoring in the functional departments should include cost reductions, reduced outsourcing, increased capacity, and improved efficiency. At the corporate level, return on investment, competitiveness, and good business control should be monitored. Choice of appropriate computer-aided-design computing systems can help meet the above monitoring objectives.

IBM Systems Network Architecture

A presentation on IBM Systems Network Architecture was given by Ian McGowan and S. Mallinson. In a communications network, the desired characteristics are: (1) ability to connect any system to any other, (2) efficient use of resources, (3) good performance, (4) ability to use new communications facilities, (5) availability, (6) support for existing terminals, (7) ability to take advantage of new terminals, (8) ease of change and maintenance, and (9) speedy resolution of problems (growth without disruption; vendor supplied and maintained).

There are numerous pressures on business communications. Business has an increasing need for information, and information systems must be able to accommodate more users and more applications. New technologies that are diverse and sophisticated are sometimes incompatible with existing systems. Furthermore, there are many internal constraints--such as employees, skills, and money--and external constraints, including legislation, competition, and customer requirements.

IBM has taken a structured approach to communications in its Systems Network Architecture (SNA). The architecture of the system is a set of rules (formats and protocols) specifying how products communicate with each other. The implementation of the architecture is an

Table 2

Obsolescence Hierarchy

Computer	0.5-1.5 years
System software	1-2 years
Application software	2-3 years
Application data	3-20 years

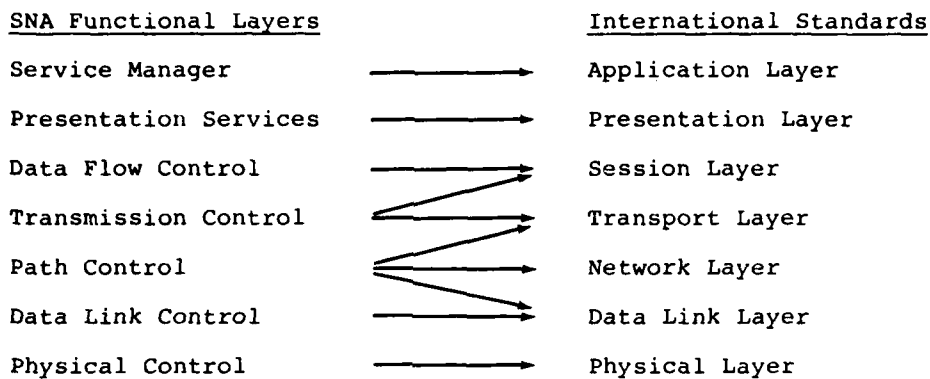


Figure 2. Functional layers and international standards.

evolving set of hardware and software products. The proper strategy includes a consistent basis for network investment.

The fundamental purpose of SNA is:

1. To define a set of standards that permits:
  - a. Continuing compatibility of terminals and applications
  - b. Access to new technologies and functions
  - c. Sharing of network resources
  - d. Access from any terminal to any application
  - e. Distribution or consolidation of function
  - f. Migration and coexistence for non-SNA devices
2. To maximize network value through:
  - a. Improved performance and availability
  - b. Effective operational control
  - c. Problem determination facilities
  - d. Nondisruptive growth

The functional layers of the SNA are compatible with international standards, although the correspondence is not one-to-one. (Figure 2). SNA supports dial-up systems, packet-switched systems, and leased lines.

The virtual telecommunications access method (VTAM) operates on a host processor to provide a common interface to applications, manage user access, maintain integrity and security, determine destination and mailing, and provide a control point for the network.

The Network Control Program operates on a communications controller to handle time-dependent network functions, control and optimize information flow, and handle and report physical errors.

The architecture of SNA offers a consistent structure for all types of communication and provides a basis for long-term investment and growth.

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## EARTH SCIENCE

### NEW DATA LOGGER

by Robert Dolan. Dr. Dolan is the Liaison Scientist for Geology and Oceanography in Europe and the Middle East for the Office of Naval Research's Branch Office. He is on leave until September 1984 from the University of Virginia, Charlottesville, where he is Professor of Environmental Sciences.

A team of geomorphologists at Queens University, Belfast, has developed a data logger designed for hard, practical use in the field. Called QLOG, the unit has a high-capacity memory which can be removed easily for simple replay into the memory of a computer; thus, expensive decoding equipment is not needed. It is rugged and lightweight (5.5 kg) and has a long battery life. The unit is 300×300×175 mm (Figure 1); the logger operates between -20° and +60°C.

QLOG records analog data as 12-bit words; each datum can be one of 4096 divisions of the analog measurement range. Up to 32 channels of data can be recorded, and channel identification is provided with each value. Time



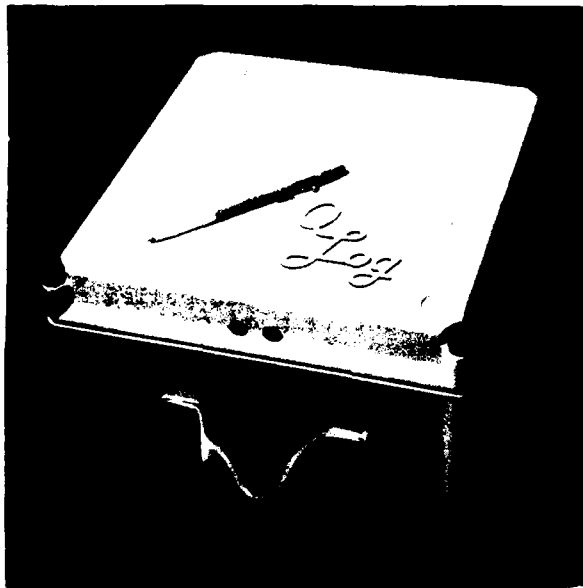


Figure 1. QLOG unit.

information is also recorded automatically; errors from transducer failure can be detected easily.

QLOG uses an 8-bit, low-power microprocessor to control its operation. This gives a versatile logging system, and the operator is free to design routines of various channels and time scans. At the simplest (and cheapest) level, such requirements are held by an erasable, programmable, read-only memory (EPROM) and can be altered by changing to another EPROM with the new logging sequence. This can be done in the field. Each logger comes with an EPROM containing a basic scanning sequence that is set up according to the individual project's requirements--e.g., channel 1 could be logged every 15 minutes, channels 2 through 5 every 30 minutes, and channels 6 through 10 every 38.5 minutes.

The Belfast team soon will add a hand-held unit which can be plugged into the logger and will allow direct access to the system EPROM so that program changes can be made easily in the field. Thus, channels can be selected and scans

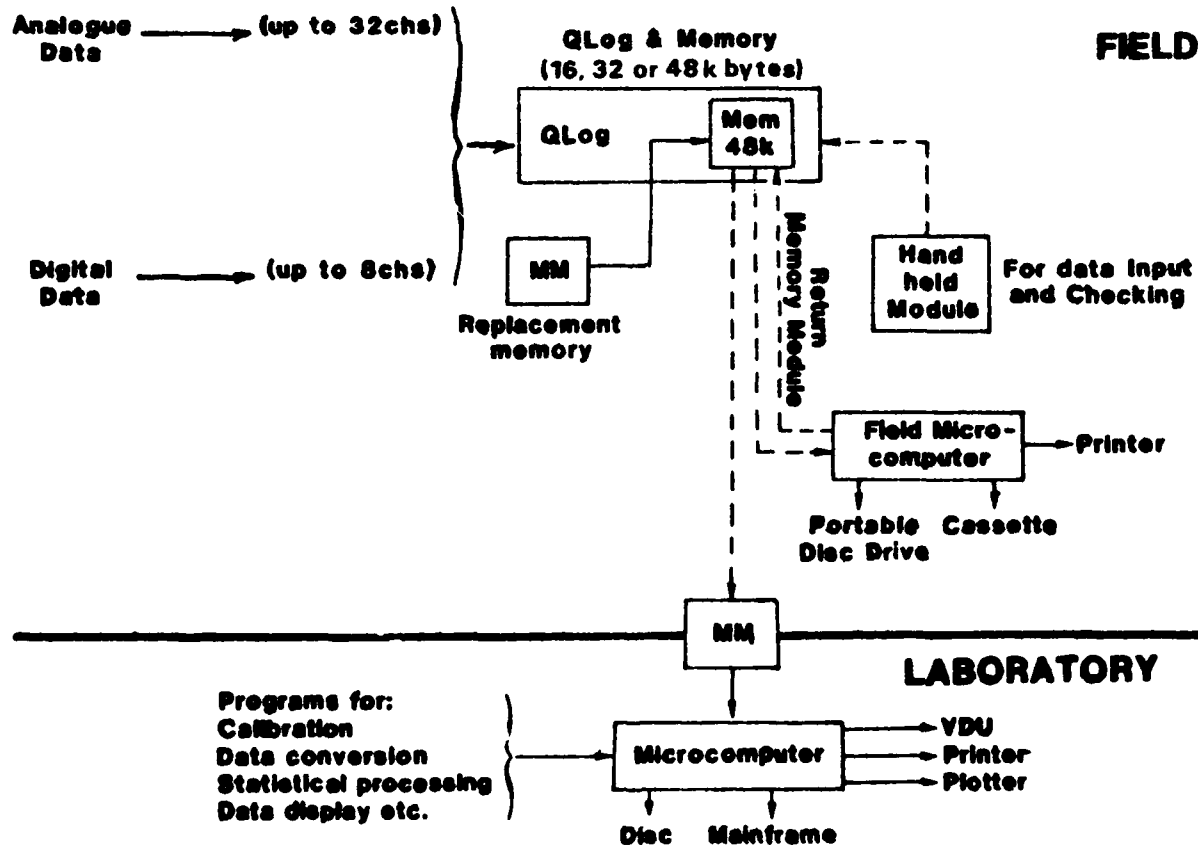


Figure 2. QLOG system.

changed. The system can be instructed to remain inactive for a period (days or weeks) before starting to log data. The unit also can monitor what is happening on one channel and switch on more channels if a threshold of interest is reached. Digital (pulse) data can also be recorded in eight 8-bit-wide channels (Figure 2), and one or more of the channels can be used as an event counter.

The system appears to be very flexible: it allows custom-designed logging sequences, and the memory modules are light and compact but store a lot of data. For example, if 16 channels are logged every hour, then a 48K-byte memory will store data at this rate for 60 days. After a full module is replaced with a fresh one, the contents of the full module can be read into the memory of a microcomputer. The Belfast group claims that the QLOG allows the operator full control over the microprocessor in the system, and it is thus possible to do complex logging tasks that are difficult with equipment costing several times as much. They are producing a limited number of the QLOG units at \$4000 each.

10/28/83

#### NORTHERN IRELAND 1983

by Robert Dolan.

In the January 1975 issue of *ESN* I reported on the research atmosphere in Northern Ireland. At that time bombings, shootings, murders, and intimidations dominated the lives of most of the people, especially those living in Belfast and Londonderry. Although the universities of Northern Ireland were not physically affected by the conflict, the social and emotional atmosphere then was highly charged, hardly a healthy environment for research. Some of the most productive faculty members left Northern Ireland, convinced that a settlement of the long conflict would never be achieved.

Although a settlement still hasn't been reached, and there is still violence in Northern Ireland, the overall level of concern and anxiety is lower in 1983. I recently spent 4 days in Belfast and Coleraine; the contrast between 1974 and 1983 was remarkable--if we assume that the departments and faculty members I visited are representative.

Rather than depression, I noted optimism and enthusiasm. This is not to suggest that all's well in Ulster,

because it's not. The impact of the continued conflict spills over to university life in many ways. The best students in the UK do not find graduate school in Northern Ireland desirable, and visitors are sometimes reluctant to travel there.

The geomorphologists I met at Belfast and Coleraine have active research programs under way that have resulted in an impressive publication record (see the references at the end of this article). Julian Orford at Queen's University of Belfast has pulled together an excellent team of colleagues, and William Carter of the New University of Ulster has several research projects under way in collaboration with associates in the School of Environmental Studies.

Orford's research, in collaboration with Carter of New University (Coleraine), on gravel beaches and barriers represents, in my opinion, an important contribution to the coastal literature. Gravel beaches are common along the UK coast, especially reaches with orientations perpendicular to fetches of high waves. Some deposits that are over 10-m above sea level overwash periodically. In visiting these sites on a calm day, it was difficult to believe that waves and storm surge could elevate the water level to such heights. But the evidence is clearly there. To the best of my knowledge there is nothing comparable along the US coasts--unless in a remote area of Alaska. Consequently, Orford and Carter's studies should add significantly to our understanding of high-energy beaches.

Cuspate landforms are also common on these gravel beaches. In some places, as many as four sets of cusps occur in a distinct hierarchical pattern. Since all the gravel beaches are in bays with rock-bounded headlands, these should be excellent sites to investigate the role of trapped energy (edge waves) in determining inshore morphology, especially cusp formation and spacing. The embayments range in length from a few hundred meters to several kilometers, and the beach morphology and cusp spacing varies from bay to bay.

In addition to their coastal research, the geomorphologists at Belfast use geochemical methods and scanning electron microscopy to explore fundamental questions concerning physical and chemical weathering of sedimentary particles. For this work, they have a modest but well-equipped laboratory. Now their greatest concern, other than the overall problem of cuts in support for higher education in the UK (see *ESN* 37-12:490 [1983]), is the lack of top-quality graduate students. Most

of the research, including laborious field work, is being carried out by the faculty and staff themselves, which restricts the scope of their research.

In the Department of Civil Engineering at Queen's, I again sensed a good deal of optimism about the future. Their research program is healthy and growing. In the area of marine engineering they are investigating wave power (see "Progress in Wave Power" elsewhere in this issue), floating breakwaters, and harbor designs.

In summary, although these are not "normal times" in Northern Ireland, the research situation is significantly better than a decade ago.

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## MATERIAL SCIENCES

### EROSION BY LIQUID AND SOLID IMPACT, ELSI VI

by R.W. Armstrong and D.R. Squire. Dr. Armstrong is the Liaison Scientist for Material Science in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until January 1984 from the University of Maryland, where he is Professor of Materials. Dr. Squire is Chief, Chemistry Branch, US Army Research, Development and Standardization Group (UK).

This was the sixth conference in a series initiated in 1965 with support from the Federal German Ministry of Defense and the Procurement Executive of the UK Ministry of Defence. The first conference's topics of liquid impact and rain erosion have now been broadened in the series to include solid impact and cavitation erosion--all involving contact stresses, hardness testing, elastic deformation, and surface problems to which the current conference chairman, Prof. David Tabor, FRS, has contributed so much, beginning from his association with the late Prof. F.P. Bowden.

The erosion properties of densified small particle (DSP) cement, metals, oxides, ceramics, cermets, elastomers, polymers, and various protective coatings were addressed in 66 papers presented at Newnham College, University of Cambridge, from 5 through 8 September 1983. There were 144 delegates from Czechoslovakia, Denmark, Egypt, the Federal Republic of Germany, France, India, Japan, Malaysia, The Netherlands,

Poland, South Africa, Sweden, Switzerland, Turkey, and the UK, US, and USSR. Support was provided by the UK Ministry of Defence and the US Air Force, Army, and Navy. The conference proceedings were printed by the Royal Aircraft Establishment (RAE) under the editorship of J.E. Field, (Cavendish Laboratory, University of Cambridge, Madingley Road, Cambridge CB3 0HE) and N.S. Corney, (RAE, Farnborough, Hants.). The proceedings may be ordered from Dr. Field.

David Tabor opened the conference with several comments on cavitation, liquid impact, and solid particle erosion. He pointed out that more information is needed about shock waves and jet formation associated with collapsing bubbles as well as improved analyses of long-life assessment from results of short-term tests. The importance of surface roughness and coatings in preventing rain erosion has to be investigated further. Distinguishing between corrosive and erosive effects in liquid impacts is becoming increasingly critical to a proper analysis of results. Strain rate effects and fatigue properties should be correlated with solid particle erosion results on ductile solids, at least. There is some question about the local temperatures generated by solid particle impacts and about critical damage effects tied to the hardness properties of the erodent. New ideas about the compaction of brittle solids might be usefully applied to problems with solid particle erosion. New materials and techniques are always in demand. Tabor concluded by proposing that the challenge in this complex subject is to gain a fundamental understanding of the processes, coupled with useful and reliable predictions for engineering applications.

#### Cavitation

Four sessions of the conference dealt with basic studies of cavitation damage and theories of erosion, testing methods, specific erosion problems, and cavitating jets. Prof. Tony Ball (Department of Metallurgy and Materials Science, University of Cape Town, South Africa) presented a comprehensive experimental survey of laboratory results on ultrasonic vibratory cavitation erosion; the work was done on polymeric materials with A. Barletta. The Mining Technology Laboratory of the Chamber of Mines Research Organization of South Africa is supporting research at Cape Town on the use of pH 4 mine water for powering hydraulic drills, hammers, cutters, and conveyors in the gold mining industry. Valves, impellers, and seals in the equipment are attacked by the fluid.

High-density polyethylene material is used as a seal in rock hammers. In the laboratory tests, four polymer groupings occurred on the basis of cumulative volume loss during erosion: polyamide and polyacetal copolymer materials exhibiting leathery behavior and slow erosion damage; related polyacetal material with glass fiber reinforcement showing erosion rates almost 10 times greater; glassy poly (amide-imide), polypropylene, polysulfone, polyethylene terephthalate and polytetrafluoroethylene materials showing appreciable erosion by brittle chip removal; and polyurethane, polycarbonate, and polyvinylidene fluoride materials giving unsuitable catastrophic failure.

Dr. Carolyn M. (Preece) Hansson (the Danish Corrosion Centre, Glostrup, Denmark) and Dr. Inge L.H. Hansson (Technical University, Lyngby, Denmark) reported on the superior cavitation erosion properties of DSP cement as a potential coating material. The DSP cement is made by blending 0.1- $\mu\text{m}$  "microsilica" as the space filler displacing water among 100- $\mu\text{m}$  clinker particles of ordinary Portland cement with the use, also, of a surface-active (superplasticizer) agent. Although three times the price of ordinary concrete, the material is very resistant to erosion, shows excellent casting properties, and adheres to steel.

The following researchers presented papers dealing with the erosion properties of metals: S. Pedersen and I.L.H. Hansson (Denmark) on nickel coated brass and steel; these same authors and T.F. Pedersen on copper and type 304 austenitic stainless steel; P.A. Lush, R.J.K. Wood, and L.J. Carpanini (City University, London) on aluminum; and B.C.S. Rao and D.H. Buckley (National Aeronautics and Space Administration Lewis Research Center, Cleveland, OH) on aluminum, copper, brass, and a Ti-5Al-2.5Sn alloy.

Inge Hansson and K.A. Mørch (Technical University, Lyngby) developed an annular guide vane to obtain uniform and reproducible cavitation results with vibrations from an ultrasonic horn, as standardized by the American Society for Testing and Materials in ASTM G-32. The testing method is being applied to measuring the cavitation erosion resistance of surface coatings. A high-speed Barr and Stroud type CP 5 camera has been employed to observe at 250,000 frames per second the formation and collapse of clusters of cavities. Mørch (1983) has given a theoretical description of cavitation collapse dynamics. M.G. Talks (Mining Research and Development Establishment, Burton-on-Trent, UK) described a multistage erosion test for 60/40

brass tips in fire-resistant water-oil emulsions in a 20-kHz vibratory cavitation apparatus.

Yoshinori Oka (Mazda Pump Mfg. Co., Japan) and Masanobu Matsumura (Hiroshima University, Japan) described experimental results for the simultaneous attack of iron by cavitation and corrosion in hydrochloric acid or sodium hydroxide solutions. M.J. Kenn (Imperial College of Science and Technology, UK) showed a variety of examples of extreme cavitation damage to concrete structures arising from severely sheared water flows. Although Kenn supported Carolyn Hansson's effort to have improved DSP concrete material adopted for wider engineering uses, he pointed out that improved design of structures was an important consideration for minimizing erosion damage, too. A.N. Kukushkin presented a paper with I.A. Shalobasov (Ministry of Power Engineering, Moscow 103906, USSR) on the effect of surface-active agents in altering the regime of cavitation flow within working fluids for generator pumps. The frequency spectrum of pressure pulses in the wall cavitation layer, the dispersal of bubbles, and their collapse dynamics are affected by the surface-active agents as well as their forming films on metal surfaces to protect against corrosion.

The use of jet cavitation for rock cutting was described by D.A. Summers (Rock Mechanics and Explosives Research Center, University of Missouri, Rolla). Volume flow through the jet exit nozzle, jet velocity, and jet pressure were investigated. In related work, A. Lichtarowicz, and P. Kay (University of Nottingham, UK) obtained results comparing water and hydraulic oil as cutting media. K.S. Janakiram (Karnataka Power Corporation, Bangalore, India) and B.C. Syamala' Rao (Indian Institute of Science, Bangalore) reported on velocity and frequency effects in the water cavitation piercing of aluminum.

#### Liquid Impact

Four sessions dealt with fundamental studies, material responses, turbine erosion, and jet production. M.B. Lesser (University of Luleå, Sweden) and J.E. Field (Cavendish Laboratory) gave a geometrical wave theory for two-dimensional (circular) liquid drop impacts on a rigid target at collision speeds generating shock and release waves. The analysis related to fast photographic results obtained earlier at the Cavendish Laboratory by Camus and Brunton. Initial jetting from the liquid surface adjacent to the contact interface was concluded to be directed toward the target and reflected away to form a jet

spray of micron-sized droplets. Simulated results were shown with computer graphics. The work has important implications for surface cleaning and was impressive in that it explains many of the features observed in photographic records of such phenomena. Nonetheless there are many unanswered questions. Spalling is a speculation invoked. Is there time for satellite drop formation? What is the effect of drop size? Finally, what roles do cohesive forces play in splashing and spalling, and what is the role of surface roughness?

P.H. Pidsley (University of Leeds, UK) gave a related numerical finite difference calculation of spherical droplet impacts. The numerical method of solution was based on codes available from the US Los Alamos Scientific Laboratories. The analysis relates to studies of shaped charges and penetration mechanics. Field, J.P. Dear, P.N.H. Davies (Cavendish Laboratory) and Marie Finnström (University of Luleå) presented experimental results of jetting of wedge-shaped cast water/gelatin sheets fired onto targets and observed at a microsecond photographic framing rate. Shock structures and critical conditions for jetting were observed. Explosive welding, shaped charges, and liquid impact erosion methods are hoped to be future applications of the work. During the discussion, the subject of satellite drop formation came up again. Lesser suggested that the relaxation time for satellite drop formation is on a nanosecond scale. However, there was not general agreement on this controversial point. These are areas that very much need investigation in this important field. Among other topics that require study are the need to understand the energy transfer mechanism between the liquid and the surface and the mechanism for surface damage during the impact of the liquid.

Crack growth in ZnS due to water droplet impacts was the subject of a paper by E.R. Case and A.G. Evans (University of California, Berkeley). The temporal nature of the stress state was employed to predict the impact velocity dependence of the depth of cracking. Field, S. van der Zwaag, and D. Townsend presented results on liquid droplet impact damage for ZnS, Ge, and Al<sub>2</sub>O<sub>3</sub> materials, especially including the effect of the material grain size for ZnS. Impact velocity and droplet size were investigated with a jet gun apparatus (Figure 1).

Fracture-toughness stress intensities derived for ZnS were shown to follow a Hall-Petch-type inverse square root of grain size dependence down to a

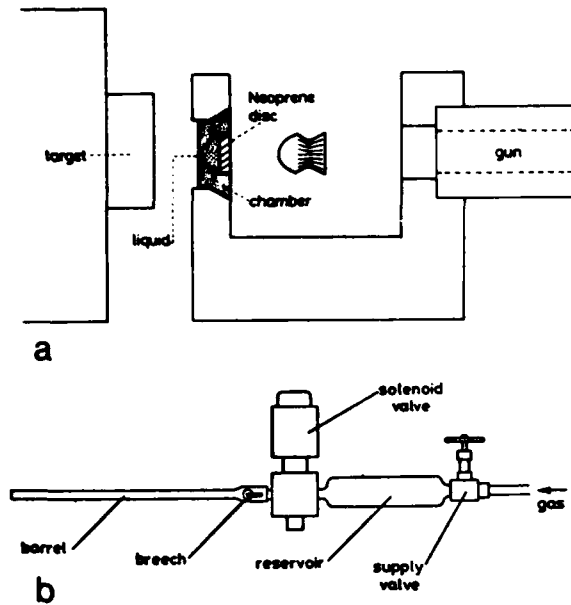


Figure 1. Cavendish Laboratory jet gun apparatus: a. chamber nozzle section; b. 22-caliber firing mechanism.

grain diameter of 10  $\mu\text{m}$ . Grain-size-dependent hardness measurements were reported also in connection with research activities at the Royal Signal and Radar Establishment, Malvern, UK. Recently, Armstrong (1983) described this type of grain-size dependence for measurements of fracture mechanics stress intensity. More recent experiments at the Cavendish Laboratory have shown that hot-pressed silicon nitride material is intermediate between  $\text{Al}_2\text{O}_3$ , which has a superior capability to withstand impacts, and  $\text{ZnS}$ , which is less effective. The high modulus of Ge coatings of 1- to 3- $\mu\text{m}$  thickness prevents the formation of Hertzian-type ring cracks. W.F. Adler (General Research Corporation, Santa Barbara, CA 93111) pointed out that such water-jet experiments were useful but that further complications were involved in actual damage situations--for example, the shape of the impacted surface is an important consideration. The key problem is that no convincing evidence was provided to ensure that jets would behave as drops do. Thus, there is difficulty in scaling to drop behavior, and in fact it would only be speculation as to whether damage begins at about 300 m/s for drops as for jets.

C.J. Hurley (University of Dayton Research Institute, US) reported superior results obtained with J. Zahavi (Israel Institute of Metals, Technion)

and G.F. Schmitt (Wright-Patterson Aeronautical Laboratories, US) on rain erosion of polyurethane as compared with fluoroelastomer-coated glass or graphite epoxy and quartz polyimide composite substrates. The results here seem different from those reported by Ball. Applications are to aircraft leading edges, radomes, antenna covers, and helicopter rotor blades. Rain erosion of radome materials was described in papers by A. Campbell (Reinforced and Microwave Plastics Group, British Aerospace, Stevenage); N.S. Corney and J.S. Pippett (Materials and Structures Department, RAE, Farnborough); and K.N. Letson (US Army Missile Laboratory, Redstone Arsenal, AL). The results of whirling arm tests of polyethersulphone, polyetherimide, and polyetheretherketone thermoplastics were described by Campbell and Corney; Letson discussed rocket sled tests of fiber reinforced polytetrafluoroethylene. The best material found to date for high resistance to rain erosion is polyetheretherketone. In this area, as well as others in this field, scaling and substitution are difficult. It was reported that nylon is a poor substitute for water in resistance studies. Another key point is the matter of monitoring the surface temperature of the radome material during real-time experiments.

J.A. Krzyżanowski (Institute of Fluid Flow Machinery, Polish Academy of Sciences, Gdansk) gave comprehensive design equations for erosion of steam turbine blades by droplet impacts and presented results obtained by Z. Szprengiel and B. Wiegler (Department of Gas Dynamics, Institute of Fluid Flow Machinery) and G. Beckmann (Ingenieurhochschule Zittau, German Democratic Republic [GDR]). Z. Ruml (Skoda Power Machinery Plant, Plzen, Czechoslovakia) presented results obtained with M. Orna and A. Liska on erosion of 12 Cr-1.5NiMoWV steel and Ti-6Al-3Sn-3Zr-2.5V turbine blade materials.

A device for creating high-speed water jets was described by R. Lövgren and G. Gustafsson (Luleå University of Technology). A device for giving passively interrupted pulses was discussed in a paper by G.L. Chahine, A.F. Conn, V.E. Johnson, Jr., and G.S. Frederick (Tracor Hydronautics, Laurel, MD 20707). In the first paper, jets were generated from (electrode discharge) moving shock waves focused by reflection within various nozzle designs. The second paper described an acoustically tuned, self-modulated resonating nozzle system for obtaining high-frequency generation of water slugs for cutting or cleaning operations.

### Solid Particle Erosion

About half of the ELSI VI conference papers (Field and Corney, 1983) were devoted to solid particle erosion studies. A.V. Levy (Materials and Molecular Research Division, Lawrence Berkeley Laboratory, CA 94720) presented excellent scanning electron microscopy results of erosion behavior in ductile and brittle (metal and ceramic) materials. Ductile erosion involves local extrusion of platelet material, forging of the platelets, and their eventual fracturing--much like "blacksmithing"--by the erodent particles. Brittle erosion involves the initiation of mostly Hertzian cone cracks and the chipping away of particles isolated by the cracks.

Field, in a paper with D.P. Andrews and S.M. Walley, described a sandblasting erosion rig and the total range of gas gun equipment, and high speed photographic cameras available within the Cavendish Laboratory for solid-particle erosion studies. A Hadland Image Converter (Imacon) Camera gave a photographic sequence at 5  $\mu$ s per frame of radial jetting of steel impacted by steel. I.M. Hutchings (Department of Metallurgy and Materials Science, University of Cambridge) presented work with A.K. Cousins on the strong influence of erodent-particle shape for spherical beads, angular glass fragments, and angular silicon carbide impacting on mild steel. Spherical particles were prone to give brittle-like erosion behavior, whereas the angular grit promoted ductile-type erosion.

In other Cambridge reports, S.M. Walley and Field discussed the impact erosion of polyethylene; S.P. Timothy and Hutchings described adiabatic shear band effects for Ti-6Al-4V material impacted by steel. The indication was that such shear-band effects are increasingly important for larger projectile impacts. An interesting connection with the specific titanium material studied is that Armstrong, Coffey, and Elban (1982) have proposed that dislocation pile-up avalanches are the fundamental cause of such heating effects; the plastic flow properties of titanium are known to show a strong grain-size dependence, indicating that dislocation pile-ups are important. R. Brown (Materials Laboratory, University of Rhode Island, Kingston 02881) gave an account of work with M. Emiliani on spherical silica particle impact erosion of Ti-6Al-4V alloy to simulate turbine blade and vane attack by ingested sand. A glassy protective layer first formed on the target and then was removed by

further erosive attack. Additional papers were by S. Hogmark and A. Hammarsten (Institute of Technology, Uppsala University, Sweden) with S. Söderberg (University of Houston, US) on the combined effects of corrosion and erosion; P. Veerabhadr Rao and D.H. Euckley (National Aeronautics and Space Administration Lewis Research Center, Cleveland, OH 44135) on the effects of exposure time on erosion of components employed for petrochemical, aircraft, and coal gasification uses; and D. Kuhlmann-Wilsdorf (University of Virginia, Charlottesville) with L.K. Ives and A.W. Ruff (National Bureau of Standards, Washington, DC 20239) on a dislocation cell model description of evaluating the subsurface stress states generated during erosion and wear damaging processes.

Erosion of corrosion-resistant coatings for jet engine compressors was reported by H.J. Kolkman (National Aerospace Laboratory [NLR], Amsterdam, The Netherlands). The NLR compressor test rig is shown in Figure 2. Eroder is injected in one half of the bifurcated nozzle so that simultaneous studies of corrosion with and without erosion may be conducted. Levy described erosion results obtained on brittle protective coatings with D. Boone, A. Davis, and E. Scholz (Lawrence Berkeley Laboratory, US). Superior properties were shown for finer microstructures in dense coatings of partially stabilized zirconia ceramic thermal barrier coatings and silicon carbide wear-resistant coatings, as was mentioned earlier for the ZnS liquid impact results of Field and colleagues. D.J. Stephenson, J.R. Nicholls, and P. Hancock (Cranfield Institute of Technology, Bedford, UK) described experiments on the high-temperature erosion of superalloy gas turbine blade materials--

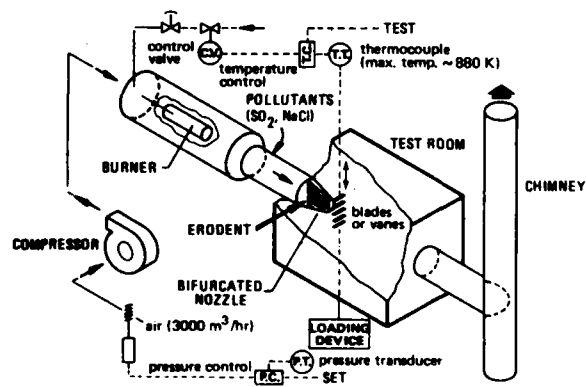


Figure 2. NLR compressor rig with incorporated erosion facility.

particularly involving fracturing of the surface scale in a ductile or brittle manner, depending on the scale thickness (see ESN 37-7:266-271 [1983]). G.T. Bursten, G.W. Ashley, P.I. Marshall, and R.D.K. Misra (Department of Metallurgy and Materials Science, Cambridge) presented combined corrosion-erosion results obtained with a technique of monitoring the electrochemical behavior of a scratched metal surface.

Solid particle erosion dynamics and further applications of erosion study methods were described in the following papers: "A Computer Model for Particle Velocity Calculation in Erosion Testing," A.J. Ninham and I.M. Hutchings (Cambridge); "Erosive Particle Kinematics in the Turbulent Combustion Boundary Layer Contacting a Solid Wall," A.C. Buckingham and W.J. Siekhaus (Lawrence Livermore National Laboratory, CA 94550); "Improved Calculations of Particle Trajectories Around Turbine Blades," D. Günes and M. Mengütlük (Bogazici University, Istanbul, Turkey); "Secondary Flow Effects on Erosion Damage of Turbine Blades," A.F. Abdel Azim (Zagazig University, Cairo, Egypt) and W.T. Rouleau (Carnegie-Mellon University, Pittsburgh, PA 15213); "Research Advances in Turbomachinery Exposed to Particulate Flow," W. Tabakoff and A. Hamed (University of Cincinnati, OH 45221); and "Effect of Particle Size and Hardness on Material Erosion in Fluidized Beds," D.A. Woodford and R.T. Wood (General Electric Company, Schenectady, NY 12301).

Other topics were: ash erosion in coal boilers (E. Raask, Central Electricity Research Laboratories, Leatherhead, UK); erosion of pneumatic pipe bends (D. Mills and J.S. Mason [Thames Polytechnic, UK], K.N. Tong [Esso Malaysia, Kuala Lumpur], K. Shimoda and T. Yukawa [Hitachi Research Laboratory, Chiba, Japan], V.K. Agarwal [Indian Institute of Technology, New Delhi], D. Mills, and J.S. Mason); erosion by solid/liquid slurries (C. Forse and A. Ball [University of Cape Town], and D.K. Shetty, I.G. Wright, and A.H. Clauer [Battelle Columbus Laboratories, OH 43201]). Laser impact damage of carbon/carbon composite material to simulate hypervelocity erosion by water or ice particles was described by A. Deom, D. Devezeaux de Lavergne, and D.L. Balageas (Office National d'Etudes de Recherches Aéropatiales, 92320 Châtillon, France). P.J. Schneider (Lockheed Missiles and Space Company, Sunnyvale, CA) described a multiparticle erosion test facility designed to simulate erosion effects on materials exposed to hypersonic flows as related to reentry vehicle systems.

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#### PHYSICAL CHEMISTRY OF THE SOLID STATE: METALS AND ALLOYS

by R.W. Armstrong.

The 37th international meeting of the Société de Chimie Physique was held at Ecole Nationale Supérieure de Chimie de Paris, 11, rue Pierre et Marie Curie, Paris, from 19 through 23 September 1983. Prof. P. Lacombe, President of the organizing committee, and C. Troyanowsky, Secretary General, were enthusiastic about the 60 papers presented on applications of physical chemistry principles to determining the microstructures and, mostly, mechanical properties of metals and alloys.

All non-French speakers gave invited keynote papers. Among 14 invited presentations were "Adsorption Phenomena and the Strength of Polycrystalline Solids" (E.D. Hondros National Physical Laboratory, Teddington, Middlesex TW11 0LW, UK); "Surface and Environmental Effects in the Elastic-Plastic Fracture Transitions in Metal Crystals" (E.D. Shchukin, V.I. Savenko, and L.A. Kochanova, Institute of Physical Chemistry of the USSR Academy of Sciences, Moscow); "Adsorption-Sensitive Flow and Fracture of Solids" (A.R.C. Westwood, Martin Marietta Laboratories, Baltimore, MD 21227); "Adsorption of Simple Elements on Cubic Transition Metals" (D. Spanjaard, Physics of Solids, University



of Paris-South, F-91405 Orsay, and M.C. Desjonquères, Laboratory of Ionic Microscopy, Faculty of Sciences of Rouen, 76130 Rouen); "The Role of Surfaces in Solid State Oxide Reactions" (J. Haber, Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, Kraków, Poland), "Structure and Electrical Conductivity of Grain Boundaries in Electronic Ceramics" (F. Buchy, Thomson-CSF-Corbeville); and "Recent Developments in Chemical Analysis with High Spatial Resolution" (C. Colliex, C. Jeanguillaume, and P. Trebbia, Physics of Solids, University of Paris-South, F-91405 Orsay). T.E. Fischer presented "A New Model for Oxidative Wear," co-authored with M.D. Sexton (Exxon Research and Engineering Company, Lindon, NJ).

L. Priester (Physical Metallurgy, University of Paris-South) presented the invited paper "Influence of Atomic Bonding at Grain Boundaries and of Intergranular Segregation on Material Properties." Emphasis was given to the interdisciplinary nature of the subject. The interface quality of grain boundaries was compared to that of free surfaces from a chemical viewpoint, involving the segregation of impurities and preferred sites for the initiation of phase changes. Both of these items depend on the "perfect" boundary structure and its associated defects, as studied in the discipline of solid state physics.

Priester has been concerned with the influence of segregated elements at grain boundaries on the presence of extrinsic (crystal) dislocations and, conversely, the effect of such dislocations on attracting impurities to boundaries and initiating intergranular phase transformations. Mechanical properties, recrystallization behavior, and intergranular corrosion are strongly influenced by these effects. Priester showed excellent transmission electron microscope results obtained at magnifications of about 30,000 $\times$  on Fe-C alloys with Cr, Mo, or V additions (Lartigue and Priester, 1983).

Segregation of the alloying elements with C at grain boundaries is very much affected by the extrinsic dislocations in the boundaries. Diffusion to the dislocation sites from the matrix, diffusion in the boundary interfaces, and diffusion along the dislocations themselves are all factors influencing the precipitation of microcarbides at the dislocation sites. The strength properties were to be analyzed on a Hall-Petch basis (Baker, 1983) particularly, in terms of grain boundary structure considerations which have been described by Grabski (1982). Intergran-

ular corrosion studies have shown pitting at vanadium carbide precipitates on dislocations. Holes form at extrinsic dislocations along grain boundaries during the thinning of specimens for electron microscope examination. Perfect coincident site boundaries don't corrode.

J. Cabane (Metallurgical Laboratory, University of St. Jérôme, Marseille) gave an invited paper on the measurement of segregation and diffusion at grain boundaries in a variety of metals and alloys. Studies of bicrystals show that the intergranular structure and segregate composition depend sensitively on the orientation of boundaries. For the case of weak boundary attraction, segregation, diffusion, and grain boundary properties can be analyzed with conventional three-dimensional solid solution models. Strong boundary attraction is more complicated and better analyzed by comparison with two-dimensional structures observed on surfaces; the interaction between atoms is akin to that between those in the three-dimensional phases at the limiting solubilities.

Related presentations were given by P. Guiraldeng (Department of Metallurgy and Physics of Materials, Ecole Centrale de Lyon) on percolation theory for intergranular diffusion; M. Biscondi (Physical Metallurgy, ENSMSE, St. Etienne) on diffusing atom paths across grain boundary interfaces and intergranular diffusion anisotropy relating to experimental results on zinc in aluminum bicrystal boundaries; and Tran-Huu-Loi, J.P. Mornirdi, and M. Gantois (Department of Metallurgical Engineering, Ecole des Mines, Nancy) on the intergranular segregation of phosphorus in tungsten relating to the ductile-brittle transition temperature and fractography observations.

J.L. Martin (Department of Physics, Swiss Federal Institute of Technology [EPFL, PHB] Ecublens, CH 1015, Switzerland) reported excellent 200- and 1000-kV electron microscope results at 50,000 $\times$  of dislocation networks within Al and Al-11Zn polycrystal grain boundary interfaces and of dislocations bowing out from boundaries. Electron replication at 2000 $\times$  showed the fanning of slip bands at grain boundaries. Subgrain boundaries obstructed dislocation motion at intermediate temperatures where thermally activated dislocation processes operated. The need for high local stresses prevented cross-slip--except at irregular points along the subgrain boundaries. Further deformation results were reported for bicrystals, tricrystals, and multicrystals of

aluminum or zinc by P. Mussot, C. Rey, and A. Zaoui (Centre National de la Recherche Scientifique [CNRS], University of Paris-North, 93430 Villetaneuse). A geometrical tensor description was given for the compatibility of deformations between grains at their boundary regions and of the internal stresses generated. D. Gratias reported work with A. Thalal and R. Portier (Centre d'Etudes de Chimie Métallurgique [CECM-CNRS], 94400 Vitry) to develop a comprehensive electron microscope diffraction analysis of dynamical multocrystal imaging for coincident and non-coincident reflections through lamellar bicrystals having special twinning orientation relationships.

H.J. Grabke presented the invited paper "Effects of Adsorbed Carbon and Sulfur on the Carburization and Graphitization of Fe, Ni and Fe-Ni Alloys in CH<sub>4</sub>-H<sub>2</sub> Atmospheres," coauthored with K. Ohla and E.M. Mueller (Max-Planck-Institut für Eisenforschung, Düsseldorf, Federal Republic of Germany [FRG]). The reversible carburization of thin metal foils was studied in flowing CH<sub>4</sub>-H<sub>2</sub> mixtures for the pure metals and alloys of 10, 20, 30, or 80 percent nickel in iron using gravimetric or resistometric methods. At high carbon activities, its segregation on Ni caused surface faceting which led to carbon monolayer stabilized (111) faces and to a striking decrease of the decomposition of methane on the surface. The adsorption of sulfur in the presence of H<sub>2</sub>S blocks the rate controlling decomposition of methane. For carbon activities greater than unity, graphite layers grow in an orientation with the basal (0001) parallel to the metal surface. Slow growth occurs epitaxially on faceted (111) surfaces of Ni. Graphite islands are observed with the scanning electron microscope to grow to irregular nodules in the presence of sulfur, which retards growth on iron and accelerates it on nickel. The chemical kinetic rate equations were evaluated both for the carburization and graphitization results. Shchukin (USSR) proposed that it should be interesting to connect such equilibrium studies with the irreversible reactions which occur at the hot tips of cutting tool steels.

D. Treheux (Department of Metallurgy and Physics of Materials, Ecole Centrale de Lyon) reported on the influence of sulfur on intergranular autographic diffusion of iron in Fe-S alloys containing between 10.5 and 120 ppm S. The segregation of sulfur on intergranular fracture surfaces was demonstrated. Diffusion measurements for ferromagnetic and paramagnetic ferritic iron were

made on either side of the Curie temperature and for austenite. Sulfur decreased the activation energy below the Curie temperature and increased it above the Curie temperature and in austenite.

The invited paper "Interfacial Phenomena in Fiber Composite Materials" was presented by R. Naslain, in cooperation with R. Paillet (Laboratory for the Chemistry of Solids, CNRS, University of Bordeaux-I, 33405 Talence). Fibers of interest are SiC single crystals or whiskers with diameters less than 1 μm, microcrystalline Al<sub>2</sub>O<sub>3</sub> or SiC fibers with diameters between 5 and 20 μm, and B or SiC filaments of 100- to 200-μm width. B fibers in Ti and SiC fibers in Ti or Ti-6Al-4V have been characterized by electron diffraction, Auger electron spectroscopy, and secondary ion mass spectroscopy of thin sections or fracture surfaces. Extracted fibers have been studied by x-ray diffraction methods. TiB and TiB<sub>2</sub> phases are found in the reaction zones surrounding the fibers. Ti<sub>5</sub>C<sub>3</sub>, TiC, and TiSi<sub>2</sub> occur in the SiC-containing Ti composites. Fiber coatings and matrix alloying additions are employed to protect against undesired reactions--for example, B<sub>4</sub>C coatings have been employed with Ti. The results are correlated with fracture mechanics tests and scanning electron microscope (SEM) observations.

R. Bonnet reported work with M. Dupeux, M. Ignat, and G. Marcon (ENSEEG, 38402 St. Martin d'Hères) on "Interfacial Properties and Deformation of Oriented Dual Phase Materials." Directionally solidified Ag-Cu and Al-Al<sub>2</sub>Cu eutectic composites (McLean, 1983) and superalloy nickel-base (Fe-NiAl) "monocrystals" were described. The interface structure of the *in-situ* composite was modeled. Compression test results were being obtained. Faceted interfaces were obtained for the lamellar Al-Al<sub>2</sub>Cu system. SEM fractographs were shown. Work is being done to optimize the alloy composition for improved strength properties associated with coherent Fe fibers in the NiAl matrix.

A. Atkinson (Atomic Energy Research Establishment, Harwell, Didcot, OX11 0RA, UK) presented the invited paper "Diffusion and Related Phenomena in Oxides." Tracer self-diffusion, solute diffusion, chemical diffusion, interdiffusion, point defect energetics, oxidation, and creep were discussed. Cation diffusivities were measured in FeO, MnO, CoO, NiO, Fe<sub>3</sub>O<sub>4</sub>, and Cr<sub>2</sub>O<sub>3</sub>; measurements for the last two were made in 1983. Anion diffusion measurements were reported for NiO (1982), Al<sub>2</sub>O<sub>3</sub> (1982)

and MgO (1983). Dopant diffusion of  $\text{Cr}^{3+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Co}^{2+}$ ,  $\text{Fe}^{2+}$ , and  $\text{Mn}^{2+}$  has been measured in NiO and CoO, for which the ions move more slowly the smaller they are. A grain boundary diffusion width of about one atomic distance has been determined for the diffusivity of Ni in NiO. The anisotropy of boundary diffusivity has been measured for  $\text{Cr}^{51}$  in MgO. The outward diffusion of Ni ions occurs along grain boundaries in NiO during oxidation. Creep deformation appears to be controlled by diffusion of the slowest moving ion, but the activation energies for creep and diffusion seem to be in greater disagreement the more closely they are measured.

C. Monty (Physics of Materials, CNRS, 92195 Meudon) reported on the "Heterodiffusion of Cation Impurities in NiO and CoO." Nonstoichiometric effects were investigated in  $\text{Ni}_{(1-x)}\text{O}$ ,  $\text{Co}_{(1-x)}\text{O}$ ,  $\text{Mn}_{(1-x)}\text{O}$ , and  $\text{Fe}_{(1+x)}\text{O}$ . The presence of Cr in NiO gave an enhanced diffusivity for Co. Although appreciable scatter occurred in the measurements, it was confirmed that the activation energy for diffusion was greater for ions with smaller radii.

Other papers dealt with the reaction of crystal  $\text{MoO}_3$  and  $\text{H}_2\text{S}$  to form  $\text{MoS}_2$  by way of conversion first to orientation-related  $\text{MoO}_2$ , by A. Steinbrunn, C. Lattaud, H. Reteno, and J.C. Colson (Laboratory for Research on the Reactivity of Solids, Faculty of Sciences Mirande, 21004 Dijon); the effect of carbon and sulfur on the properties of  $\text{Cr}_2\text{O}_3$  and  $\text{Al}_2\text{O}_3$  formed by the oxidation of Ni-Cr, Ni-Cr-Fe, and Fe-Cr-Al alloys, by G. Ben Abderrazik, J. Rousselet, G. Moulin, and A.M. Huntz (Physical Metallurgy, University of Paris-South); the effect of aluminum and chromium additions to titanium on the mechanical properties of oxides formed at high temperatures, by A.M. Chaze, C. Coddet, and G. Beranger (University of Technology, 60206 Compiègne); and the flow and fracture mechanics properties of Al-bonded SiC material, by R. Moussa, F. Osterstock, and G. Nouet (Laboratory of Crystallography, Chemistry and Physics of Solids, University of Caen, 14032).

P. Hancock presented the invited paper, coauthored with J.R. Nicholls (Cranfield Institute of Technology, Bedford, UK), on "The Industrial Challenge to High Temperature Alloys." Whereas chromium gives both protection against oxidation and solid solution strengthening of Fe-based alloys, opposite effects are produced in Ni- and Co-based alloys. Corrosion resistance is provided, but reduced strengthening

occurs with chromium addition; so a balanced amount of the alloying element is used. Vanadium is present in lower-grade fuels; it forms  $\text{V}_2\text{O}_5$ , which has a disastrous corrosive effect on turbine blades. Magnesium is added to form  $\text{Mg}_3\text{V}_2\text{O}_8$ , but then  $\text{MgSO}_4$  is formed with sulfur to give a worse corrosion problem. Sea salt is another difficulty. Creep deformation and corrosion are intimately connected because corrosive penetration occurs at fissures in the creep-fractured oxide films. Solid particle erosion occurs also in accordance with a ductile or brittle behavior of the oxide films, depending on their thickness. Alloy coatings are an active topic of research to alleviate these surface-related problems.

The conference proceedings are to be printed within 6 months by Elsevier Scientific Publishing Company, Amsterdam. Papers from poster sessions will compose about 50 percent of the book, including written discussion collected at the posters. A number of the poster presentations were outstanding. J. Desseaux-Thibault, J.M. Penisson, and A. Bourret (DRF-PHS; F-38041 Grenoble) showed atom imaging with Japan Electron Optics Laboratory Co. (JEOL) high-resolution electron microscopy of coincident site grain boundaries in Mo bicrystals, oxide-decorated dislocation core structures in Si, and ion bombardment and thermal defect clusters in Si. F. Gaillard, M. Charbonnier, A. Roche, R. Bador, and M. Romand (University Claude Bernard-Lyon I, 69622 Villeurbanne) described low-energy, electron-induced, x-ray spectrometry results on the adhesive bonding of 5- to 100-nm-thick oxide films on steel or aluminum surfaces. D. Michel (Laboratory for Chemical Applications of Solid State Physics, CNRS, 94400 Vitry) showed lattice imaging of interface structures in the  $\text{Al}_2\text{O}_3$ - $\text{ZrO}_2$ ( $\text{Y}_2\text{O}_3$ ) eutectic system for which the orientation relationships were established:

$$(0001)\text{Al}_2\text{O}_3 \parallel (001)_{\text{t-ZrO}_2} \text{ and } [1\bar{1}00] \parallel [100] \text{ or } (0001) \parallel (110) \text{ and } [1\bar{1}00] \parallel [001].$$

J. Wach (LARIGS, CNRS, University of Nancy, 54600) presented a unified atomic model description of sublimation, diffusion, and melting of metal structures, including development of the kinetic equations for these processes. J. Vicens, S. Lay, F. Osterstock, G. Nouet, and J.L. Chermant (University of Caen) showed excellent transmission-electron-microscopy results on dislocations in the grain-boundary interfaces of WC deformed at temperatures in the range 1500 to 1700°K.

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NATO and Company Cantieri Navali Riuniti of Genoa, Italy, signed a contract for a \$37 million modern oceanographic research ship. While member nations own fleets of ships, this will be the first ship to be owned and operated by NATO. The new vessel will be built at the Maggiano Shipyard, La Spezia, and when completed (in about 29 months) will be operated by NATO's SACLANT Anti-Submarine Warfare Research Centre, La Spezia.

When the new ship becomes operational it may well be the finest oceanographic research vessel in the world. Some of the general specifications are listed in Table 1. By virtue of its size, type of construction, and endurance it will be able to carry out oceanographic research in support of NATO in all areas of interest. With its present research ship (a converted cargo ship, which is nearing the end of its useful life) SACLANT Centre has been restricted to conducting most of its research in the Mediterranean. Specifications for the new ship call for operation at zero speed in sea state 5, full operation under tow at sea state 6, limited operation at 7, and survival in sea state greater than 8.

Basically the new vessel is a cargo-type ship that will provide a large amount of laboratory space and ample winches and cranes. A large well runs vertically through the ship. Most of the cabins are for one person, with a few for two people.

Navigation equipment will include Decca Mainchain, dual channel satellite, GPS (Global Positioning System), Loran C, Transit, and Omega. There will be extensive computer equipment, recorders, and displays for both scientific work and ship control. Ship performance and operation will be automatically

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**OCEAN SCIENCES**

**NATO BUYS ITS FIRST SHIP--A NEW OCEANOGRAPHIC RESEARCH VESSEL**

by Chester McKinney. Dr. McKinney is the Liaison Scientist for Underwater Acoustics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until September 1984 from The University of Texas at Austin, where he is Senior Research Scientist at Applied Research Laboratories.

A first for the North Atlantic Treaty Organization (NATO) occurred on 10 October 1983, when representatives of

Table 1

Preliminary Design Figures

Length overall	93 m
Molded beam	15 m
Draft, design full load, molded	4.9 m
Full load displacement	3000 MT
Fuel oil tankage	315 m <sup>3</sup>
Fresh water tankage	100 MT minimum
Shaft power (ABS max. cont.)	2970 kW
Sustained sea speed	16.3 kn
Range at 12 kn	8000 nmi minimum
Crew	30
Scientific party	20

Table 2  
Operational States

<u>State</u>	<u>Speed (kn)</u>	<u>Duration</u>	<u>Power Supply</u>
Quiet drift	0	1 hr on 6 hr off	Battery
Semi-quiet drift	0	12 hr on 14 hr off	Silent ship service Generator
Semi-quiet tow	6	12 hr on 4 hr off	Aux. propulsion and silent ship gen.
Cruise	5-16.3	continuous	Main propulsion
Low speed tow	8	continuous	Main propulsion
High speed tow	12	continuous	Main propulsion

Table 3  
Underwater-Radiated Noise Specifications

<u>Band Levels Third Octave (dB//1 <math>\mu</math>Pa at 1m)</u>			
<u>State</u>	<u>20 Hz</u>	<u>100 Hz</u>	<u>20 kHz</u>
Quiet drift	101	101	89
Semi-quiet drift	101	118	106
Semi-quiet tow	119	126	116
Low speed tow	131	134	122
High speed tow	144	144	132

monitored. The engine room will be unmanned (remotely controlled).

A major emphasis is being placed on making the new research platform acoustically and electromagnetically quiet. The propulsion and electric power generating engines are all mounted on vibration-isolation pads and in sound-absorbing enclosures. The operational states are shown in Table 2 and the underwater-radiated noise specifications in Table 3. All intakes and exhausts to the sea are on one side of the ship, with the other being the "quiet side."

Dr. Ralph R. Goodman, Director of SACLANT Centre, says that acquisition of the new ship with its special features of long range and quiet background will have a significant impact on the formulation of the future research program of the centre. During the construction phase, he will have a dedicated team to oversee the work. At the same time, the research staff will be making and refining specific plans for taking full advantage of the ship's capabilities. To this end, the Centre proposes to hold an international symposium in 1984 on the

quiet ship and its application in underwater research.

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#### OCEANEXPO/OCEANTROPIQUES 1984

by Robert Dolan. Dr. Dolan is the Liaison Scientist for Geology and Oceanography in Europe and in the Middle East for the Office of Naval Research's London Branch Office. He is on leave until Septem' 1984 from the University of Virginia, where he is Professor of Environmental Sciences.

Oceanexpo was held in Bordeaux, France, from 11 through 15 October 1983. The meeting included a display of oceanographic equipment for exploration and exploitation of the seas and symposia of invited and submitted papers.

The last time Oceanexpo was held in Bordeaux the program attracted 223 exhibitors and over 9000 visitors from 90 countries--that was in 1980. This year's meeting must have been a disappointment to the organizers because I doubt that more than 2000 people attended. By the afternoon of the second day, the great exhibition hall at times seemed almost deserted. The manufacturing representatives I talked with agreed that attendance was far below what they had expected. The technical program was poorly attended also; the early session on the first day attracted only a dozen or so participants, and by the third day some of the sessions had as few as four in the audience, a real embarrassment to the chairmen and those offering papers. One can only speculate about the reasons for this dramatic drop in participation in Oceanexpo. It could reflect the world economic situation, perhaps coupled with the fact that things may not be changing very rapidly in the field of ocean exploration and exploitation.

The technical program consisted of simultaneous sessions (morning and afternoon) of six to eight papers each. Topics ranged from marine robotics, to navigation and safety, to development's impact on coastal ecosystems. Perhaps by chance I selected the weakest sample of the overall program. But whatever the reason, I found the papers far too general to be of technical value, or far too site-specific to be of general applicability. Several papers were essentially "canned" audiovisual presentations clearly designed for public relations. The one paper that generated the largest audience (still only about 50 people) and considerable debate was presented by the head of the US delegation to the UN Conference on Sea Law. He summarized the US point of view on exploitation of resources on the international seabed.

The overall low attendance at Oceanexpo made it difficult to assess how well the participants received the exhibits of equipment and instruments. The Japanese firms displayed impressive electronic instruments. In contrast, the USSR display seemed almost antiquated, at least 10 years behind the times. The electronics in particular appeared dated--with manual relays and toggle switches, for example.

#### PROGRESS IN THE DEVELOPMENT OF WAVE POWER

by Robert Dolan.

With the pause in the spiraling cost of oil and gas, the UK Department of Energy has lost some of its enthusiasm for research and development of wave energy projects (see ESN 32-4, 33-3, and 34-3). Nevertheless, progress on wave energy is being made at several institutions, including the Department of Civil Engineering at Queen's University, Belfast. During a recent visit to Northern Ireland, I spent an afternoon with the head of the department, Prof. A.E. Long, and one of his young colleagues who has specialized in wave energy, Dr. Trevor Whittaker.

The primary problems in exploitation of wave power are the variability of wave height (energy) and direction, transmission of the power from the source to users, structural moorings, structural size, structural strength, corrosion, marine growth, and cost. The Belfast engineers are convinced that their wave energy system offers excellent prospects for selected applications and that some of the most troublesome problems are minimized. Their wave-energy converter uses the oscillating water column principle (Figure 1). The progression of a wave past the device causes a vertical motion in the water column housed within the structure. This in turn forces air through a special turbine coupled to a conventional generator, which produces the electrical output. A complete wave power station would consist of several lines of these devices mounted on the seabed in about 30 m of water.

To rectify an oscillating air flow, conventional turbines use complex ducting and nonreturn valves which reduce performance and reliability. The Belfast engineers solved this problem using the "Wells Self-Rectifying Turbine," which was invented by Prof. A.A.

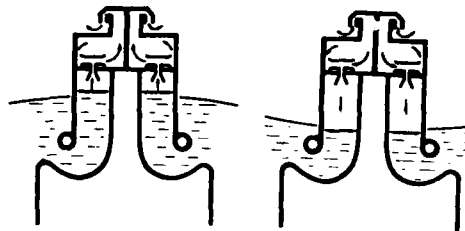


Figure 1. Operating principle of wave energy converter.

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Wells, FRS, and patented by Queen's University. The turbine is always driven in the same direction for either direction of air flow, and the only moving part is the rotor.

Their present design is a product of years of research that have resulted in a better understanding of the wave-water column interaction and the design criteria for the Wells turbine. The device can be matched to various sea-state climates, and the turbine characteristic can be matched to the site hydrodynamics, thus maintaining a high power-conversion efficiency (Figure 2). A single water-column floating buoy was considered initially; the Belfast engineers now believe that multi-column structures placed on the seabed would be better suited for a large-scale wave power station. These fixed structures could be constructed and installed using present-day technology. The difficulties associated with mooring and flexible transmission cables would then be eliminated.

The Wells turbine consists of several symmetrical aerofoil blades arranged around a central hub, as shown in Figure 3. The special feature of the turbine is that even though the cyclic airflow produces an oscillating axial force on the aerofoil blades, the tangential force on the rotor is always in the same direction. This induces the required rotation of the rotor and pro-

duces power output without the need for the added complexity of rectifying valves.

Another feature of the turbine is that it is a high-speed system; its rotational speed is only limited when the blade tips approach the speed of sound. It therefore has the advantage that its speed is appropriate for direct coupling to standard electrical generators.

The Belfast engineers are currently investigating a wave-powered buoy for the lighthouse authorities in the UK. The product of this work to date has been development of a small Wells turbine coupled to a 100-W generator for use on navigation buoys (Figure 4).

The first 100-W Wells turbine generator has been tested at sea during the past year for periods of up to 4 months. Although the buoy is moored in a sheltered site with wave periods between 3 and 5 seconds and low heights, the alternator has maintained the battery charge for the navigation lights. Two further units are being prepared for installation on fully instrumented buoys in order to test the generator's performance, and a further eight units will be evaluated on other buoys.

The Belfast team also is optimistic about larger applications. At present, the estimated cost per kilowatt-hour for a Wells turbine of a larger size is comparable to that of a new oil-fired power station. And with further developments already under consideration, a cost of less than 7 cents per kilowatt-

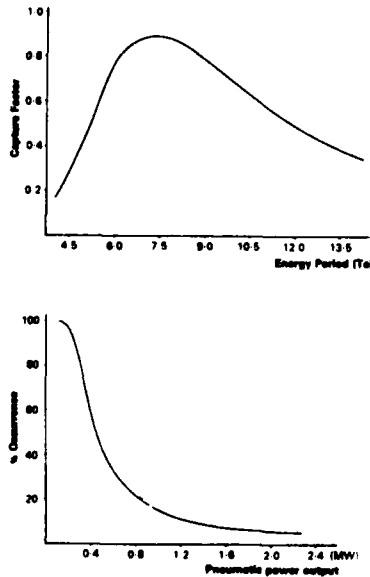


Figure 2. Device performance.

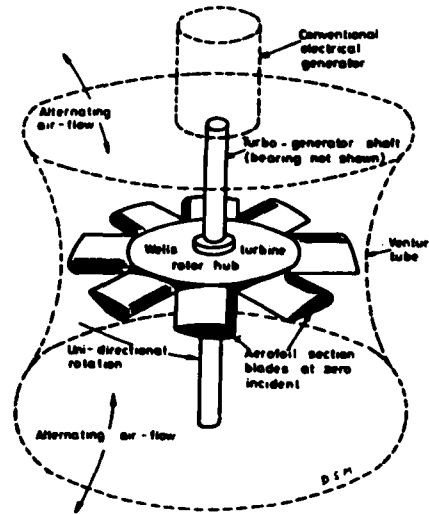


Figure 3. Wells turbine.

hour may be possible. However, the problems of transmission and maintenance remain.

The size and number of units in a large-scale installation have not yet been determined, but Whittaker believes that the cost of foundations and transmission emplacement can be reduced. His investigation also has suggested that tunnels between installations would be economically feasible, which would simplify the electrical interconnection and maintenance of the devices.

The Belfast engineers will construct a larger turbine in 1984, one with a blade diameter of 1 m and a generating capacity of about 125 kW. It will be a laboratory unit for further testing and research. The long-term goal is to design a system that could supply power for a sizable island community. The ideal island would be isolated--so that the cost of any energy source (oil, for example) would be high. And it would be within the high wave energy zone of the British Isles, probably off the Outer Hebrides north of Scotland. Within this zone, waves are large enough to run a turbine at 50 percent capacity 70 percent of the time, and at nearly 90 percent capacity 50 percent of the time. Thus, the wave-

generating system would have to be coupled with a diesel generator, with the diesel supplying the "fine power" for uses such as radios, lights, and other essential constant power needs. Electricity from the wave generator would be used for "coarse power" needs, such as large-scale refrigeration, heating, seawater desalination, and perhaps industrial applications. In collaboration with a group of engineers at Manchester Polytechnic and a commercial firm, the Belfast team now has a feasibility study under way for development of a 1-MW wave power unit. A 1-MW generator could provide energy for an island community of approximately 750 to 1000 people.

Regardless of the attractiveness of wave power, oil and gas today is still so cheap that there is really no potential competition in the foreseeable future. Consequently, support in the UK for further research on large-scale systems will be limited. Some engineers believe that even if oil prices doubled, wave-power stations still could not compete and that tidal power would be a better alternative energy source (see ESN 37-8:312 [1983]). Consequently, the Belfast engineers have decided to concentrate their efforts for the time being on what they term small- and intermediate-scale units (100 W to 125 kW) for special applications, looking into the 21st century for larger-scale developments.

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#### THE IAPSO SYMPOSIA AND OCEANOGRAPHY AT THE 18TH IUGG

by Robert E. Stevenson. Dr. Stevenson is Scientific Liaison Officer, Office of Naval Research, Scripps Institution of Oceanography, La Jolla, CA.

The 18th General Assembly of the International Union of Geodesy and Geophysics (IUGG) was held in Hamburg, Federal Republic of Germany, in August

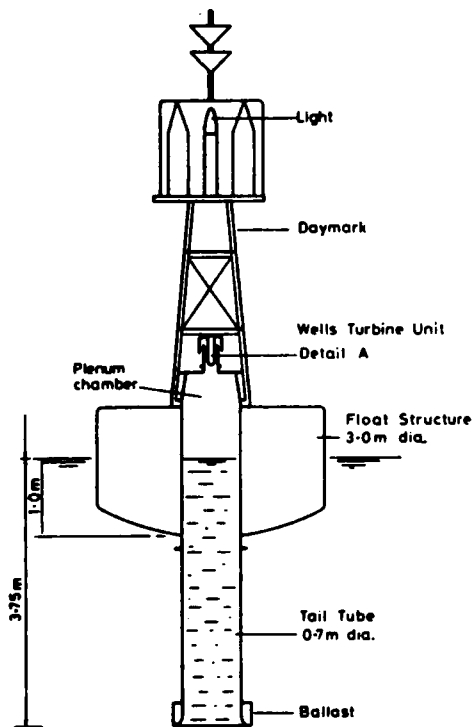


Figure 4. Navigation buoy.



1983. This article highlights some of the symposia sponsored by the International Association for the Physical Sciences of the Ocean (IAPSO), and some of the sessions on oceanography. For detailed information, see the proceedings, which are available from the IUGG Publications Office, 39ter Rue Gay Lussac, 75005 Paris, France.

#### IAPSO Symposia

The symposium on the effects of interfacial processes opened with an intriguing conceptual talk by John Steele, director of the Woods Hole Oceanographic Institution. It set the pattern for all the papers. There were several innovative ideas, such as S. Tsunogai's question: "Is the blooming of blue-green algae in the Kuroshio induced by airborne dust?" His data are interesting, but it is difficult to come to conclusions. Dave Brooks (Texas A&M University) presented data and analyses of water motion in the Gulf of Mexico in the wake of a hurricane. He learned that current speeds of 90 cm/s, near-inertial "wake," 20-m upwelling at depths of 200 to 300 m, and coherent wake oscillations over the scales of the current-meter array remained after the storm had passed. R.S. Lampitt (Institute of Oceanographic Sciences, UK) reported on the fate of marine snow in the deep sea. Apparently it aggregates quickly on the sea floor, and soon disappears from ocean currents. Biological activity within the surficial sediments results in an interesting artifact: natural radioisotopes that are "scavenged" by the snow as it falls through the water column.

The IAPSO symposium with the largest number of papers was on large-scale dynamics and circulation in the ocean, convened by W.R. Holland. Some 55 presentations were expected, although only one of the nine Soviet speakers appeared. In the first three sessions, the emphasis was on mesoscale turbulence in the North Atlantic--primarily from data gathered during the POLYMODE and TOURBILLON experiments. Basically, the spectrum of efforts was covered--from dynamic forecast models, Lagrangian studies of vorticity balance, and energy budgets (from the Local Dynamics Experiment), to the census of eddies and isolated lenses in both the east and west North Atlantic Ocean.

Another set of sessions in Holland's symposium addressed the mean, wind-driven circulation of the North Atlantic, its variability, and the influence of the mid-ocean ridge and seamounts on the general flow. Inland seas--such as the Mediterranean, the Red

Sea, and the Persian Gulf--were covered from the points of view of mixing, circulation as traced by tritium, and circulation at the very bottom. Finally, two sessions looked at the North Pacific Ocean, especially at the time and space variables of the Kuroshio, the generation of Rossby waves, and the eddy fields of the Kuroshio.

The symposium convened by Christopher Mooers (Naval Postgraduate School, Monterey, CA) was on intermediate scales of motion. Mooers drew together some outstanding works on nonlinear inertial waves, internal tides, Kelvin waves generated by transient atmospheric fronts, shear and vorticity from topographic effects, storm surges, the Malaga Eddy in the Alboran Sea, and dynamics in shallow, marginal seas. The session chaired by George Creswell (Commonwealth Scientific and Industrial Research Organization, Australia) was especially interesting in that several approaches were discussed in studying the dynamics of warm-core eddies in the Alboran and East Australian seas, and eddy structures in the shallow Baltic and over the shelf break off the California coast.

Dr. Michael Gregg (University of Washington) convened an extraordinarily good symposium on small-scale motions and structures. The research covered the spectrum--from micro-scale thermal and salinity variability and bubbles, through fossil turbulence, to a variety of internal wave origins and interactions. Presentations by Murray Levine (Oregon State University) and Charles Eriksen (Massachusetts Institute of Technology) were especially well attended. Levine discussed the "Malaise of Upper-Ocean Internal Wave Research," and as one would guess, the title alone drew a large audience. They were not disappointed, for they heard a thought-provoking presentation pointing out that the differences in the physical processes between the upper (surface) and deep (internal) wave fields are surprisingly small, that any progress to be made beyond our present state of knowledge must come from theory-driven observations, and that the complexity of the problem has yet to be suitably addressed with theoretical ideas.

Eriksen pointed out that the spectrum of the internal wave field can be radically modified by both ocean currents and seafloor topography. The modifications involve changes in wave number or frequency, as well as energy density of the Fourier components. Eriksen also showed how internal waves influence ocean circulation.

The new president of IAPSO, Gunther Krause (Kiel, Federal Republic of

Germany), convened a symposium on the oceanography of the North and Baltic seas. Most of the papers were on the Baltic; the variability of currents, appropriate models, and the characteristics of "macroturbulence" (mesoscale) were discussed. Kullenberg pointed out that the temperature and salinity changes imply an "oceanization" of the Baltic, but man's interference has clearly resulted in measurable and detrimental differences in the 20th century. An interesting discussion on horizontal macroturbulence was presented by A. Jankowski and Z. Catewics (Poland) from data gathered from a set of buoys with current meters in the southern Baltic. Values near shore were two orders of magnitude larger than those in the open sea.

A symposium on oceanographic advances from new technologies was convened by R.E. Stevenson (US Office of Naval Research [ONR]/Scripps). It was organized into three-session groups: one, chaired by Neil R. Andersen (Intergovernmental Oceanographic Commission/National Science Foundation), on new knowledge in chemical oceanography; the second, chaired by Peter Worcester (Scripps), on recent advances in acoustic tomography; and the third, chaired by the convener, on space oceanography from data gathered by manned and unmanned spacecraft. Both Gene Traganza (Naval Postgraduate School, Monterey, CA) and Jan Duinker (The Netherlands) gave thought-provoking papers, and the entire session on acoustic tomography lent real excitement to the potential of that "remote-sensing" technique. Michael Parke (Jet Propulsion Laboratory), A.D. Kirwan, Jr. (University of South Florida), and M. Janopaul (Environmental Research Laboratory/National Oceanographic and Atmospheric Administration) showed the tremendous breadth of oceanography that is coming from both space and earth-borne remote sensing. From all the presentations in this symposium it is easily seen that oceanographers around the world are readily taking advantage of new technologies to probe the unknown--especially the mesoscale ocean.

Ray Smith (University of California, Santa Barbara) put together five sessions on marine optics of the upper ocean. A lot of work has been done in this field over the past 4 years, especially from data gathered by the coastal zone color scanner (CZCS) from the NIMBUS-7 satellite, and by the Optical Dynamics Experiment (ODEX); the work is funded by ONR and led by Ron Zaneveld (Oregon State University). There were several exceptional reports. Particularly good, I thought, were the

following: "Ship and Satellite Chlorophyll Observations in Gulf-Stream Warm-core Ring 82-B," by Karen Baker, Ray Smith, Otis Brown, Jim Brown, and R. Evans (US); "Optical, Physical, Biological, and Chemical Structures Mid-latitude Northeast Pacific Ocean, October-November 1982," by Jim Mueller (Naval Postgraduate School, Monterey, CA); "Phytoplankton Dynamics and Optical Properties," by Dale Kiefer (University of Southern California); "Maximum Effects of Sunlight Focusing Under a Disturbed Sea Surface," by Jerzy Dera and D. Stromski (Poland); and Ron Zaneveld's overview of ODEX.

"Chemical Fluxes in the Water Column," convened by S. Krishnaswami (India), was an extremely popular symposium. The opening paper by R. Chesselet (France) on "Chemistry of Marine Suspended Matter and the Trace-Element Cycle" set the tone. It was clear that fine particles (smaller than 5  $\mu\text{m}$ ) remains suspended for 100 years or more--embedded, in many cases, in particular dynamic ocean features, such as fronts or eddies. Anthropogenic inputs are but a few percent of the natural ocean fluxes--except for lead. Cycles of trace metals, cadmium, zinc, nickel, and copper are internally self-sustained in the ocean.

Details of organic compounds in the deep-ocean water column, from sediment-trap experiments, were discussed by John Farrington (Woods Hole Oceanographic Institution); he showed contrasts with data from shallow waters that were described by Victor Smetacek (Kiel, Federal Republic of Germany). The organic products are vastly different, primarily because of the great variation in time and distance from the basic source: surface-layer plankton.

Ted Wu (California Institute of Technology) put together a symposium on tsunami wave propagation; there were several papers of note, especially from the Japanese contributors. T. Kajiura (University of Tokyo, Japan) opened the program with a paper on the beach runup of transient waves. He noted that friction can be expressed simply by a single relation to two easily determined ratios. When the slope is steep and the time scale of the solitary is small, the effect of friction is minor. Turn the ratio around, and friction becomes significant. Hisashi Miyoshi (Tokyo Fisheries) described the energy convergence of tsunamis approaching an island. He pointed out that a gentle island slope can converge all the wave's energy and can, therefore sharply direct the tsunami wave.

### Oceanography

In oceanography, there were nine interdisciplinary symposia: "Geodetic Features of the Ocean Surface and Their Implications," "Hot Spots and Mantle Plumes," "Remote Sensing for Climate Studies," "Sea-Ice Margins," "Low-Latitude Coupled Ocean/Atmosphere Circulation," "Ridge Crest Hydrothermal Activity and the Chemistry of Sea Water," "The Ocean and the CO<sub>2</sub> Climate Response," "Oceanic and Atmospheric Boundary Layers," and "Coastal and Near Shore Zone Processes."

The first two sessions on geodetic features were basically composed of reports on the results of satellite altimetry--mainly SEASAT. Several excellent papers clearly showed that orbiting radar altimeters provide data essential to our knowledge of the geoid, topographic features of the seafloor and mesoscale ocean variability. The next four sessions covered specific geodetic questions in both concept and geography--e.g., gravimetry of the South Atlantic, and the M<sub>2</sub> model of global ocean tides.

The symposium on hot spots was successful. Extremely interesting data and modeling of the complicated, hot-spotted Pacific were presented--along with some apparently comparable ancient remnants (China and Africa), information on episodic, globally synchronous discharges, and deep-mantle-plumes.

"Remote Sensing for Climate Studies" attracted a large audience throughout its six sessions; those attending heard about ways that satellite data can be used to answer questions about climate. There were studies of aerosols, atmospheric moisture, ozone, clouds, snow, soil moisture, and radioactive flux measurements. In short, researchers discussed many parameters that seem to influence climate and that can be remotely sensed.

"Sea-Ice Margins" included two sessions on ocean processes and modeling, two on sea-ice processes, one on meteorological processes, and one on remote sensing and sea-ice processes. The last session was particularly interesting in that marginal ice zones covered by the various active and passive microwave sensors on the SEASAT and NIMBUS-7 satellites were studied. It is clear that microwave sensors on future spacecraft (the Space Shuttle, NROSS, ERS-1, and TOPEX) can provide data essential to an understanding of the marginal ice zone.

The symposium on low-latitude coupled ocean/atmosphere circulation dealt with teleconnections, both latitudinal and longitudinal; a variety of

models, global and otherwise; the effects of oceans on monsoons, and vice versa; the interannual variability of local, regional, and global winds, and the influence of such variations on the oceans; examinations of the current El Niño, with some intriguing data from the western Pacific; fluctuations and variability in the troposphere. A session on the equatorial Atlantic permitted known equatorial processes to be brought together and new directions to be suggested in analysis, modeling, and event recognition.

Ridge-crest thermal activity and the associated chemistry of the surrounding seawater has become of increasing interest as the use of deep submersibles permits precise sampling of the areas in question. Work has been done primarily in the Atlantic and parts of the East Pacific spreading centers, so most of the papers covered these studies. A particularly interesting paper by researchers from the University of Edinburgh dealt with the metalliferous sediments of the Semail ophiolite, Oman, formed at a late cretaceous spreading center; although ancient collapsed "sinters" could be identified, it was shown that they differed from the domes on the Galapagos Ridge.

"Oceanic and Atmospheric Boundary Layers" brought together in one symposium models, measurements, and the variations of response in the atmosphere and the upper mixed layer. Furthermore, the scales of interest did not cover the spectrum, but were confined to the microscale and mesoscale, where the actions of importance really lie anyway.

10/17/83

## OPERATIONS RESEARCH

### NEW DECISION SUPPORT SYSTEM

by D.R. Barr. Dr. Barr is Professor of Statistics and Operations Research at the Naval Postgraduate School, Monterey, CA.

Many military situations seem to be characterized by multiple objectives in the face of fuzzy data. The US Army has been supporting a German research program examining the performance of decision support systems (DSS) dealing with such situations, according to Dr. George Sokol, Chief of the Communications Engineering and Computer Science Branch, Army Research, Development and Standardization Group (UK) (USARDSG).

Prof. H.-J. Zimmermann (Aachen Institute of Technology, Federal Republic of Germany) and several of his associates have recently developed a working DSS described as an efficient algorithm for fuzzy linear programming with multiple objectives. (For a definition and discussion of fuzzy set applications, see ESN 36-8:180-182 [1982].)

The system has been installed on a Cyber 175 computer, and there are now plans to exercise the algorithm by solving various typical military problems. To demonstrate the workability of the DSS, Zimmermann is looking for applications to actual military problems which may be amenable to modeling as fuzzy linear programs with multiple objectives. Interested readers are invited to submit representative problems they believe might be suitable for exercises. Such problems should be submitted through USARDSG, at the following address:

Chief, Communications and Computer Science  
 US Army European Research Office  
 P.O. Box 65  
 FPO NY 09510.

To illustrate a problem Zimmermann believes is amenable to this approach, let us consider one for which a solution has already been attempted on the Aachen system. The problem concerns capital budgeting of military aircraft expenditures; it has been adapted from B.W. Taylor III et al., "An Integer Goal Programming Model for Determining Military Aircraft Expenditures," *Journal of the Operational Research Society*, 34 (1983), 379-390. The decision variables are the numbers  $x_i$  of different types of aircraft to be acquired; multiple goals and constraints reflect the weapon system's effectiveness, cost, and performance. Effectiveness constraints reflecting requirements to destroy at least specified numbers of enemy air and surface targets may be paraphrased as follows:

- The total air-to-air loss exchange ratio for all aircraft must be at least as large as the total number of air targets one wants to destroy;
- The total air-to-surface loss exchange ratio for all aircraft must be at least as large as the number of surface targets one wants to destroy;
- A fighter force is to be procured that will be sufficient to reduce the enemy's air and surface forces to a given level within a specified period of time.

The cost goal is to minimize the total flyaway cost,

$$\min_i \sum (FAC_i + (YR)(FHYR)(Loss_i) | x_i,$$

where:  $FAC_i$  is the flyaway cost of aircraft  $i$ ,  
 $YR$  is the operating time under steady state conditions,  
 $FHYR$  is the planned flying time, and  
 $Loss_i$  is the expected peacetime loss of aircraft  $i$ .

The performance goal is to maximize the total payload (sum over aircraft of external payloads the aircraft can carry). The resulting problem is modeled by Zimmermann and his associates as a fuzzy multi-objective linear programming problem. The fuzziness in this model accommodates flexibility in the constraints and objectives. The objective functions may be fuzzy, for example, because the performance goals to be maximized might be nondichotomous expressions, or the cost goals might involve preferred levels and tradeoffs which contradict "crisp" minimization. Such problems, which in many actual applications will be of much higher dimensionality, can be solved by the Aachen system, according to Zimmermann.

10/5/83

**PHYSICS**

**CHANNELING RESEARCH IN SWITZERLAND**

by David Mosher. Dr. Mosher is the Liaison Scientist for Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on reassignment until July 1984 from the Naval Research Laboratory, Washington, DC, where he is Supervisory Research Physicist.

During the past year, activities at CERN--the European Organization for Nuclear Research--have made headlines with the discovery of a family of subatomic particles called intermediate vector bosons. These particles carry the weak nuclear force just as photons carry the electromagnetic force, as predicted by the Glashow-Salam-Weinberg theory unifying the two forces. The three theorists won a Nobel prize for their efforts, and the experimental discovery will probably receive next year's prize. The vector bosons were discovered in collision experiments at 540 GeV between oppositely rotating proton and antiproton beams on the Super Proton Synchrotron (SPS).

Although the most visible, these collider experiments represent only a small part of CERN's program to understand elementary particles and their interactions with matter. For many experiments, proton beams are extracted from the SPS or the 28-GeV Proton Synchrotron (PS) and are directed to fixed targets. The secondary beams of various particles produced in the target are sorted and guided by electrostatic and magnetic fields to a number of experimental areas. In one of the PS experimental areas, radiation associated with channeling of positrons and electrons in crystals is studied with a view toward development of coherent gamma-ray sources. In a similarly configured experiment on the ring accelerator at the Swiss Institute for Nuclear Research (SIN, Villigen), channeling of positrons produced by the radioactive decay of muons is used to yield crystal structure information in group-IV semiconductors. Research in these programs is described here.

#### Background

In the PS experiment, an Aarhus-CERN-Strasbourg collaboration has been studying channeling effects in silicon and germanium crystals. The photon radiation from 1- to 10-GeV electrons and positrons channeled along crystal axes and planes has been investigated in detail. This experiment is of particular interest because it investigates coherent radiation with a wiggler structure operating in a very different regime from those of magnetic insertion devices and free electron lasers (FELs).

The last decade has seen the emergence of high-quality photon sources for condensed-matter physics, material structure, and chemistry based on synchrotron radiation from electron storage rings (ESN 36-12:345 [1982]). During the last few years, synchrotron radiation has been enhanced at short wavelengths (into the x-ray regime) by the use of wiggler magnets inserted into the ring. Similar structures contained within optical cavities form the bases for FELs. The wiggler provides a periodic magnetic field which causes electrons to oscillate transverse to the propagation direction. The oscillations produce a forward-directed cone of electromagnetic radiation called bremsstrahlung. At certain photon energies, the contributions from each wiggler in the electron orbit can add coherently to produce enhanced, monoenergetic radiation. As one might expect, the emission wavelength decreases (i.e., photon energy increases) as the wiggler period decreases and as electron energy

increases (ESN 37-10/11:419 [1983]). Technological limitations prevent construction of wigglers with periods much below 1 cm, so radiation is limited to below about 100 keV for the highest energy accelerators dedicated as synchrotron radiation sources. Thus, it has not been possible to conduct a wide range of experiments requiring higher energy photons.

#### Channeling

High-energy charged particles incident on crystals experience strong electrostatic steering forces when the incidence angle to close-packed crystal-line directions is small. These forces guide the particles between adjacent crystal planes and cause them to oscillate in the transverse direction. The particles undergo correlated small-angle scattering from atomic nuclei. For larger angles of incidence, particles are stochastically scattered across crystal planes. Channeled orbits are shown schematically in Figure 1 for positive and negative particles.

The channeling effect has been extensively studied for heavy particles and can be understood using a classical orbit description (Gemmel, 1974). Interestingly, the classical treatment holds for high-energy positrons and electrons as well because the large relativistic factor provides an effective large mass. Just as in a wiggler magnet, the oscillations of channeled electrons and positrons cause these light particles to emit polarized radiation in a forward-directed cone. The difference is the small periodicity length of the crystal lattice spacing which leads to high photon energies. Coupled with gigaelectronvolt particle energies, this spacing can result in efficient generation of channeling radiation in the form of about one gamma-ray photon per incident lepton. Since channeled electrons and positrons see different electric fields, their channeled radiations are expected to be different. For electrons, an enhancement in bremsstrahlung is observed with

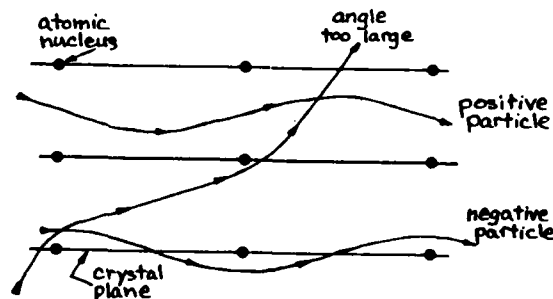


Figure 1. Channel orbits.

a broad spectral peak. For positrons, a dramatic increase in intensity is seen at sharper distinct spectral peaks. The spectra can be understood by averaging over the orbits of channeled particles with different transverse energies and angles of incidence.

The orbits of channeled particles depend on the arrangement of scattering nuclei in the crystal lattice. Thus, by measuring the angular distribution of particles which exit the crystal, one can acquire information about crystal structure in a fashion analogous to x-ray diffraction. Recent experiments at SIN have employed the decay of low-energy muons embedded in crystals as a source of positrons. The angular distribution of the emerging channeled positrons gives information about the crystal structure and the bonding sites of charged muons in the lattice. Since muons are heavy cousins of electrons (they are leptons not mesons), the manner in which they bond provides other information about the electronic structure of the crystal.

#### The CERN Experiment

I reviewed CERN's work with S.P. Møller, a member of the research team. Following preliminary studies of the channeling of 5- to 50-GeV electrons and positrons using an SPS secondary beam (Atkinson et al., 1982), the research program has continued on PS for the 1- to 10-GeV regime. The emphasis of the current program is to develop channeling radiation as a monoenergetic source of gamma rays. Thus, positrons are of greatest interest because of their narrow peaked spectra. Positrons and positive pi mesons are produced by collision of the PS proton beam with a fixed target.

Bending and focusing magnets are used to select positrons with a well-defined momentum out of the shower of particles and photons produced in the target. Since only a small fraction of the  $10^5$  positrons produced in each PS burst are momentum-selected and transmitted through the beam line for analysis, channeled particles and their photons are discriminated and characterized individually with a sophisticated array of detectors coupled to a data acquisition computer. Only data from events in which channeled positrons produce forward-directed gamma rays are stored in the computer.

One detector element which triggers data storage is a chamber filled with a few atmospheres of He gas. The index of refraction of the gas is such that only positrons have a velocity greater than light in the medium. Thus, Cherenkov

radiation (emitted only by superluminal charged particles) is used to trigger data storage. Wire detectors in front of and behind the silicon crystal determine the position and angle of positrons which enter it. Emerging channel radiation photons are reduced in energy by pair production in CdTe targets, and the total energy of the transmitted photon plus electron-positron pairs is measured in a large NaI detector. The total signal determines the energy of the channel radiation photon. Only events for which the pairs produce a signal in a scintillator backing the CdTe are recorded.

Figure 2 summarizes channeling radiation spectral data for positrons of different momenta incident along the [110] plane of a 100- $\mu$ m-thick Si crystal. The spectra are normalized to that of incoherent bremsstrahlung expected from an amorphous target of the same thickness. The figure therefore shows the enhancement due to coherent effects as a function of emitted photon energy, E. The inserts show the variation of radiation intensity in the first peak as a function of angle to the [110] plane. Angles are normalized to  $\psi_p$ , the maximum incident angle for channeling (about 0.1 mrad for gigaelectronvolt positrons and decreasing with increasing particle energy).

The data show a distribution of equally spaced peaks. This harmonic structure is most easily understood as the distribution of quantum mechanical energy states, expected from the nearly harmonic motion of positrons in the transverse plane. The corresponding spectra of channeled electrons do show a large enhancement (about 20 for the momentum range shown in Figure 2), but because they move in a highly anharmonic potential, radiation is broadly distributed over photon energy.

The solid curves show the prediction of classical orbit theory using a potential distribution which simulates the actual one more accurately than does a simple harmonic distribution (Ellison et al., 1982). Overall agreement between measurements and the theory is good, especially at higher energies. Discrepancies can be understood in terms of neglected incoherent scattering and particle dechanneling effects. A major triumph of the theory is the ability to explain why the peak structure is unexpectedly sharp in the 5- to 20-GeV/c momentum range in the presence of a transverse energy spread. This new understanding of anharmonic effects suggests the possibility of developing monoenergetic gamma ray sources in the 10- to 100-MeV energy range by choosing

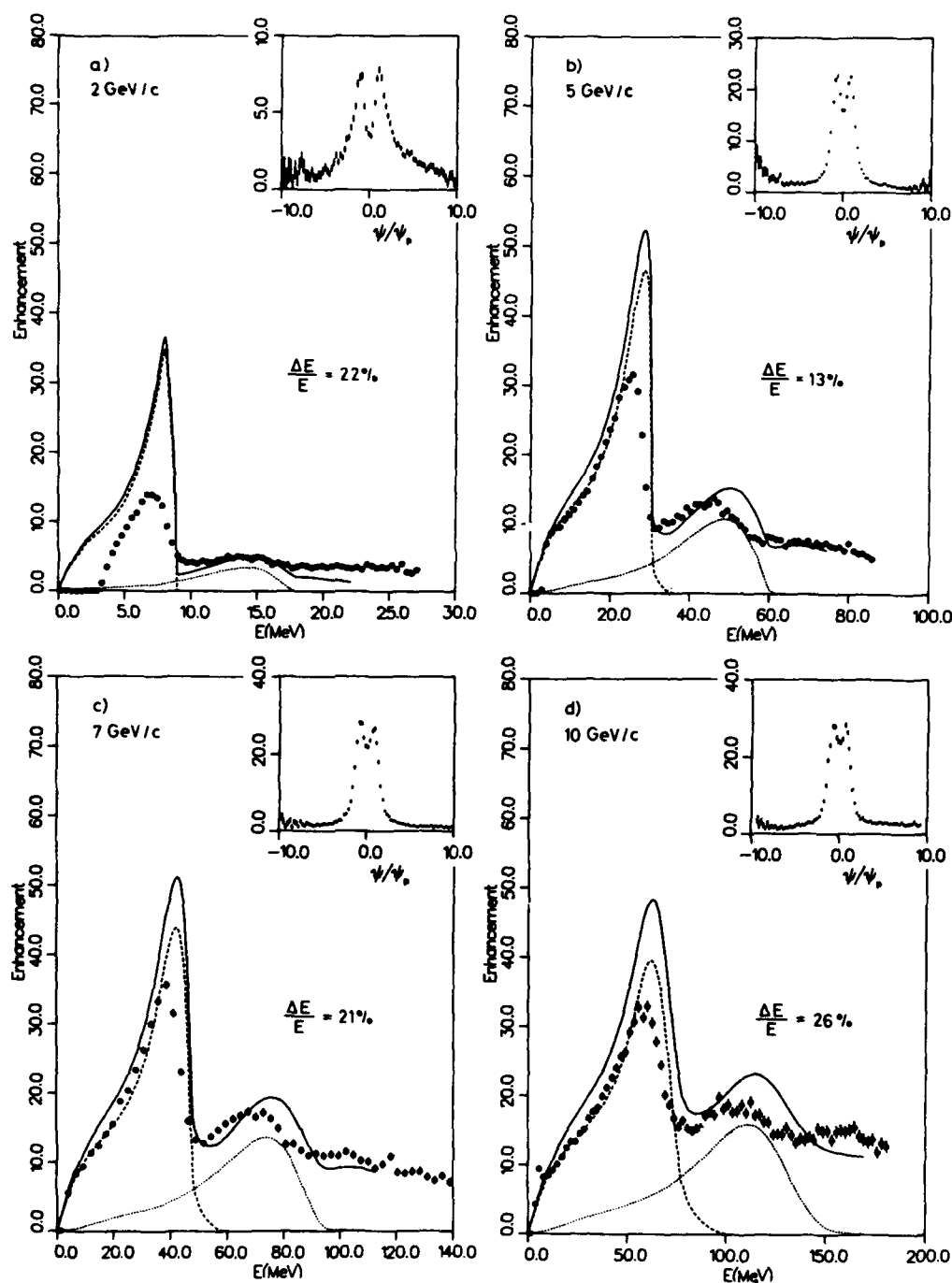


Figure 2. Channeling radiation spectral data.

different crystals and planar directions. For projectile energies in the 5-GeV range, the photon energy is nearly independent of incident angle within  $\psi_p$ .

Thus, thick crystals can be used without regard to multiple scattering effects to obtain high gamma-ray efficiency. For each 5-GeV/c positron incident on a 2-mm-thick Si crystal, about 1 photon in

the 10- to 30-MeV range would be emitted.

#### Applications of Channeling

In addition to providing a radiation probe for nuclear structure analogous to synchrotron radiation for atomic structure, the channeling effect has other applications that are under

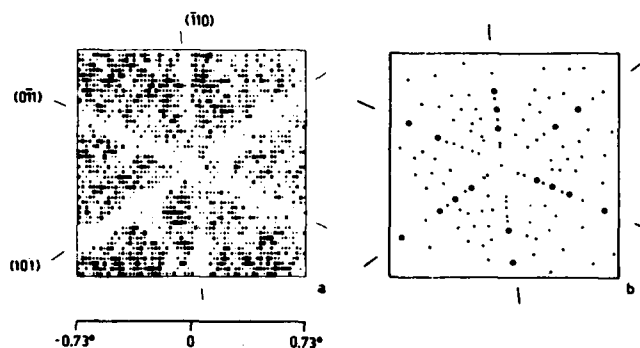


Figure 3. a. Positron channeling pattern; b. x-ray diffraction pattern.

investigation. One intriguing idea is to channel particles through curved paths using elastically bent crystals. Experiments in Dubna, USSR, have demonstrated bending of 8-GeV/c protons through 30 mrad by planar channeling (Elishev et al., 1979). The technique may be applicable to beam guidance--it allows bending with much smaller radii of curvature than do steering magnets. The sharp bend also enhances synchrotron radiation at short wavelengths.

Another application area for channeling was described to me by B.D. Patterson (University of Zurich), who is conducting experiments at SIN. For this work, low-energy (less than 30 MeV) positive muons are selected out of the fixed-target secondary beam of the 600-MeV proton ring accelerator. The muons enter a silicon wafer and come to rest at some point in the lattice near the surface of the crystal. Subsequently, the muon decays into a positron and two neutrinos (half-life of 2.2  $\mu$ s). A measurement of the angular distribution of the channeled decay positrons shows a maximum for a lattice site in the channel and a minimum for a site shadowed by a host atom in the direction of observation.

Multiwire proportional chambers are used to determine the angular distribution of positrons which leave the crystal. Figure 3a shows a positron channeling pattern for a Si crystal at room temperature. The spot intensity is proportional to the number of detections in the two-dimensional angular space. A Laue x-ray diffraction pattern for the same sample is shown in Figure 3b. The lines of minimum counting rate can therefore be identified with positron blocking by atoms in the (110) plane.

The channeling patterns can be used with other experiments to obtain information on the lattice sites at which

muons come to rest. To date, the experiments have revealed the sites of hydrogen-like muonium ( $\mu^+e^-$ ) states in the group-IV semiconductors (Bosshard et al., 1983). The change in location of these states with temperature and crystal type can reveal much about the electronic structure of matter.

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10/27/83

#### MUON-CATALYZED FUSION

by David Mosher.

Thermonuclear fusion of the lightest elements in stellar interiors is the universal source of radiant energy and the heavier elements. On earth, man has been attempting to control the process for energy production since the 1950s. The attractions of fusion for power production are freedom from fossil fuels, an inherent safety compared to fission, and virtually inexhaustible fuel--the hydrogen isotopes can be extracted from seawater.

Two main approaches to controlled fusion have been developed, with the aim



of commercial power production at the beginning of the next century. Both magnetic-confinement and inertial-confinement fusion techniques rely on heating a deuterium-tritium mixture to kiloelectronvolt temperatures (10 to 100 million °K). At such temperatures, colliding nuclei have enough energy to overcome electrostatic repulsion and approach sufficiently closely to fuse. One requirement for conventional fusion is then to heat the fuel to high plasma temperature. A second requirement is that the plasma be held together for a sufficient time to "burn." In stars, such confinement is provided by a balance of plasma pressure with huge gravitational forces.

Scientific feasibility of magnetic-confinement fusion (MCF) will probably be demonstrated with tokamak devices within the next 5 years on recently commissioned US and West European devices and on machines in construction in the USSR and Japan. Such devices employ strong magnetic fields to isolate a large-volume tenuous plasma from the walls of a doughnut-shaped container. The inertial confinement (ICF) concept relies on irradiation of small fuel pellets with several megajoules of laser- or charged-particle beam energy to compress the fuel and heat it to ignition temperature. Scientific feasibility for ICF with both laser and ion beams may also be demonstrated during this decade.

Following these predicted successes, both MCF and ICF must be evaluated for engineering and economic feasibility as commercial power producers. Clearly, many problems with power production could be avoided if a means were found to promote continuous fusion at temperatures and pressures which allow for material contact between the fuel and container. An entirely different approach to the problem, muon-catalyzed fusion, provides hope for a solution.

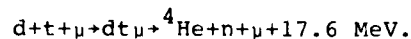
This topic was one of many discussed at the Third International Conference on Emerging Nuclear Systems (ICENES3) held in Helsinki, Finland, from 6 through 9 June 1983. The intent of the conference was to provide a forum for assessing the commercial power-producing capabilities of advanced fission and fusion reactors, hybrid and symbiotic fission-fusion reactors, novel fusion and fuel-breeding concepts. The broad scope of ICENES3 encouraged the participation of scientists interested in the engineering, economic, and political aspects of the well-established fission technologies, as well as researchers investigating the scientific feasibility of more speculative concepts. Muon-

catalyzed fusion was the most speculative of these concepts and one of the most interesting.

I learned about this intriguing concept at the conference and in later discussions with Anil Kumar at the Institut de Génie Atomique of the Ecole Polytechnique Fédérale in Lausanne, Switzerland. The conference results indicate that muon-catalyzed fusion may be scientifically feasible. However, analyses of Kumar and others indicate that it will be commercially interesting only if the high energy cost of muon creation with an accelerator can be offset by incorporating fissile-fuel breeding assemblies to boost energy gain.

#### The Basic Concept

W.H. Preunlich of the University of Vienna described the process of muon-catalyzed fusion. Muons are heavy cousins of electrons ( $m_{\mu} = 207m_e$ ) produced by high-energy reactions in accelerator targets and are unstable, with a 2.2- $\mu$ s half-life. The major fusion reaction of interest occurs when a negative muon stops in a high-density, diatomic gas mixture of deuterium ( $d_2$ ) and tritium ( $t_2$ ) and forms a muonic atom with a d or t nucleus. If  $d_{\mu}$  forms, the muon transfers irreversibly to a triton because of the higher  $t_{\mu}$  binding energy. Owing to the large mass, the muon is bound to the nucleus in a Bohr orbit 200 times smaller than is an atomic electron. The muonic molecule  $dt_{\mu}$  then forms with the nuclei 200 times more tightly bound than in  $d_2$ . The closeness of the two nuclei leads to rapid tunneling through the coulomb barrier and, as the nuclei come within range of the strong force, fusion occurs. Following fusion, the muon is usually liberated to induce further cycles of the process. The main reaction is



The muon therefore serves as a catalyst permitting fusion to occur at cold (even cryogenic) temperatures without being consumed. Muons are lost to catalysis in three ways. First, the muon can decay into an electron and two neutrinos. However, the mean lifetime is much longer than the reaction cycle time. Second, there is a probability of about 1 percent that the muon will stick to the helium ion and be lost. Third, the muon can be scavenged by impurities such as helium formed in tritium decay.

It is important that each muon be available to promote many fusion

reactions because of the high energy cost of its creation--conference participants assumed a cost in the 3- to 10-GeV range for each muon. Since each fusion releases 17.6 MeV of energy, each muon must be used for several hundred fusion cycles to produce energy.

**Reported Research**

The simplified description of catalyzed fusion presented above represents only the dominant process in the cycle. The mesomolecules  $dd_\mu$  and  $tt_\mu$  can also form and fuse. The  $dd_\mu$  fusion can occur in two ways, and each process can have products with the muon either free or bound. Also, the muon itself can decay at any time during the cycle. The full process is shown in Figure 1, where the  $\lambda$  and  $\kappa$  labels indicate the process rates.

To calculate energy production and the number of cycles catalyzed per muon, one must determine the time-dependent behavior of the components shown in the figure. Results of such a calculation were presented in a point kinetic analysis by A.A. Harms (McMaster University, Hamilton, Canada). The density of each constituent in the cycle was determined by solution of coupled rate equations of the form

$$\frac{dN_i}{dt} = -\lambda_i N_i + \sum_j \lambda_j N_j - \sum_k \kappa_{ki} N_k N_i \quad (1)$$

The first term represents the decay of arbitrary species  $N_i$ , the second the production of  $N_i$  by decay of precursors, and the last represents the loss of  $N_i$

in compound reactions. Although Figure 1 suggests 14 coupled equations of the form shown, Harms worked with subsets of four to six equations which described the most important processes and were much easier to solve numerically. The results show a rapid decrease in muon density in the first nanosecond as mesomolecules are formed, followed by a 1- $\mu$ s plateau due to recycling of muons before their decay. With an initial muon density of  $10^{12}$   $\text{cm}^{-3}$ , the energy and neutron yields per muon were determined as functions of  $dt_\mu$  formation rate. For rates consistent with experiments discussed below, about 1-GeV energy yield per muon was calculated with 50 to 70 neutrons produced per muon. Harms concluded that a favorable energy balance will require use of some nuclear synergetic system.

Harm also considered more exotic fusion cycles that could be catalyzed by muons and are neutron lean, such as  $d\text{-}^3\text{He}$  and  $p\text{-}^{11}\text{B}$ . The  $p\text{-}^{11}\text{B}$  reaction produces no neutrons but three alpha-particles ( $^4\text{He}$  nuclei). Since all fusion energy is carried off in charged particles, it may be converted to electricity with higher efficiency than neutron kinetic energy. One disadvantage is that the energy yield per muon cannot be boosted by breeding without neutrons, so that large muon fluxes (about  $10^{14}$ /s) are required for net energy production. However, the other side of the same coin presents a political advantage--the cycle cannot be used

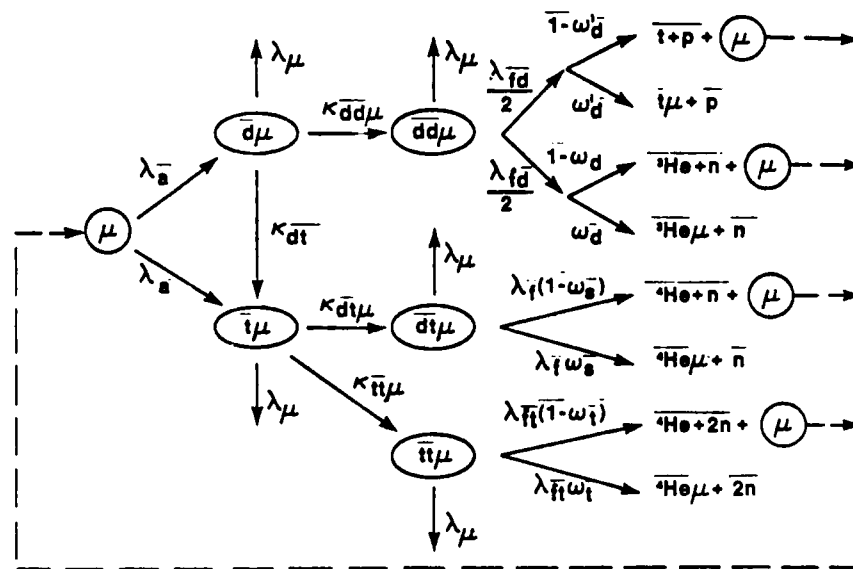


Figure 1. Muon-catalyzed fusion in a deuterium-tritium mixture.

for breeding weapons-grade fissile material.

An experiment determining the absolute neutron yield in muon-catalyzed dt fusion was described by Steve E. Jones (Idaho National Engineering Laboratory). High density deuterium-tritium mixtures were irradiated at the Anderson Meson Physics Facility (LAMPF) at the US Los Alamos National Laboratory. One important feature of this experiment was the ability to vary dt concentrations and temperature, which allowed one to determine a number of constituent rates and their variation with temperature.

The apparatus is shown in Figure 2. Scintillation counters define incoming muons, and their decay into electrons is detected by other scintillators placed between the target and neutron detectors. About 25 percent of the muons entering the target window are stopped in the dt gas, and the probability is low for more than one active muon to be in the gas at any one time. The event signature for data recording is registration of one muon entering the target window, one muon decay electron, and at least one high energy neutron. The target vessel design reflects constraints at the LAMPF biomedical channel and the requirement to contain gas mixtures with up to 35,000 curies of tritium at 1000 atmosphere pressures and 100 to 600°K temperatures.

At low and intermediate deuterium concentrations, the muon catalysis rate shows an increase with temperature above 250°K, in agreement with previous Soviet results (Bystritsky et al., 1980). The present experiment is the first carried out at high tritium levels, and a new phenomenon was observed under those conditions--muon catalysis cycle rates showed a strong temperature dependence. The  $dt_{\mu}$  formation rate, expected to peak at about 540°K on theoretical grounds, continued to increase above this temperature. From the variation in neutron yield versus temperature from an equimolar dt mixture at 60 percent of liquid hydrogen density, the sticking probability of the muon to the He fusion product

was estimated to be  $(7.6 \pm 0.5) \times 10^{-3}$ , somewhat less than the 0.009 theoretical value. The fusion yield per muon of  $90 \pm 9$  was correspondingly higher than the value calculated by Harms. Results also demonstrated the disastrous effects of impure mixtures. After the tritium was allowed to decay for 6 days, producing a  ${}^3\text{He}$  concentration of  $4.2 \times 10^{-4}$ , a 40 percent reduction in neutron yield was observed. Thus, the tritium inventory must be frequently filtered to prevent muon attachment to the decay product.

A team of researchers from the Austrian Academy of Sciences in collaboration with C. Petitjean from The Swiss Institute for Nuclear Research

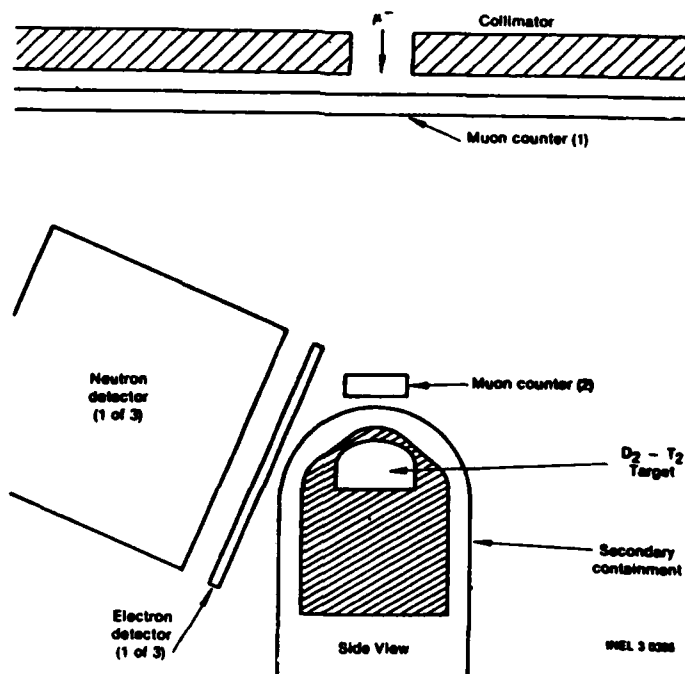


Figure 2. LAMPF experimental arrangement.

(SIN, Villigen) presented three papers at ICENES3 on hyperfine effects in muon catalysis. Hyperfine effects were first observed in neutron counter experiments at SIN while fusion of  $dd\mu$  was being studied (Kammel et al., 1982). Two different molecular formation rates were found to be related to the  $F = 3/2$  and  $F = 1/2$  vibrational states of the initially formed  $\mu d$  atom. Petitjean described more recent experiments measuring the gamma ray yield in the fusion reaction  $pd\mu + \mu He^3 + \gamma$ . From the enhancement of yield at high  $d_2$  concentrations, the contributions from the two  $\mu d$  hyperfine states could be individually determined.

P. Kammel of the Austrian group discussed hyperfine effects in the reaction kinetics of dt systems. Kammel made the point that these effects should not be neglected in experiments or reaction kinetic studies and must be understood for reaction optimization. The  $F = 0$  and  $F = 1$  levels of the  $\mu t$  atom have  $dt\mu$  formation rates which are very different in magnitude and temperature dependence, so that the total formation rate must be deduced from five allowed transitions between  $t\mu$  and  $dt\mu$  hyperfine states. Kammel presented an expression for  $dt\mu$  formation which predicted the variation with temperature

for the two initial atomic states, and explained the temperature-independent neutron yield observed in Bystritsky's experiments.

Reactor Concepts

Although each conference presentation had a different emphasis, researchers were in substantial agreement concerning applicability to power production. At best, about 100 14-MeV neutrons can be produced by each muon--a factor of three or more is still lacking to produce the energy cost. For the most part, this limit is due to the muon's sticking to the helium fusion product with a probability slightly less than 1 percent. H. Takahashi (Brookhaven National Laboratory) suggested that a powerful x-ray laser might reduce the sticking factor by tuning to the bound-state resonance. However, no such laser is technologically feasible. Even if it were, the finite  $dt\mu$  molecular formation time would still limit production to a few hundred neutrons in a muon decay time. W. Seifritz (SIN) and B. Goel (Karlsruhe Nuclear Institute, Federal Republic of Germany) investigated muon-catalyzed inertial confinement fusion with a similarly poor evaluation for power production. Thus, all are in agreement that additional

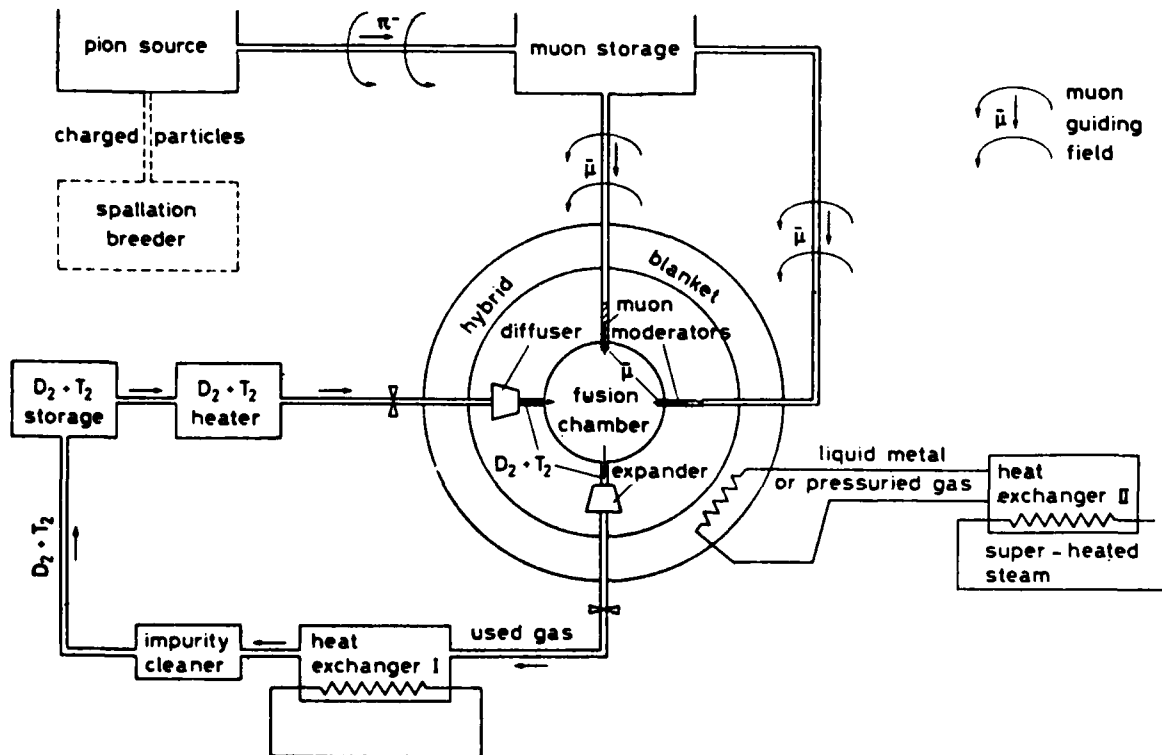


Figure 3. MCHR conceptual design.

neutron-induced nuclear reactions must be used for power production.

Anil Kumar looked at the constraints for power production and has developed a conceptual design for a Muon Catalyzed Hybrid Reactor (MCHR). Figure 3 shows the conceptual design of the MCHR. The muons are produced through the decay of pions that, in turn, are produced by the interaction of accelerated light nuclei with light targets. Negative pi mesons are extracted from the target and are confined by a magnetic field until they decay with a half-life of 26 ns into negative muons. The gigaelectronvolt-energy muons created must be moderated in a few centimeters of high-Z material before entering the fusion chamber. Moderation allows the muons to be stopped in a 100-cm-diameter chamber for gases in the 1/10 liquid-hydrogen density range. The moderated megaelectronvolt muons enter the chamber with the pressurized deuterium and tritium gas kept at about 600°K, the temperature of fastest dt<sub>μ</sub> formation.

When muon-catalyzed fusion occurs, the charged helium nucleus heats the fluid and the 14-MeV neutron heats the hybrid blanket. The gas mixture and blanket working fluid are cooled in heat exchangers and recirculated, and the extracted heat is used to produce electricity in a thermal cycle. The energy liberated per muon is boosted by breeding tritium and fissile fuel in the blanket. However, Kumar states that blanket breeding does not produce sufficient energy to make the process economical. He suggests that the wasted portion of the accelerator beam (i.e., the portion scattered or transmitted by the pion target) can be used to produce fissile fuel by the spallation of fertile materials like <sup>238</sup>U and <sup>232</sup>Th. The addition of a spallation breeder substantially complicates the reactor design but can represent an important improvement--80 percent of the original beam energy is carried by the "waste" beam.

The efficiency,  $\eta_r$ , of such a reactor is given by

$$\eta_r = \eta_e - (M\eta_a)^{-1}, \quad (2)$$

where  $\eta_e$  is the efficiency of electrical power production from thermal power,  $\eta_a$  is the accelerator efficiency, and M is the energy multiplication provided by fuel breeding. It has been estimated that  $M \approx 35$ ,  $\eta_a \approx 0.6$ ,  $\eta_e \approx 0.35$  so that  $\eta_r \approx 0.3$  (Petrov, 1980). Kumar believes that this figure makes the MCHR attrac-

tively competitive with concepts based on either accelerator breeding or thermonuclear breeding alone.

It seems that a successful MCHR must await development of commercially viable accelerator and fusion breeding techniques. Achievement of economical breeding by these means depends not only on technological advances, but also on high fission-ore costs and a future public acceptance of fission reactors. These issues were main areas of discussion at ICENES3. Yet, as a plasma physicist, I find exciting the concept of controlled fusion at normal material temperatures and with conventional "plumbing," rather than at above 10 million °K with magnetic bottles. A compact MCHR for shipboard use might make more sense than either a magnetic or inertial confinement fusion system. However, its realization will first require the development of a sufficiently compact and efficient gigaelectronvolt-level accelerator. But that's another story (ESN 37-1:32[1983]).

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11/3/83

#### SECOND INTERNATIONAL SYMPOSIUM ON ACOUSTIC REMOTE SENSING OF THE ATMOSPHERE AND OCEANS

by Chester McKinney. Dr. McKinney is the Liaison Scientist for Underwater Acoustics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until September 1984 from The University of Texas at Austin, where he is Senior Research Scientist at Applied Research Laboratories.

The Second International Symposium on Acoustic Remote Sensing of the Atmosphere and Oceans (ISARSAO) was held at the Consiglio Nazionale Delle Ricerche (CNR), Rome, Italy, from 29 August through 1 September 1983. This meeting was hosted by CNR and the University of Rome. There were 38 participants (plus about five local students) from 13 countries, and 44 papers were presented.

Most of the papers dealt with using acoustic echo ranging (ER) equipment to probe the atmosphere, while only seven involved underwater acoustic measurements. Sodar (for sound detection and ranging, analogous to radar) appears to be the accepted acronym for atmospheric echo ranging, although some of the authors used terms such as acoustic radar (not very appropriate) and air sonar. All the papers were presented (in English) in an informal manner, and the discussion was lively. Prof. G. Fiocco, who organized the symposium, plans to publish the proceedings in some form, but this may take a year. Readers interested in a detailed description of the meeting are referred to US Office of Naval Research, London, conference report C-16-93; this article presents only a brief overview of the technical program.

#### Acoustic Remote Sensing in the Atmosphere

The technique of echo ranging must rank as one of the most important and popular measurement methods known to man, but only in the past 15 to 20 years has it been exploited for atmospheric remote sensing. During that period the science and technology have matured significantly, and at present there are perhaps 500 or more sodar systems in use worldwide. Commercial equipment is available from at least six manufacturers at prices ranging from a few thousand dollars for the most elementary devices to \$100,000 and more for advanced systems. Operating frequencies range from about 1 to 10 kHz, with 2 to 4 kHz being most common, pulse lengths of 50 to 200 ms, and beamwidths of a few degrees. A common type of acoustic array is a tweeter loudspeaker driving a parabolic reflector, all of this being surrounded on sides and bottom by a box-type baffle to minimize local noise. Three popular types of configuration are: (1) single-beam, upward-looking array, (2) three-beam arrays, and (3) bistatic arrays. Each of these has good and bad features.

As with any echo-ranging system, sodar depends on a change in the impedance of the medium for echo generation. In general, sodar depends on temperature changes, which cause density changes, for echoes. These impedance changes are quite small, and it is necessary to integrate the received signals over a considerable volume and for a matter of minutes to achieve useful signal-to-noise ratios. This situation tends to discourage any move to obtain higher resolution. A single-beam, upward-looking system can be used to measure

features such as the heights of inversion layers and regions of turbulence; if provided with Doppler processors, such a system can give a measure of vertical wind speed. A multibeam Doppler sodar can provide three-dimensional contours of wind vectors. Typically, measurements can be made for altitudes from about 20 to 600 m; in this height regime, sodar can fill a useful complementary role with tower-mounted instruments for the first few meters and radar for the higher altitudes.

By using first- and second-order statistics, sodar--sometimes in combination with other instruments--can measure a number of characteristics of the atmosphere, but wind speed, wind shear, turbulence, and temperature are the basic ones. Sodar appears to have two major areas of application. One is for the measurement of wind shear and turbulence near airports. The capability of sodar has been demonstrated, but operational acceptance has been low. The other major use is for detecting and tracking air pollution, especially around industrial complexes, and for site selection. About a dozen of the papers related to this application.

It is evident that the small sodar community has collected a vast quantity of atmospheric data in a wide variety of locations, including industrial sites, airports, urban areas, Antarctica, coastal areas, and remote mountain peaks. Some of the data collection programs have run for at least 5 years. At present the research effort seems to be shifting to and emphasizing model development and signal processing. One author listed the following advances since the first ISARSAO:

- Improvements in the measurement of wind parameters
- Advances in theoretical work
- Active integration of sodar into air monitoring work
- Advances in the interpretation of pollution data
- Improvements in using sodar simultaneously with radar, lidar, towers, and radio sondes.

Two papers reviewed a considerable body of work which has been done on the radio acoustic sensor system (RASS). This technique involves the use of a high-power acoustic source (beamed upward) to modify the electromagnetic impedance of the atmosphere, which in turn can be remotely sensed with a higher resolution radar probing the same column of air. With RASS, useful data can be obtained for altitudes up to 3000 m for strong winds. The RASS equipment

is considerably more complex than conventional sodar.

#### Underwater Acoustic Remote Sensing

The seven papers dealing with underwater acoustic remote sensing, while small in number, were high in quality and interest. All the papers described experimental work, but some included theoretical models.

A paper by D.M. Farmer (Canada) described four techniques for acoustically measuring water flow and turbulence: (1) a conventional high-frequency depth sounder, (2) a forward-looking sonar, (3) a correlation sonar, and (4) a forward-scatter system. R. Lhermitte (US) described a five-beam, bottom-mounted, high-resolution sonar used to measure the three-dimensional water current field. Ted Brown described his work (which is in an early phase) to develop a technique to measure the speed of sound (and thus temperature) as a function of depth. H. Medwin (Naval Postgraduate School, Monterey, CA) presented experimental data on the generation of a boundary wave by a volume wave moving over a slightly rough ocean bottom at very low grazing angle. Inversely, a measurement of the boundary wave can be used to infer the nature of the bottom roughness. Papers by Farmer and by B.R. Kerman (Canada) presented work on the relationship between wind and ambient noise for shallow water and high frequencies. John Proni reviewed the US National Oceanographic and Atmospheric Administration's program of the past decade; the research uses active acoustic sensing to detect and track pollution in the oceans.

10/17/83

## **SCIENCE POLICY**

### SUPPORT OF SCIENCE RESEARCH BY THE BRITISH MILITARY

*by James W. Daniel, Scientific Director for Europe and the Middle East for the Office of Naval Research's London Branch Office. Dr. Daniel is on leave until 1985 from The University of Texas, where he is Professor of Mathematics, of Computer Sciences, and of Education.*

The British Ministry of Defence (MoD) provides only a small fraction--less than 2 percent--of the financial

support for basic scientific research conducted in the nation's universities. The level of funding is far higher in the US, for example, where the corresponding figure is 8 to 10 percent.

Yet because of the way it is administered, the roughly £9,000,000 (\$13,500,000) that the MoD spends each year on some 300 projects has greater impact than one might expect. In addition, a significant amount is spent on basic research conducted in the MoD's own research establishments.

I met recently with Mr. H.G.R. Robinson, the MoD's Assistant Chief Scientific Advisor for Research. Robinson explained that the ministry's present general research interests are (with the highest priority areas listed first):

1. Electronics
2. Mechanical engineering
3. Aeronautical engineering
4. Civil and electrical engineering
5. Computer sciences
6. Acoustics
7. Materials science
8. Physics
9. Chemistry
10. Biology
11. Behavioral sciences

These areas of basic science are viewed as directly supporting the so-called Major Fields in which the MoD seeks technological improvements (see Table 1). All research and development in a given Major Field is coordinated by a single individual, often the director or deputy director of one of the MoD research establishments; this Major Field Leader is therefore responsible for activities that may take place at several universities and research establishments, all in support of a single Major Field.

#### Extramural Research Support

Research projects funded by the MoD at universities are called "extramural" --as opposed to the "intramural" projects funded at MoD research establishments. Although lower figures have been reported incorrectly, Robinson stated that there are presently about 300 extramural research projects supported at universities, with a total annual expenditure of about £9,000,000. The system for awarding these funds differs from that in the US in two ways, each having important consequences.

First, individual researchers are invited to request support for work of interest to a particular Major Field Leader; no public call for research

proposals is made. Each Major Field Leader has an Assistant Director for Extramural Research (ADXR) at an MoD research establishment, one of whose tasks is to be aware of relevant research being performed in universities.

The ADXR then approaches a researcher with the suggestion that he or she submit an informal request for support on a particular topic; the ADXR and the researcher's university then draw up an agreement that the MoD will provide

Table 1

MoD's Major Fields

<u>Major Field Number</u>	<u>Major Field Title</u>
1	Aerodynamics, Structures, and Materials
2	Gas Turbines
3	Rocket Propulsion
4	Armored Fighting Vehicles & Engineering Equipment
6	Ships and Submarines
7	Guided and Air-launched Weapons
8	Undersea Warfare
9	Conventional Weapons, Armaments, & Pyrotechnics
10	Chemical and Biological Defense
11	Electronic Components
12	Electronic Systems
14	Navigation and Avionics
20	Space

Table 2

Research Establishments and Their Fields

<u>Research Establishment</u>	<u>Major Fields of Interest</u>	<u>Major Fields as Leader</u>
Admiralty Marine Technology Establishment	6,8,11,12	6
Admiralty Surface Weapons Establishment	9,12,14	---
Admiralty Underwater Weapons Establishment	6,8	8
Royal Signals and Radar Establishment	7,11,12	11, 12
Atomic Weapons Research Establishment	Nuclear,1,3,4,6,7,9,10,11,14	Nuclear
Chemical Defense Establishment	9,10	10
Military Vehicles and Engineering Establishment	4	4
Propellants, Explosives, & Rocket Motors Establishment	3,9	3
Royal Armament Research & Development Establishment	7,9	9
Royal Aircraft Establishment	1,2,6,7,8,9,11,12,14,20	1,2,7,14,20



certain funds and that the researcher will work in a certain area. All research results are unclassified and available for publication in the open literature. This system has the important advantage of closely relating basic research in the universities to the work in the research establishments where the ADXR sits. It has the disadvantage of depending on the ADXR's knowledge of who is working in related fields in the universities, although this problem is more apparent than real since university researchers can usually make themselves known to relevant ADXRs.

A second important difference in the funding systems is that British research agreements between the MoD and the university do not include overhead funds; universities are assumed to provide overhead support themselves. As a consequence, expenditures by the MoD go for the direct support of research work. Since, in addition, university salaries are lower in the UK than in the US, it is clear that the MoD's £9,000,000 buys appreciably more direct research than would be the case in the US; it is perhaps equivalent to \$26,000,000.

#### Intramural Research Support

Robinson explained that the MoD feels that it must stimulate basic scientific research within its own research establishments as well as in the universities; thus the intramural research program was created. Each research establishment is required to devote 5 percent of its budget (magnitudes of the resulting expenditures are classified) to in-house research in basic science--that is, to projects whose direct application appears to lie at least 15 years in the future. This helps not only to keep the establishments informed about leading-edge research but also to make them more attractive environments for young scientists completing their university training. Results from this research are generally classified and not openly published. Intramural research is naturally concentrated at each establishment in those areas in which it has existing strength or in which it wishes to develop strength. Table 2 lists the major establishments, the Major Fields (by number) in which they participate, and the Major Fields in which they are the lead establishment.

#### Conclusion

The UK's MoD provides a relatively small fraction of the support for basic

scientific research in the universities. Yet the funds that are allocated establish close ties between the MoD research establishments and the universities, avoid the "deflation factor" associated in the US with high overhead costs, and maintain the research vitality of the establishments. Thus the MoD funds have greater impact than might at first appear to be the case.

10/27/83

## STATISTICS

#### ISI MEETINGS

by D.R. Barr. Dr. Barr is Professor of Statistics and Operations Research at the Naval Postgraduate School, Monterey, CA.

The 44th session of the International Statistical Institute (ISI) was held in Madrid, Spain, from 12 through 22 September 1983. A program with approximately 60 sessions, each with six to eight papers, was presented to over 1000 attendees. About half of the sessions were composed of invited papers; these, together with the contributed paper sessions, covered a remarkably wide range of statistical topics--including, for example, exploratory data analysis, microcomputer developments, sample survey design and evaluation, official statistics, as well as more "traditional" sessions on time series, classical and Bayesian inference, and reliability. Two special lectures were presented: the Fisher lecture, by Prof. D.J. Finney (University of Edinburgh, UK), was "Biological Assay: A Microcosm of Statistical Practice." Finney recounted the development of bio-assay methods, in which he played a key role, and described current research in the area. The Mahalanobis lecture was presented by Barbara Bailar (US Bureau of the Census), who gave an historical account of Mahalanobis' work, leading up to current problems under study at the Bureau of the Census.

A unique session was devoted to the three best unpublished papers by recent graduates living in developing countries. The ISI had invited individuals

to submit candidate papers for review by a jury of distinguished statisticians: C.R. Rao (University of Pittsburg), O. Barndorff-Nielsen (Aarhus University, Denmark), and A. Stuart (University of London). The winners, whose expenses in attending the conference were paid by ISI, were:

- S.M. Ogbonmwan (University of Benin, Nigeria), "A New Nonparametric Multiple Comparison Test Based on Sen's Nonparametric Generalization of the T-Method of Multiple Comparisons for the One Way";
- R. Srinivasan (Bangalore, India), "Supply and Demand Model for Short-haul Air Services in India";
- Xie Xinghong (East China Normal University, People's Republic of China), "The Uniqueness of Optimal Sequential Decision."

A somewhat controversial paper was given by E.B. James (Computer Center of Imperial College, UK)--"Microcomputers: The Coming Revolution in Statistics." James said that with respect to microcomputers, he takes a position which is unusual for a computer scientist working in a large university computing center: the microcomputer can provide a quality of support to the statistician which cannot be provided by a centralized computing system, however powerful and efficiently managed. He believes the programs now being provided for microcomputers are generally better than those provided on larger machines, in two ways: they are more efficient, so as to allow significant computing on the less powerful machines; they have far better user-friendliness.

James discussed the impact microcomputers are having on the practice of statistics, in terms of interactiveness, graphics, word processing and report writing, and--of extreme importance, James feels--portability. He described his vision of future computers for statistical work. He believes the keyboard will disappear, possibly in favor of voice input of commands. He thinks the dividing line between hardware and software will disappear, and a range of specialized "engines" will be available for work in different application areas. Statisticians would have available a statistical engine--and if required, a range of reference data bases of very great size realized as video disks. "The processing power of a personal unit designed especially for statistics could easily rival that of the largest existing general-purpose computers very soon," James said.

In a session on geological and geophysical statistics, Pierre Delfiner (Études et Productions Schlumberger, France) gave an interesting paper, "Selected Problems in Geostatistics." Delfiner discussed two significant problems currently receiving much attention in geostatistics: the change of support problem and the local prediction problem. The geostatistical support of a variable is the basic sampling unit (volume or area) over which it is measured. The variable  $Z(\chi)$  is often defined as an average of  $Z$  over the support centered at  $\chi$ . The study of the distribution of  $Z(\chi)$  as a function of the support  $\chi$  is one of the most important problems of geostatistics, Delfiner stated. It is also one which standard statistical methods do not address. Delfiner discussed the problem of estimating recovery of ore from a mine, and the effect of having data samples on one support while inferences are desired for some other (usually larger) support.

Delfiner discussed Kriging, a method often used for the prediction problem. Basically, the problem is: given values of  $Z(\chi)$  at  $n$  sample points  $\chi_1, \chi_2, \dots, \chi_n$ , estimate the value  $Z(\chi_0)$  over a support centered at  $\chi_0$ . In the Kriging method, which was described later by a discussant of the paper as "a particular variant of linear regression which seems nonparametric," the value  $Z(\chi)$  is modeled as the sum  $m(\chi) + y(\chi)$ , where  $m$  is a low-frequency mean trend or "drift," and  $y$  is a high frequency stationary term. The basic challenge is the inclusion of environmental factors, such as the nature of the deposit involved (dunes, alluvial deposits, river deltas, and so on) in the estimation of the drift,  $m$ . Delfiner discussed several Kriging approaches, including procedures he called "universal Kriging" and "disjunctive Kriging." He described coming methods of computer mapping, which he called "intelligent Kriging," that will use qualitative knowledge translated into a form Kriging algorithms can "understand."

L. Ljung (Linköping University, Sweden) gave an excellent review of models for "dynamical" systems in his paper, "Recursive Identification of Stochastic, Dynamical Systems." He discussed methods for sequential estimation of parameters in dynamical systems. (In the control theory and signal processing fields, these methods are called adaptive algorithms.) Ljung discussed the relationships between general recursive identification algorithms and

the corresponding off-line identification problem, with particular emphasis on the roles of the algorithms in off-line identification problems. He stressed the role of prediction of future outputs and its gradient with respect to the parameters, and presented some basic asymptotic properties of the algorithms he discussed.

The meeting was distinctive in several ways. The hospitality of the Spanish authorities and various Spanish organizations involved was exceptional. The breadth of the program and the wide variations in the sessions was remarkable. It is, in short, a very interesting experience to share 2 weeks of intensive statistical presentations with a thousand statisticians from all corners of the world.

10/13/83

## NEWS & NOTES

### IONOSPHERIC RESEARCH EMPHASIZED IN USSR

The USSR's Kazakh Academy of Sciences has announced the programs and objectives of its recently established Institute of the Ionosphere. According to the *Daily Snap* (Soviet News Abstract Publication, 15 September 1983), previously existing meteorological and ionospheric facilities, equipment, and stations in the region are being upgraded and expanded. The institute has established a joint program of courses and research with the Kazakh State University to train students in ionospheric physics. New capabilities at the institute will include remote control of field stations and a radar system for studying the ionosphere and upper atmosphere. The radar will be powerful enough to generate gravitational waves and will use a laser system.

Satellite and rocket launches in the Soviet space program are made from Kazakh, which is located at high latitudes in a remote region of the USSR in the West Siberian Plain. The territory also has been used for planned explosions and tests of an "industrial character." So-called active experiments will be conducted at the institute to modify, diagnose, and study properties of the upper atmosphere. V.M. Krasnov, Deputy Director of the institute, has said that "research planning is oriented toward the integrated approach. Emphasis is on . . . active methods, purposefully directed explosions, launches of geophysical rockets,

and so forth. An explosion which was conducted for scientific purposes 2 years ago thus yielded unique results; we recorded waves with a speed of 1 km/s. Various parameters were measured from the earth, but also from space. The ionosphere is a natural laboratory [and] allows plasma processes to be created in conditions which are difficult to obtain with terrestrial models."

The institute will address practical problems and will conduct cooperative programs with other nations.

*R. L. Carovillano*  
10/5/83

### LÜST CHOSEN TO HEAD ESA

At its June meeting, the Council of the European Space Agency (ESA) chose Prof. Reimar Lüst as its next Director General. Lüst will succeed E. Quistgaard on 15 May 1984.

Dr. Lüst brings to his new post with ESA a strong background in space science and a successful record of administrative leadership in science. He currently heads the Max-Planck-Gesellschaft (MPG), where he is completing his second 6-year term as president. MPG is the governing agency of the prestigious complex of Max Planck Institutes located throughout the Federal Republic of Germany (one institute is in The Netherlands). Lüst has served on many high-level ESA committees and was scientific director of the European Space Research Organization (ESRO) from 1962 to 1964. (ESRO eventually evolved into ESA.) In addition, the disciplinary emphasis of several of the Max Planck Institutes is in space science, astronomy, or astrophysics.

Lüst's personal accomplishments are in space physics, notably his theoretical work in the early sixties on the solar wind, and his contributions to the German barium-cloud active-experiments program that pioneered this important field.

Lüst will face many difficult issues in directing ESA. Foremost among these will be to strike an effective balance between ESA programs and the national programs of strong member states. Critics complain that ESA launch costs are excessive and that ESA gives too little attention to applied programs. As in the US, programs with communications satellites are complicated by developing commercial and industrial interests. On the other

hand, if the recent successes of the European rocket launcher, Ariane, continue, prospects for program development, financing, and planning will be brightened considerably.

*R. L. Carovillano*  
10/5/83

#### IMS WORKING GROUP REPORT

ESN 37-9: 382-386 (1983) described the Sixth Workshop on IMS Observations in Northern Europe, held in Windsor, England, from 16 to 20 May 1983. A theme of the workshop concerned reactions of the ionosphere and neutral atmosphere; one of the study periods chosen for comprehensive data coverage was 26 to 27 January 1982. Following the Windsor meeting, a booklet entitled "IMS Working Group Report on the January 26, 27, 1982 Event" was prepared on the assembled data. Coverage includes: (1) magnetic field data from the French-Soviet ARCAD 3 project, carried out on the AUREOL 3 satellite; from ground-based measurements by the World Data Center, Russia; and from the Air Force Geophysics Laboratory magnetometer chain; (2) electron and ion data from ARCAD 3 and the GEOS 2 satellite; (3) extremely low frequency/very low frequency waves from ARCAD 3 and GEOS 2; (4) electric field data from GEOS 2; (5) relaxation sounder data from GEOS 2 and the ISEE 2 satellite; (6) incoherent scatter radar data from EISCAT, Saint Santin, and Chatanika; (7) aurora data; (8) riometer data; and (9) ionospheric neutral wind data determined by interferometers. The assembled data base is useful to study substorm events, the magnetospheric convection electric field, magnetic field aligned currents, and synoptic studies by means of space and ground-based observations.

C. Mazaudier coordinated assembly of the data base and may be consulted for further information:

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*R. L. Carovillano*  
10/5/83

#### ACARD LAUNCHES NEW STUDIES

The UK's Advisory Council for Applied Research and Development (ACARD, 70 Whitehall, London SW1A 2AS),

which advises the government on the exploitation of research and technology, has begun two new studies.

The first follows up ACARD's recent report on advanced manufacturing technology: "New Opportunities in Manufacturing: The Management of Technology." The working group assigned to the new study will examine developments in control and instrumentation technology and the manufacture and use of control systems in the UK. Dr. Bryan Lindley, Director of Technology, Dunlop Holdings, will chair the group. The following questions will be addressed:

1. What new developments will occur in sensors, processors, actuators, instrumentation, and other components of control systems, as well as associated methods of data handling and transmission over the next 10 years?
2. Is the underlying research, design, and development base strong?
3. What measures are needed to ensure that new and existing technology is used in industry and widely exploited?

The second study is linked to ACARD's role in advising the government on its annual review of research. The working group for this study will survey current scientific developments and advise ACARD on work which shows commercial and economic promise in the medium to long term. The study will be led by Dr. Charles Reece, Director of Research and Technology at Imperial Chemical Industries.

*L.E. Shaffer*  
11/2/83

#### YARSLEY PIEZOELECTRIC AND PYROELECTRIC POLYVINYLIDENE FLUORIDE FILMS NOW IN PRODUCTION

Metallized poled films of polyvinylidene fluoride are now in full pilot plant production (see also ESN 36-9:213 [1982]). The width is 15 cm, and continuous reels up to 200-m long are available in thicknesses of 9, 25, and 40 microns. Greater thicknesses are under development. Aluminum is the normal metallizer, but nickel, gold, and other metals are available on request.

The properties (average figures) of the commercial product are given in Tables 1 and 2. Further details may be obtained from Yarsley Research Laboratories Ltd., The Street, Ashstead, Surrey KT21-2AB, England.

*Vivian T. Stannett*  
10/28/83

Table 1  
Ageing, Stability, Heat Shrinkage

*Ageing Characteristics*

Thermal ageing tests on the stability of the piezoelectric coefficient and shrinkage in the machine direction indicate that Yareley PVDF films appear to be superior in ageing characteristics to other piezoelectric PVDF films which are commercially available.

*Stability of Coefficient (25- $\mu$ m film)*

Temperature ( $^{\circ}$ C)	Time	$\epsilon_{31}$ aged
		$\epsilon_{31}$ initial
90	100 minutes	0.91
120	100 minutes	0.71
150	100 minutes	0.35
67	2500 hours	0.97
100	2500 hours	0.77
-20 $\leftrightarrow$ 60 $\leftrightarrow$ -20	100 1-hr cycles	1.00

*Heat Shrinkage (25- $\mu$ m film)*

Temperature	Time	% Shrinkage (MD)
90	100 minutes	- 3.5
120	100 minutes	- 8.1
150	100 minutes	-19.2
70	100 hours	- 4.5
65	2500 hours	- 2.5
100	2500 hours	-10.0

Table 2  
Properties

Property	40 $\pm$ 3 $\mu$ m		25 $\pm$ 2 $\mu$ m		9 $\pm$ 1 $\mu$ m		Units
Piezoelectric coefficient*	$d_{31}$		18-20				PCN <sup>-1</sup>
	$d_{32}$		2.8-3.2				PCN <sup>-1</sup>
	$\epsilon_{31}$		0.12-0.14				Vm N <sup>-1</sup>
	$\epsilon_{32}$		0.018-0.022				Vm N <sup>-1</sup>
Piezoelectric coefficient			24-28				$\mu$ cm <sup>-2</sup> K <sup>-1</sup>
Surface conductivity (metallized film, Al)			2				$\Omega$ cm <sup>-2</sup>
Tensile strength (at break)	MD**	TD	MD	TD	MD	TD	$\times 10^6$ Nm <sup>-2</sup>
	250-290	34-38	225-265	34-38	180-220	29-35	
Elongation at break	MD	TD	MD	TD	MD	TD	%
	14-16	430-450	13-15	440-490	16-20	300-400	
Tensile modulus	MD	TD	MD	TD	MD	TD	$\times 10^6$ Nm <sup>-2</sup>
	2400-2700	2300-2700	2200-2600	2000-2500	1800-2200	1750-2200	
Tear strength (machine direction)	250-320		160-200		170-245		N mm(thickness) <sup>-1</sup>
Dielectric constant ( $\epsilon'$ )			12 $\pm$ 1				at 1 kHz
Dielectric loss tangent			0.02-0.025				at 1 kHz
Volume resistivity			5 $\times 10^{12}$				$\Omega$ .m
Dielectric breakdown strength	135-145		160-170		290-310		kV(DC)mm <sup>-1</sup>
Heat shrinkage (machine direction after annealing at 70 $^{\circ}$ C for 100 hr)	4.5		4.5		5.5		%

\*  $d_{33}^{\circ}$  -  $d_{31}$  and  $\epsilon_{33}^{\circ}$  -  $\epsilon_{31}$

\*\*MD = Machine direction; TD = Transverse direction

SCIENTIFIC JOURNAL LOWERS PRICE--AN UNHEARD OF EVENT

*Interdisciplinary Science Reviews* (ISR), the English journal of science and humanities, has lowered its subscription price from \$45 to \$28 for private subscribers and from \$99 to \$75 for institutions. This buys four quarterly issues of about 100 pages each.

ISR, now in its eighth year, has published nearly 500 contributions containing the thoughts of leading scientists, senior technologists, and humanists about the past, present, and future of those fields. It is all-embracing, ranging from relativity to economics, from Gothic cathedrals to space exploration, from the OKLO reactor to theology; it is interdisciplinary and international.

ISR is published by J.W. Arrowsmith of Bristol. For a free sample copy, write to: Dr. A.R. Michaelis, Editor ISR, Spectrum House, Hillview Gardens, London NW4 2JQ, England.

James W. Daniel  
10/12/83

INFORMATION TECHNOLOGY IN THE UK

A recent issue of the *SERC Bulletin*, published by the UK's Science and Engineering Research Council, contained several items relating to the UK's current activities in information technology (IT). The IT program concerns information acquisition, processing, and use--exploiting state-of-the-art techniques in microelectronics, computing, and telecommunications.

The UK announced its \$150 million, 3-year program in IT about 1 year ago. Included was a \$30 million fund in IT postgraduate education to be administered by the SERC. The main aim of the

SERC funding has been to establish courses for "converting" non-IT students into IT practitioners. With the aid of this funding there are IT conversion courses in about 40 universities and polytechnics throughout the UK. Nearly 900 "studentships" (grants to individual graduate students) have been awarded for the conversion course; about 200 3-year postgraduate research studentships, for graduates from IT programs, have been granted. The SERC has commented that it receives about three times as many applications for these grants as the number available.

In a related matter, the SERC publication announced that Bryan Oakley has left his post as Secretary to the SERC to become director of the new Alvey Directorate (see also *ESN* 37-12:448 [1983]). The Alvey Directorate has been set up to run the UK's National Advanced Information Technology Program. This program is supported jointly by the UK's Department of Trade and Industry, Ministry of Defense, SERC, and industry. For further information on the Alvey Directorate, contact:

Mr. B. W. Oakley  
Director, Alvey Directorate  
Room 1131, Department of Industry  
Millbank Tower  
Millbank, London SW1P 4QU  
England

D.R. Barr  
11/2/83

CORRECTION

*ESN* 37-8:297 (1983) reported that the turnover for the clothing industry in England's West Midlands is \$250 billion; the figure should be \$250 million.

OCTOBER MAS BULLETINS

The following *Military Applications Summary (MAS) Bulletins* were published by the ONR, London, Military Applications Division during October. The *MAS Bulletin* is an account of naval developments in European research, development, test, and evaluation. Its distribution is limited to offices with the US Department of Defense. DoD organizations should request copies of the *Bulletins*, by number, from ONR London.

<u>MASB Number</u>	<u>Title</u>
114-83	Royal Navy South Atlantic Operations (CONFIDENTIAL)
117-83	The Royal Navy Equipment Exhibition (RNEE) 1983: Aerospace Highlights Part 3
118-83	Denmark Considers XBT Program
119-83	A Simple "Hush House" Technique for Testing Jet Engines Installed in Aircraft
120-83	German Research Into "Supermaneuverability" and its Enhancement of Air-to-Air Combat
121-83	A New Deep-Penetration, High-Payload British Parachute Designed for Use With Special Forces

ONRL REPORTS

To request reports, check the boxes on the self-addressed mailer and return it to ONRL.

- C-15-83: *The 11th International Congress on Acoustics*, by Chester McKinney. This report provides an overview of trends in acoustic research, based on the subject matter of the 11th International Congress on Acoustics. The report includes an appendix written by David Blackstock (Applied Research Laboratories, The University of Texas). The appendix deals with nonlinear acoustics at the congress.
- C-16-83: *Second International Symposium on Acoustic Remote Sensing of the Atmosphere and Oceans*, by Chester McKinney. This report discusses papers dealing with sodar (for sound detection and ranging), which is used for atmospheric echo ranging. In addition, work on underwater acoustic remote sensing is examined.
- C-17-83: *Ninth World Computer Congress: IFIP 83*, by J.F. Blackburn. Highlights of the conference included discussions of the design of Ada, the VLSI/ULSI chip, logic programming, multiprocessor data bases, high-performance computers, fifth-generation computers, dataflow machines, and high-speed processors.

ONRL COSPONSORED CONFERENCES

ONR, London, can nominate two registration-free participants in the conferences it supports. Readers who are interested in such participation should contact the Scientific Director, ONR, London, as soon as possible.

Third UK Solar Maximum Mission Workshop, Oxford, UK, 26-28 March 1984.

Vacuum 84--Technological Aspects of Surface Treatment and Analysis Conference, York, UK, 1-4 April 1984.

International Symposium on the Properties and Applications of Metal Hydrides IV, Eilat, Israel, 3-9 April 1984.

Second International Meeting on Lithium Batteries, Paris, France, 25-27 April 1984.

International Conference on Laser Processing and Diagnostics--Applications in Electronic Materials, Linz, Austria, 15-19 July 1984.

International Conference on Digital Signal Processing, Florence, Italy, 4-8 September 1984.

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SCIENCE NEWSBRIEF FOR OCTOBER

The following issues of *Science Newsbrief* were published by the ONR, London, Scientific Liaison Division during October. *Science Newsbrief* provides concise accounts of scientific developments or science policy in Europe and the Middle East. Please request copies, by number, from ONR London.

Science Newsbrief Number

1-1-83

1-2-83

Title

Bacteria Produce a Unique Thermoplastic-Polyhydroxy-Butyrate (PHB), by Thomas C. Rozzell and Vivian T. Stannett

British Cabinet-Level Science Policy, by James W. Daniel



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