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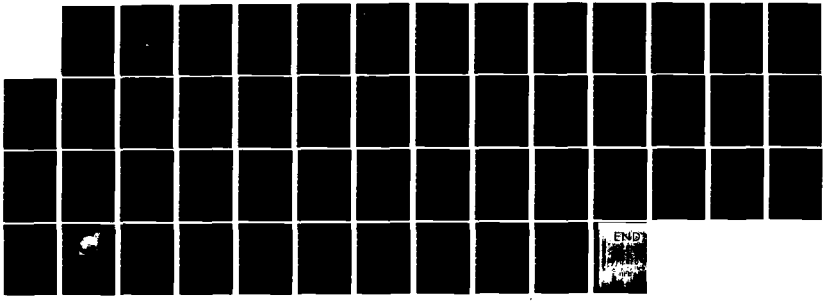

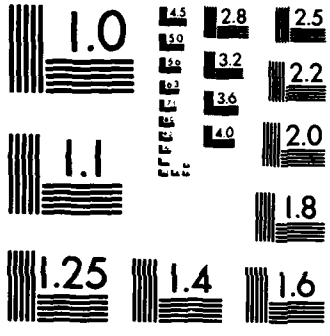

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EUROPEAN SCIENTIFIC NOTES

ESN 37-10/11

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European Scientific Notes (ESN) is a monthly publication with brief articles on recent developments in European scientific research. The publication is not intended to be part of the scientific literature. The value of ESN articles to Americans is to call attention to current developments in European science and technology and to the institutions and people responsible for these efforts. ESN authors are primarily ONRL staff members. Occasionally articles are prepared by or in cooperation with staff members of the USAF

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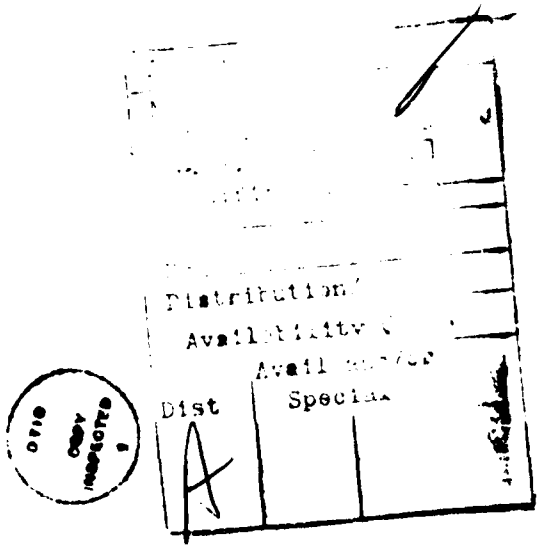

EUROPEAN SCIENTIFIC NOTES
OFFICE OF NAVAL RESEARCH
LONDON

Edited by Larry E. Shaffer

October/November 1983
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BIOLOGICAL SCIENCES

The Institute of Bioelectrical Research, Ltd., is examining the use of electromagnetic fields for healing wounds; clinical and laboratory studies are under way.

CHEMISTRY

In the field of polymers, researchers are studying combustion and thermal degradation, including flame and smoke inhibition by metal, halogen, and other compounds.

COMPUTER SCIENCES

IBM-United Kingdom is establishing standards for the use of function points in scheduling and cost-estimating for software development.

Imperial College, London, is working on a graph-reduction computing system. It will be used for processing symbolic expressions in optimizing high level language programs.

EARTH SCIENCE

Earthquake prediction has become an important scientific development in geophysics during the last two decades. Although progress has been substantial, the methods of earthquake prediction are still evolving.

The 17th General Assembly of the International Union of Geodesy and Geophysics included 12 sessions on the assessment of natural geophysical hazards. Papers dealt with topics such as hydrological processes, seismology, volcanology, and tsunamis.

MATERIAL SCIENCES

MATHEMATICS

OCEAN SCIENCES

PHYSICS

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Scientific Director

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BIOLOGICAL SCIENCES

SCOTTISH INSTITUTE STUDIES BIOMEDICAL APPLICATIONS OF ELECTROMAGNETIC FIELDS

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 leave until August 1985 from the Office of Naval Research, Arlington, VA, where he is Group Leader for Cellular Biosystems.

The biological effects of electromagnetic fields (EMF) have been the subject of extensive research during the past 10 to 15 years. The US Department of Defense has realized that there are many opportunities to use such energy in diagnostic and therapeutic applications in medicine and in other ways. Some of the most promising uses of EMFs include facilitating the repair of soft tissue wounds, healing certain types of bone fractures that do not respond to normal methods of treatment, and stimulating repair of injured nerves.

The Institute of Bioelectrical Research, Ltd. (IBR), in Scotland is one of the first research organizations to be formed almost exclusively for studying biomedical applications of EMFs. Located outside Edinburgh, IBR was conceived and is headed by Dr. Richard H.C. Bentall, whose work in wound healing and cellular effects is known worldwide. As stated in the founding charter, the objectives of the institute are:

"1. To undertake and promote the advancement of scientific research in relation to the interaction of electromagnetic energy with living biological systems (including, without prejudice to the foregoing, horticultural mechanisms, bacteria and viruses).

"2. To promote closer awareness among the general public of the work in the fields referred to in (1) above.

"3. To seek to develop ways of utilizing the results of the work referred to in paragraph (1) above for the benefit of humans and animals."

Essentially all the work at IBR is centered around a simple radio frequency (RF) current-inducing device developed by Bentall. The induction treatment coil (ITC) is manufactured with the trade name PORTIC. As shown in Figure 1, the ITC consists of a loop antenna, RF signal generator, and associated electronics sealed in a silicon housing.

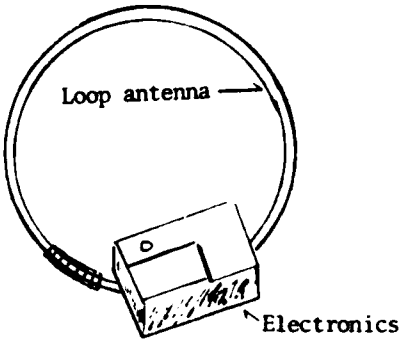

Figure 1. Induction treatment coil for inducing current.

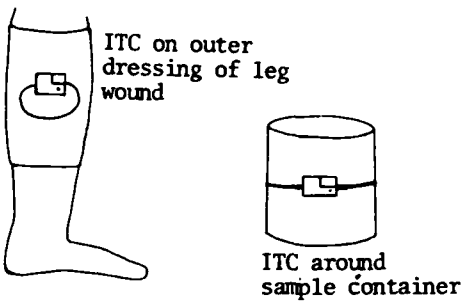

Figure 2. Examples of the ITC in use in human and laboratory studies.

A miniature battery provides power for about 4 weeks of continuous use. The frequency is approximately 27 MHz and is square wave pulsed at 950 pulses per second. The device produces a low intensity RF field of approximately 3 $\mu W/cm^2$. The configuration of the ITC allows it to be placed either on the surface of the body or around an animal or sample container, as shown in Figure 2.

When the switch is removed, the unit is activated and the emitted RF field induces a minute current flow in the tissue of the patient or in the animal or sample being studied. The diameter of the antenna can be varied to accommodate sample holders of different sizes.

Although the institute is still partially under construction, several ambitious research studies using the ITC are already under way, and several pilot studies have been completed. Bentall recently outlined the laboratory and clinical studies in progress or being planned for the near future.

Clinical Wound Healing Projects

The major clinical study involves a pool of 27 hospitals in six cities throughout the UK. Bentall is examining how the induced currents produced by the ITC affect the healing of recalcitrant decubitus ulcers (bedsores) and leg ulcers (of varicose veins). This is a double blind study seeking to confirm that the small induced currents accelerate the healing of epidermal wounds by promoting the formulation of granulated tissue. A placebo group acts as control. However, the protocol allows for a double blind crossover so that the initial placebo group of patients may also receive the benefit of the currents, if indeed there is one. There are now 35 patients with decubitus ulcers and 36 with leg ulcers. Preliminary studies have shown that, clinically, a significant portion of the patients do respond favorably, as evidenced by improved formulation of granulation tissue and subsequent re-epithelialization. At this point, though, it is too early in the study to decode the results, and Bentall does not know if the patients healing faster are experimentals or controls.

During the past year, Bentall has conducted several pilot studies aimed at establishing techniques and protocols for additional full-scale clinical studies. The first of these was on the use of induced electrical currents for the treatment of non-union fractures in bone in humans and fresh fractures in rabbits. Both gave good evidence of accelerated healing, and now the studies will be expanded. Although the treatment of non-union bone fractures is well accepted, little use has been made of this type of treatment for fresh fractures, primarily because there is little increase in the rate of healing by the two most common techniques of treatment, inductive coupling and direct current (Bassett, 1982; Compere, 1982). Bentall is not certain whether his device can provide a significant increase in fresh fracture healing; but to be satisfied on this point, he feels that the study must be done.

Another pilot study was carried out to determine whether the locally induced currents would have any effect on reduction of post-operative bruises and edema. This study, limited as it was to only a few patients, has indicated that adverse local reactions are reduced. In other studies, Bentall has also shown that there is a 100 percent increase in the rate of repair in the water barrier of injured skin after epidermal injury. In these pilot studies, a commonly used skin-wound model was used: epidermal skin stripping was performed on the forearms of human volunteers. Bentall even has wounds on each of his legs for epidermal wound healing studies. This type of research is common in certain parts of Europe and Great Britain because the restrictions for the use of human volunteers are much less severe than in the US and Canada.

Laboratory Wound Healing Studies

Research on electrical stimulation of wound healing would be incomplete without efforts to understand the electrical interactions at the cellular and membrane sites. IBR is investing considerable effort in developing a suitable, inexpensive model that will provide consistent information about wound-healing physiology. The chick embryo has been chosen for this purpose and they are attempting to adopt the shell-less culture technique of Dunn (1974). Chick embryos are cultured with associated yolk and albumen outside the eggshell and shell membranes. The technique allows direct access to and continuous observation of cultured embryos almost to time of hatching. The embryo is first cultured normally in the intact shell for about 48 hours. Then the shell is carefully opened, and the developing embryo and associated egg contents are transferred to a culture well consisting of an 8-cm-diameter section of plastic pipe that supports a "pouch" of plastic wrap. The well is covered with a glass cover that allows constant observation of the contents. Bentall and his coworkers are experimenting with different methods of inflicting wounds in the embryos; he is using controlled burning, cutting, and pinching. Once a reproducible wounding method is chosen, the culture containers will be outfitted with ITCs (both sham and operational). The advantages of this live membrane model are that it is well characterized, is low in cost, and behaves predictably. In addition, large numbers of samples can be run in a small amount of space, enabling a number of different electrical parameters to be tested in a short period of time. The ability to observe the healing means that time-lapse microphotography can be used to document the events. IBR plans to automate this under control of a PDP/11 computer.

Other healing parameters, such as wound tensile strength, histology, and *in vitro* dielectric measurements will require a larger animal model. Such models will be used to supplement the clinical results.

A pilot study is under way in the IBR greenhouse to determine if the ITC

will have any effect on germinating seedlings; barley is the test crop. It will be a few months before this series of tests yields meaningful results.

Literature Collation

The activities of IBR include systematic searching and collation of the world's bioelectromagnetic and associated literature. Under the direction of Diane Beard, over 2000 reprints have been collected and catalogued. This information will be used in a computerized literature-retrieval service that will be made available to the worldwide scientific and medical communities.

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9/2/83

CHEMISTRY

COMBUSTION CHEMISTRY OF POLYMERS AT CITY UNIVERSITY, LONDON

by Vivian T. Stannett. Dr. Stannett is the Liaison Scientist for Polymer 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 North Carolina State University, where he is Camille Dreyfus Professor in the Chemical Engineering Department.

The Department of Physical Chemistry at the City University, London, has developed a strong program in combustion chemistry under the direction of Prof. C.F. Cullis, Head of the Department of Chemistry. General research topics include isotopic tracer studies of the combustion of hydrocarbons, the emission of particulates in the combustion of diesel fuels, and atmospheric pollution.

In the field of polymers, studies are being conducted by Cullis, Dr. M.M. Hirschler, and their coworkers. They are studying many aspects of combustion and thermal degradation, as well as flame inhibition by metal, halogen, and other compounds. The equipment used includes a fully automated simultaneous thermal analyzer. The mass of the polymer, the rate of mass change (with automatic differentiation), and the temperature were all measured simultaneously. Flammabilities were determined with the standard ASTM D635 test and the limiting oxygen index (LOI) in equipment designed to meet the ASTM D2863 test requirements.

Smoke determinations were made either by igniting candles of the polymers similar to those used for the LOI measurements at an oxygen concentration 1 percent higher than the LOI, or in air if the LOI was less than 19.9. The candles were burned for 3 minutes. A smoke chamber 62-cm high, 61-cm deep, and 122-cm wide was installed above the exhaust of the LOI apparatus. The smoke concentration was estimated by means of a photocell and a light source with a 1.22-m light path across the smoke chamber.

One general approach has been to try to relate the combustion properties to the actual thermal behavior of the polymer--in particular its thermal stability. The relationships are necessarily vague because the heating rates used in thermal analysis (normally less than $100°min^{-1}$) are vastly different from those encountered during flaming combustion. However, thermal stability often does give a strong indication of the flammability. Thermally stable polymers, for example, normally have low flammability characteristics. The City University group usually prefers to use the temperature required to decompose 1 percent of the polymer. This temperature is much less sensitive to sample size and heating rate than the minimum decomposition temperature, T_D. Thus with polybutadiene, T(1%) varied only from 564 to 567°K, with sample weights from 9.6 to 78.2 mg; this compares with T_D values which varied from 524 to 482°K. In similar experiments with constant weight, 10 mg, polyvinylidene fluoride, T(1%) varied from 684 to 674°K with heating rates of 5 and $100°min^{-1}$, whereas the corresponding T_D values were 604 and 463°K, respectively. Even the T(1%) figures give poor correlations with the flammability itself. They are considerably more useful, however, for indicating the effect of additives on

flammability. A detailed discussion of these effects and of the significance, in general, of thermoanalytical measurements is provided in the assessment of polymer flammability recently published by Cullis and Hirschler (1983).

Cullis and Hirschler have conducted a systematic series of studies on how various combinations of metal and halogen compounds affect flammability. High density polyethylene (HDPE) and acrylonitrile-butadiene-styrene terpolymers (ABS) were the chief polymers studied; somewhat less work was done with polypropylene and polystyrene. The well-known synergism between the metal oxides and the organic halogen compounds was clearly demonstrated. The relationships between the composition (polymer plus metal plus halogen compounds) and the flammability and smoke suppression were found to be extremely complex. However, fourth-order polynomials and the corresponding triangular diagrams have been used to derive meaningful correlations. Antimony trioxide (Sb_2O_3) appears to be the most effective additive with decabromobiphenyl (DBB), and chlorinated wax with ABS and HDPE, respectively. Several less expensive oxides, including iron III and aluminum trioxide (Al_2O_3) were investigated; the anhydrous form of the latter is the most effective, but the trihydrate gives better smoke suppression properties (Antia, Cullis, and Hirschler, 1982; Hirschler and Tsika, 1983). Tin IV oxides have also been investigated (Donaldson, Donbavand, and Hirschler, 1983). Significant reductions in both flammability and smoke reduction were found in combinations with DBB and with ABS terpolymers. Hirschler (1983) has made combined thermal analyses and LOI studies with both the HDPE and ABS-halogen composition; a number of metal oxides were used. The mechanism of flame retardancy appears to be involved mainly in the solid phase with Al_2O_3 and in the vapor phase with Sb_2O_3. A rather comprehensive review of the role of specific elements in flame retardant mechanisms has been published by Hirschler (1982).

Finally, the effect of a number of relatively unreactive oxides on the smoke suppression of burning polystyrene has been studied. Pyrogenic silica, even in small amounts, is particularly effective. The LOI changes little, and a combination with other fire-retardant systems is necessary. The mechanism is believed to be the formation of a hard, rigid skin on the polymer surface during the burning process. Descriptions of these effects and the proposed mechanism have been published recently (Chalabi and Cullis, 1983; and Chalabi, Cullis, and Hirschler, 1983).

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8/29/83

COMPUTER SCIENCES

FUNCTION POINTS IN SOFTWARE DEVELOPMENT

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.

Over the last decade, software development has superseded hardware development as the most expensive development item for computer companies. In a company like IBM, spending well over $2 billion per year for development, it is easy to see how important it is to be able to measure the productivity of program development units and individuals. It is also important to be able to predict the cost and the time required to develop programming systems.

In mid-1983 IBM established corporate guidelines for using function points to estimate the funding and time needed for software development and to measure programmer productivity.

In the past, most estimates of software development costs and schedules, whether in the private sector or in the US government, have been quite

incorrect, and there have been no good measures of programmer productivity. One standard used extensively is that of lines of code per programmer per unit of time. However, this is far from a perfect measure because it may be possible to perform the same job with widely differing numbers of lines of code. In general, the fewer lines of code used to perform a given function, the better the program.

IBM's use of function points depends on the concept that the external features of the program--i.e., the functions the program is designed to carry out--determine the size of the effort required to create the software. The system can be defined from the point of view of the informed user. From a complete description of the external requirements of the system, including the files it uses, a special technique can numerically score the use of the system. The score can be translated by formula into the amount of effort in terms of man-months, for example, required to create the software.

The function value of a program is a measure of what it does for the user. For example, the program will supply the user with various reports, graphic displays, and interfaces for communication with other systems. It represents a quantification of all the many functions the program is designed to perform for the user.

Within IBM, IBM-United Kingdom is playing a leading role in establishing standards for the use of function points. The concept has been tested in IBM-United Kingdom's programming development operation at Havant, and several instructors have been sent to the US to discuss the concept and their experiences in its testing.

IBM-United Kingdom at Havant has about 190 systems programmers engaged in developing programming systems and in adapting programming systems developed elsewhere. About 30 percent of the application packages are from sources outside the UK and require adaptation for local use; the remaining 70 percent are developed by the group.

Michael F. Parker, Systems Manager, Information and Business Systems of IBM-United Kingdom recently described the program currently under way. The company is trying to answer questions such as:

- Are new development tools and techniques effective?
- What is the long-term impact of these development tools?
- What sort of tool is needed to measure individual programmer productivity?
- How can estimates of cost and manpower requirements be made and validated?

IBM-United Kingdom believes that using function points can help provide answers to these questions.

Productivity Measure

In IBM-United Kingdom, the measure of development productivity on any project is the function points delivered by the project divided by the work hours needed to create the system. Maintenance productivity of an application is the function points of the application divided by the work hours per year needed to maintain the application.

As stated before, function points for a system are designed to quantify the utility of the system from the user's viewpoint. As contrasted with counting lines of code in the system, this approach allows flexibility in the technology used internally and gives consistent credit for the user functions provided by the system. The function point value of an application is calculated by first completing a questionnaire concerning the functions to be performed by the system. The various counts, classifications, and questions of the questionnaire are directly related to what the system is supposed to do--i.e., its external manifestation. Since these quantities can be reliably determined early in the development cycle, they can be useful in estimating the cost and manpower needed to carry out the development of the system.

The function points are evaluated by listing; classifying as simple, average complexity, or above-average complexity; and counting the following items:

1. User external input types
2. User external output types
3. User external inquiries
4. Master files from a user logical view, and
5. Interfaces to other applications.

The function points determined from this counting process are then adjusted by various factors--for example, data communications, distributed processing, and on-line data entry. The number and complexity of these factors is considered. The result is the adjusted number of function points that measure the function value or work product output of an application development or supported by a maintenance group.

The problem of developing a totally new programming system requires a somewhat different weighting of the function

points from that of adapting a system developed elsewhere.

To complete a productivity measurement or analysis, measures are needed to identify the amount of work effort and the types of tasks used to create the system. This information is provided by normal administrative processes.

Use of Productivity Analysis

The productivity measurement system is used:

- To determine the productivity of one project relative to other projects. The less productive projects can be analyzed for practices to be avoided in future projects. The more productive projects provide positive input for planning other projects.
- To support the actions and decisions that improve the output of the site. The number of successful projects can be increased, and the cost may be reduced. The effect of new development tools can be evaluated.
- To determine productivity trends. This shows the results of action taken to improve productivity.

Productivity measurements may assist in estimating the funding and manpower needed for development. General productivity rates now being achieved on projects of a specific type can be used as a check on estimates for new projects. Productivity measurements can be used to highlight optimistic assumptions or cases in which it appears that too much is being spent on providing a particular level of function. When a limited amount can be spent on a particular project, estimates of the required productivity rates can indicate what types of tools should be used. Expected gains (or losses) in productivity also can be built back into the estimating process.

Function points are used in internal design, external design, and delivery of systems. As mentioned earlier, a weighting factor is applied to the raw function counts of external inputs, external outputs, logical master files, interfaces to other systems, and external inquiries. The weighting factor depends on the processing complexity of the function being weighted. In determining whether this weighting factor is simple, average, or complex, 14 factors are considered--for example, use of data communication, use of distributed functions, and required performance. The end products needed from the process for development or installation are function points divided by man-months.

Some of the problems encountered thus far by IBM-United Kingdom are: (1) interpretation of rules for real situations, (2) inconsistency in completing questionnaires and other forms, (3) the need for more education and experience in using the function point technique.

The IBM group at Havant is evaluating the effectiveness of the technique on systems developed in 1981 and 1982, and is making measurements on current production systems. Workshops on the use of function points are being run by UK personnel in the UK and in the US.

9/1/83

IMPERIAL COLLEGE BUILDS MULTIPROCESSOR REDUCTION MACHINE

by J.F. Blackburn.

At Imperial College, London, work is under way to build a graph reduction computing system. According to Dr. John Darlington, it will be used for processing symbolic expressions in optimizing high level language programs. This is one of a number of approaches to designing parallel processors that avoid sequential passing of data and instructions through a single link to a central memory. Another example is the Data Flow Computer at the University of Manchester (*ESN* 36-12:323-25 [1982]).

The performance on conventional computers of functional or applicative language programs has been poor. John Backus, who headed a small group which invented FORTRAN, is now a strong proponent of functional programming. He says it is capable of "combining forms to use high level programs to build still higher level ones in a style not possible in conventional languages." Examples of such programming languages are HOPE (Burstall et al., 1980) and KRC (Turner, 1980). The work at Imperial College is intended to find a computer architecture more amenable to such processing than are conventional computers.

Given the dramatically increased densities that can be achieved for digital circuits and the lower costs of mass production, future computing systems probably will be constructed from standard building blocks. Baron's Transputer, a single chip microcomputer, has been chosen as the basic element in the Imperial College system. The plan is to have large numbers of concurrent activities in the system. In the following section a simple example is

given of parallel reduction in computing factorial n [n! = n(n-1). . . 2·1].

Parallel Reduction of Applicative Languages

Using a first order recursion language (Burstall, 1980), we have the following program consisting of sets of equations definir functions:

```
Factorial:  Integer ——→ Integer
Factorial n = Fact B(1,n)
Fact B:  Integer x Integer ——→ Integer
  Fact B(i,i) = 1
  Fact B(i,i+1) = i+1
  Fact B(i,j) = Fact B(i,mid) x Fact B
                          (mid,j)
Where mid = Integer Divide (i+j,2)
```

In evaluating factorial 5, for example, a conventional system reduces one sub-part at a time. But because of the independence of sub-expressions in applicative language sub-parts can be reduced in parallel, giving the sequence shown in Figure 1.

In Figure 1 the functions appearing in parallel horizontally on the graph are computed in parallel. In computing the factorial of a very large n, this simultaneous computation saves a substantial amount of time.

Modeling Graph Reduction

In the Imperial College system, the graph of an expression is represented by a collection of packets, each of which represents one node of the graph and the arcs extending down from that node, and necessary control information. A packet consists of three primary and three secondary fields (Figure 2). The former contain the information required to represent a node, while the latter contain the control information required for evaluation.

The functions of the three primary fields are as follows:

1. Identifier--contains an identifier unique to the packet and provides a name by which the packet may be referenced.
2. Function--contains the function associated with the node represented by the packet.
3. Argument List--contains the identification of the packets representing the offspring of the node (i.e., the arguments of the function). When the packet is used to represent a numeric value, the argument list field is replaced by the value field that contains the binary representation of the value.

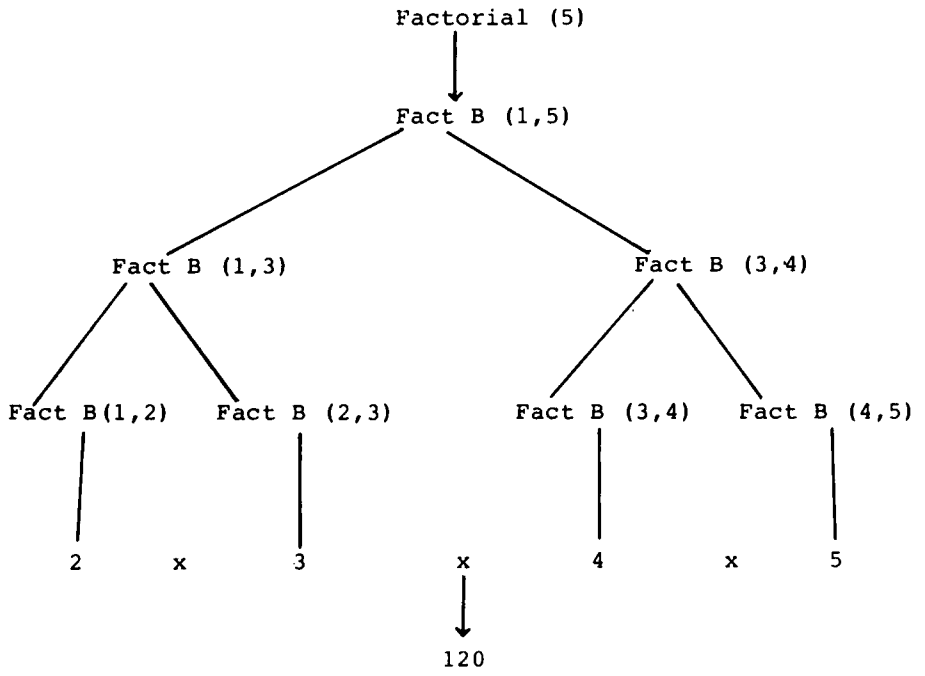

Figure 1. Parallel evaluation.

Primary fields			Secondary fields		
Id	Function	Arg list value	Status	Ref count	Signal list

Figure 2. Primary and secondary fields.

For a node to be reducible, it must be associated with a reducible function--i.e., one for which there are rewrite rules, as in Fact B (i,j) = Fact B (i,mid) × Fact B (mid,j)--and the arguments must match the left-hand side of some equation in the function definition. Sometimes the function field of some argument packet does not contain, at the time it is polled, the required function for continued processing. The situation may be handled in one of two ways: (1) the packet could repeatedly poll the failing argument packets until the required information is there, or (2) the failing argument packets could be made responsible for informing the packet when they reach the correct form.

The second approach has been adopted, and the signal-list field and the pending argument sub-part of the status field are used to implement this mechanism. Once a packet has received signals from all its failing argument packets, it represents a reducible node.

To avoid generating elements of a list without reference to their need, the status field of the packet identified in the argument list of another packet is used to indicate "required" or "not required," depending on whether the function field of the requiring packet is ready with the appropriate function.

Languages Supported

The Imperial College system will be able to accommodate so-called variable free languages--e.g., Turner's combinators (Turner, 1980) or Backus' BP languages (Backus, 1978). There is a fixed set of rewrite rules defining the combinators or the BP operators that are applied to the collection of packets that represent the program source.

The higher order functional languages can be compiled into variable free languages, but they can also be supported directly. The higher order functional languages can pass functions as arguments and return them as values; first order languages cannot. Two events are associated with such functions: (1) definition, where function valued objects are formed, and (2) application, where such objects are applied to appropriate arguments.

Abstract Architecture

The machine, according to Darlington, can be regarded as a pool of packets and a collection of packet-processing agents. Agents do the following:

1. Remove a processible packet from the packet pool. The packet's function field contains a function for which there are rewrite rules (i.e., it is reducible) and its status field indicates that it should not be processed.
2. Decide whether it is reducible--that is, check whether the argument packets contain the required functions for continued processing. If not then,

a. Leave the identifier of this packet in the signal field of each failing argument packet.
b. Mark this packet as being "not-yet-required" pending the appropriate number of wake-up signals.
c. Restore this packet to the packet pool.
d. Go to 1.

3. Determine the appropriate rewrite rule. That is, match this packet and its argument packets, if any, with the left-hand side of some rewrite rule.
4. Generate the packets representing the right-hand side of the rule and deposit them in the packet pool. That is, for each:

a. Acquire an unused identifier. Remember that the packet representing the outermost function on the right-hand side adopts the identifier of this packet.
b. Form the contents of the packet body.
c. Deposit the packet in the packet pool.

5. Go to 1.

Agents could be allowed to specialize in the execution of particular functions--e.g., input/output. In the Imperial College scheme, each agent has a local copy of the function definitions. This requires distributing the associated function definitions before a program

can be evaluated; however, it could be done concurrently with the evaluation.

A simulator (written in Pascal language) has been developed for the abstract machine described here. This simulator permits execution of programs compatible with the HOPE compiler, which has been written for the system.

Implementation Considerations

Two distinct types of access are made to the packet pool. The first is an access directed at a packet with a specific identifier, and the second at an arbitrary member of a particular class of packet. (For example, when an agent requires work, it must find a packet whose function field contains a reducible function and whose status field does not indicate that it should not be processed for some reason.) The machine implementation separates the mechanisms by which these types of access are implemented.

In the physical realization of the abstract architecture, a packet's identifier is equated with a global address in a packet store. A mechanism comparable to the task schedules and storage management system of a conventional machine provides each agent with immediate access to the set of processible packets and the set of unused packet identifiers. Imperial College plans to implement two communication rings with a slot on each of these rings available to each agent. One ring will represent the set of processible packages and the other the set of free locations available for packet store.

Although the locations within the packet store are accessed through a global address, that address is implemented in a distributed fashion by interconnecting a collection of small segments. The planned implementation employs a building block consisting of several processing agents connected to a local memory through a shared base. The local memory represents one segment of the packet store. Building blocks are assembled into larger systems using an interconnection network. This network maps the local memories onto the global address space of the system and shares work and free storage among the building blocks.

To achieve better system performance, the number of concurrent accesses that may be made to each packet must be maximized and the time per access minimized. The implementation planned allows any number of reads to occur concurrently, but writes must have exclusive access to a packet.

Darlington estimates that a desktop-sized system with 20 processing agents will be capable of executing about 150,000 packets processed per second. This is viewed as the system building block for larger systems. He estimates that a system consisting of about 4000 building blocks could execute over 150 million packets processed per second.

A system using Baron's Transputer--a single chip microprocessor with 4000 eight-bit bytes of memory--is being used for the implementation. These transputers are made by INMOS Ltd. of Bristol. A 20-processor system is expected to be operational by the summer of 1985.

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8/24/83

EARTH SCIENCE

EARTHQUAKE PREDICTION

by R.L. Carovillano. Dr. Carovillano is the Liaison Scientist for Space Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until June 1984 from Boston College, where he is Professor of Physics.

Earthquake prediction has become important in geophysics during the last two decades. About 25 papers on earthquake prediction were presented at the August meeting of the International

Union of Geodesy and Geophysics (IUGG), held in Hamburg, Federal Republic of Germany.

Although progress has been substantial, and some impressive successes have been achieved, the methods of earthquake prediction are still evolving. National programs of roughly the same size now exist in Japan, China, the USSR, and the US. Although western Europe is not a high risk area, national networks of earthquake monitoring stations have been established by the French and Germans, and an appeal for an increased monitoring capability in the UK was made at the August meeting of the British Association for the Advancement of Science.

Research activity has resulted in the establishment of the new international journal, *Earthquake Prediction Research*, edited by Prof. T. Rikitake (Nihon University, Japan) and published by D. Reidel Publishing Company (P.O. Box 17, 3300 AA Dordrecht, Holland). The journal is highly interdisciplinary, extending even into areas such as animal behavior and socioeconomic aspects of earthquake prediction.

The importance of prediction capability is clear since more than 500,000 people have been killed by earthquakes in the last 20 years alone. In a recent study based on historical data of seismically active areas, V.I. Keilis-Borok, T.L. Kronrod, and G.M. Molchan (Institute of the Physics of the Earth, Moscow) estimated that about eight large cities, each with a population exceeding 1 million, will experience the tremors of large earthquakes (magnitude M>8) in the next 30 years. Hundreds of thousands died in the large earthquake (magnitude M = 7.8) that took place in Tangshan, China, in 1976. The irony of this tragedy is that the Chinese had been successful in predicting four large earthquakes during 1975-76 on a time scale ranging from long term (several years) to imminent (several hours).

Furthermore, earthquakes often precede volcanic eruptions. In some areas, earthquake monitoring is the primary means by which scientists predict volcanic activity, which often has major effects. The recent eruptions of El Chichón in March and April of 1982 produced the largest atmospheric impact since the eruption of Krakatau 100 years ago. Stratospheric effects included enormous amounts of sulphur and a 25 to 33 percent decrease in the intensity of solar radiation reaching the earth's surface, the largest change ever observed at the Mauna Loa Observatory.

Various methods are used for earthquake prediction, but the guidelines or physical framework to study causes of major geophysical events such as earthquakes, volcanic eruptions, and mountain formation are now well established in terms of plate tectonics (or global geodynamics). A network or chain of stations often measures earthquake precursors, which are geophysical or geochemical in nature. Data analysis, particularly when real-time requirements pertain, is a formidable burden and task. The approach taken to study earthquake prediction varies according to the local geological condition. For example, earthquakes in Alaska are associated with reverse faults in the subduction zone (i.e., there are subsurface overlapping plates), whereas earthquakes along the San Andreas fault are of the strike-slip type. Many of the large earthquakes in China are quite shallow and therefore highly destructive.

Networks to study possible precursors use instrumentation such as seismographs, tide guages, resistivity variometers, gravimeters, magnetometers, tiltmeters, and strainmeters. China and the USSR also monitor the chemical constituents in underground water flows for possible premonitory changes. The usefulness of certain techniques to identify a precursor is controversial, while others have widespread acceptance. The time scale for different precursors varies enormously, from years to hours.

The most widely accepted approach to earthquake predictions is to study data in the context of plate tectonics. Thus data are interpreted and described in terms of features such as seismic moment, stress drop, corner frequency, and moment tensor. It is widely accepted that the boundaries of major plates are the sites of large earthquakes, and that future large earthquakes probably will occur at sites along the boundary between points of past earthquakes (the so-called seismic gap hypothesis). Therefore, strain buildup and release are often monitored. China and Japan have earthquake data spanning more than 2000 years; the information is especially useful in studying earthquake morphology and the repeat time for large earthquakes at the same site. Earthquake history in the Middle East has been compiled by N.N. Abraseys (Imperial College, London). Some of the more modern methods of earthquake monitoring are *in situ* stress measurements with near-real-time data accessibility and space-geodetic methods for monitoring local crustal deformations.

Several patterns of seismic activity have been identified preceding large earthquakes. These include foreshocks, a period of quiescence, precursory swarms of earthquakes, and a doughnut

pattern of earthquake activity. These patterns require a carefully archived data base for identification since the phenomenon often extends over a period of years. Foreshocks follow no simple rules or categorizations, but small shocks often occur before a large earthquake. Quiescent periods have been identified by the Japanese as a gap in seismic activity about 2 years before the main event. Precursory swarms of small earthquakes have occurred on time scales of 2 to 10 years prior to a moderate quake (M≥5) in California. The doughnut pattern of activity was found prior to larger earthquakes in Japan (M≥6).

The use of seismic-activity schemes for prediction is limited because uniform data coverage and classification criteria do not exist. Thus, each report serves more as a case study for a particular earthquake and does not contribute to the identification of general principles that may be applied broadly. This same criticism applies to most other means of studying earthquake prediction.

The USSR has invested significant resources in earthquake prediction. S.K. Negmatullayev, director of the Institute of Earthquake-proof Construction and Seismology and chairman of the regional council for prediction of earthquakes in Central Asia and Kazakhstan, reported recently on the plans to establish an automated system of earthquake prediction (*Daily Snap* [Soviet News Abstracts Publication], 28 June 1983). Negmatullayev stated that the Russians are investigating a new type of ultrasonic precursor phenomenon with short-term prediction capability. The precursor signal intensity is reported to begin 54 to 36 hours before the earthquake, peak at 18 to 12 hours before, and diminish to essentially zero when the earthquake occurs.

The USSR plan in central Asia is an expansion and modernization of their past programs. The observational network in the region will be more dense and cover all seismically active zones. Some sites will have additional geophysical and geochemical monitoring capabilities. Data will be transmitted automatically to a new computer center established in Dushanbe.

So-called electromagnetic or geomagnetic precursors have been reported for many years. Claims here can be aggressive and overly optimistic. An example is the recent public report by A.G. Polov (Institute of Earth Magnetism, USSR) that magnetic surveying at sea led to the discovery of sharp changes in the magnetic field several hours to days before an earthquake (*Daily Snap*, 1 February 1983). Polov also indicated that successful forecasts of earthquakes were made on the basis of the geomagnetic effect.

The scientific reports on geomagnetic variations as an earthquake-prediction parameter have an interesting history. About a decade ago, it was suggested that rather large geomagnetic signatures were related to earthquakes. With the use of more accurate proton-precession magnetometers in recent years, however, the reported geomagnetic variations have generally grown smaller. Proponents have suggested that the geomagnetic precursor effect may depend primarily on the direction of the magnetic field and not on the magnitude, which is measured by the precession magnetometers. More accurate measurements should therefore be made of components of the geomagnetic field to observe the possible rotation of the field as the precursor signal.

Observations of the geomagnetic precursor effect give a wide range of results. Two months before a moderate earthquake (M = 5.2) in California, the local geomagnetic field magnitude increased by 1γ (1γ = 10^{-5} G). The field change was followed by a fault creep and a change in ground tilt (Smith and Johnson, 1976). Slightly larger field magnitude changes (≥5γ) were observed about a month prior to a moderate earthquake in Japan. For large earthquakes (M>7.0), the Chinese have reported larger effects, about 20γ, with changes in both field magnitude and direction.

There are several difficulties with the geomagnetic precursor approach. First, there is the problem of using standardized equipment, site coverage, and data analysis in comparing events. This alone severely inhibits the likelihood of achieving standardized criteria. In addition, the reported signatures are not large and are difficult to distinguish from other possible effects, such as those caused by numerous disturbances in the geospace environment.

Presumably the physical mechanism underlying the geomagnetic precursor effect would be local changes in the electrical conductivity near the surface of the earth. The currents that sustain the geomagnetic field reside deep within the earth, at far greater depths than earthquake effects, and probably would not cause an earthquake. The conductivity change would provide an altered field signature for given earth-current intensities. The mechanism for the process would have to be capable of

producing increases and decreases in electrical conductivity, in accord with the observed characterizations of the so-called geomagnetic precursor effect for different earthquakes.

The search for precursors is widespread and involves a variety of studies beyond those mentioned above. Major conferences are held regularly on the subject, and several books have been published recently that review the field (Asada, 1982; Rikitake, 1982; Simpson and Richards, 1981).

In view of the present state of the field, where accurate predictions are rarely possible, the sociolgical and political aspects of issuing earthquake warnings are particularly fascinating and complex, says D. Blandell (University of London, Chelsea College). Widespread anxiety and panic could easily be generated with premature warnings. In 1978 for example, the mayor of a Mexican city said that public reaction to a successful US earthquake forecast did more damage to the economy than the earthquake itself.

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8/30/83

THE ASSESSMENT OF NATURAL GEOPHYSICAL HAZARDS

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 London Branch Office. He is on leave until September 1984 from the University of Virginia, where he is Professor of Environmental Sciences.

The 17th General Assembly of the International Union of Geodesy and Geophysics (IUGG) was held in Hamburg, Federal Republic of Germany, in August There were 3400 participants, and the program included five union lectures, 21 IUGG Interdisciplinary Symposia, and over 100 Association Symposia. This article focuses only on papers presented at meetings on the assessment of natural geophysical hazards. When a paper is mentioned, I provide its title and the name and address of the author, so that readers can send for further information. The abstracts of papers presented have been published in two volumes available from the IUGG Publications Office, 39ter Rue Gay Lussac, 75005 Paris, France.

The 12 sessions on the assessment of natural geophysical hazards included papers on extreme geophysical events associated with hydrological processes, seismology, volcanology, and tsumanis. A few papers dealt with avalanche dangers, debris slides, ash clouds, and world mapping projects. Based on the papers I heard, my overall appraisal is that no major breakthroughs have occurred in hazard assessment during the past few years, but there has been rather slow progress.

The hydrology sessions were, in my opinion, among the best. There were eight papers on the problem of coupling river-flooding data with high tide and storm surges in estuaries. Several papers were presented by UK engineers and hydrologists on the joint probability problems in the UK, where the tidal ranges commonly range from 8 to 15 m in long, narrow estuaries. When these are coupled with frequent, severe storm surges and river flooding, the results can be catastrophic flooding in densely populated lowland and coastal areas (see *ESN* 37-6:232 [1983]). The method that appears most acceptable is an empirical relationship between the low water level (w) of the site in question and the upstream gauging station ("River Flooding in Tidal Estuaries," M.A. Beran and A.D. Hewson, Institute of Hydrology, Wallingford, Oxfordshire, OX10 8BB, UK). The distribution of the low water levels is then deduced from the upstream record. A distribution is fitted to the tidal peaks, t, as measured at tidal stations. A model is constructed relating high water estuary level, h, to low water level and tidal peaks. A distribution function of the high water estuary levels is then calculated using the convolution equation:

$$\Pr(H \leq h) = \int_0^h \int_0^\infty f\{t(h,w)',w\} \frac{\partial h}{\partial t} \partial w \, \partial h$$

One of the well-received papers was presented by R.A. Bailey and R. Wood ("Developments in Flood Forecasting and Warning in Severn-Trent Water Authority," Severn-Trent Water Authority,

Abelson House, 2297 Coventry Road, Sheldon, Birmingham, B26 3PU). They discussed developments in flood forecasting and warning in the Severn-Trent Water Authority. This was an excellent example of a direct application of state-of-the-art methodology to the problem of flood forecasting and warning. Bailey and his associates are responsible for warning 8 million people of impending floods, both riverine and estuarine. Their forecasts include when, where, and how much flooding will occur. The cost for this service to 8 million people in 20,000 km^2, including 40 cities and towns, is $1.5 million per year; the cost has decreased each year as they have fine tuned their forecast system. The benefits of about $2 million per year are increasing annually as the population grows.

Seismic Hazards

The sessions on seismic hazards included six papers on regional analysis, two on site-specific studies, two on planning, and four on prediction or recurrence probabilities. Again, the papers I heard did not suggest that a major breakthrough in earthquake prediction was imminent (see the article by R.L. Carovillano elsewhere in this issue). But one thing is clear: there is increasing interest in earthquake predictions and almost universal certainty that some of the world's great urban centers are going to be seriously damaged by a major earthquake within the next few decades. The risk is that as many as 40 million people in eight great urban centers will experience a major and devastating earthquake during the next 30 years ("Seismic Risk for the Largest Cities of the World, I VIII," V.I. Keilis-Borok, T.L. Kronrod, and G.M. Molchan, Institute of the Physics of the Earth, Academy of Science, USSR).

However, even with these alarming predictions, only one paper addressed what I would call regional planning for earthquake risks ("Assessment of Mean Periods of Earthquake Recurrences on the Seismic Zoning Map of the USSR," V.I. Bune, Institute of the Physics of the Earth, Academy of Sciences, USSR). There were several papers concerning specific seismic zones and the probability of a major earthquake within those areas, but nothing suggested a ubiquitous methodology or guidelines at this time. One of the most heated discussions dealt with the difference between seismic gaps and seismic pauses, and their significance in forecasting ("Strong-Motion Data for Subduction-Zone Tectonic Settings and Alaska Off-Shore Environments," K.H. Jacob and J. Mori, Lamont-Doherty Geological Observatory of Columbia University, Palisades, NY 10964; also, Department of Geological Science, Columbia University, Palisades, NY 10964). It was agreed that the term "seismic gap" should refer to locations near plate boundaries, and "seismic pauses" should refer to earthquake-prone areas within plates.

Volcanic Eruptions

The state of the art for predicting volcanic eruptions seems to be even less advanced than that for earthquakes. For the most part, the papers dealing with volcanic predictions were based on historical and stratigraphic data used to develop qualitative recurrence analysis. The problem with volcanics is the lack of data, not to mention the seemingly irregular nature of eruptions. However, there are exceptions. Strombolian eruptions occur rather often; the rich data sets assembled in some areas may help make predictions more reliable ("Risk Statistics of Strombolian Eruptions at Erebus and Stromboli," R.R. Dibble, Victoria University of Wellington, New Zealand).

A paper on hazards on volcanic islands was very effective in pointing out that pyroclastic eruptions, among the most dangerous of all on volcanic islands, may not leave an obvious record in the stratigraphic section, and thus may be overlooked as part of the historial record ("Volcanic Hazard on Island Volcanoes," Geroge P.L. Walker, Hawaii Institute of Geophysics, 2525 Correa Rd., Honolulu, HI 96822; and Stephen Self, Department of Geology, University of Texas at Arlington, Arlington, Texas 76019).

Two contributions by US Geological Survey (USGS) and Arizona State University investigators summarized the deformation in Long Valley Caldera California. The researchers assessed potential events, ranging from a small phreatic eruption to a cataclysmic explosion over hundreds of square kilometers ("Volcanic Hazards Implications of Recent Seismicity, Deformation, and Hydrothermal Activity, Long Valley Caldera, California, U.S.A.," C. Dan Miller, USGS, MS 903, Federal Center, Denver, CO 80255; and C.G. Newhall, USGS, Vancouver, WA 98661. "Computer-Assisted Maps for Explosive Eruptions: Long Valley Caldera, California," Michael F. Sheridan and Michael C. Malin, Department of Geology, Arizona State University, Tempe, AZ 85287).

Tsunamis

The research papers on tsunamis included six dealing with propagation

and attenuation, two on seiches, one on mitigation, three on coastal defense, and three on warning systems. From these papers, it seems clear that with existing technology and understanding of tsumani propagation and attenuation, a worldwide warning system is possible. However, there are social and political problems with any warning system. A paper by a group of Russian geophysicists pointed out that their tusmani-warning system resulted in two to three false alerts for each true hazard ("Threshold Earthquake Magnitudes for Issuing Tsunami Alert at the Pacific Coast of the USSR," C.N. Go, A.I. Ivanshchenko, K.I. Nepop, S.L. Soloviev, Sakhalin Complex Scientific Research Institute, Far East Science Centre, Academy of Sciences, Sakhalin Administration for Hydrometeorology and Environment Control, State Committee for Hydrometeorology, Institute of Oceanology, Academy of Sciences, USSR). Their solution was quite simple. They increased the magnitude of the threshold event that triggers the warning system.

Finally, one theoretical study suggested that edge waves along bounded oceans may have important bearing on the distribution of tsunami impact ("An Extension Of Ball's Edge Wave Solution to Convèx Upward Topographies," R.P. Shaw, Department of Civil Engineering, State University of New York at Buffalo, Buffalo, NY 14260, and D. Paskausky, US Coast Guard Research and Development Center and Marine Sciences Institute, University of Connecticut, Groton, CT 06340).

Ash Clouds and Fault Zones

Volcanic eruptions of the magnitude of Mount St. Helens, for example, can produce an ash cloud large enough to cause engine failures on jets flying in the area; this effect can last for hours. Harmful gases remain in the upper atmosphere much longer ("The Hazards of Ash Clouds to Civil Air Transport," M. Reddan, IATA/Air France, B.P. 10201, 95703 Roissy Charles de Gaulle Cedex, France). Airborne radars are unable to register echoes from ash clouds, and ground-based surveillance is not always dependable. Infrared satellite imagery appears to give the best results.

My favorite paper was presented by a group of French and Russian geophysicists, who described two approaches to delineate an earthquake-prone area in the Western Alps (A. Cisternos, Institut de Physique du Globe [Paris], et al.). The Russian team used traditional morphostructural analysis of lineaments. A collaborating team of French geophysicists investigated the same region independently using neotectonic knowledge of the active faulting within the region and data on deep structure. The Russians analyzed their data with factor analysis, and the French applied a form of characteristic analysis that the USGS has used to locate economic minerals. The approaches, although quite different, resulted in remarkably similar conclusions concerning potentially dangerous fault zones.

9/2/83

MATERIAL SCIENCES

FIBER COMPOSITE MATERIALS IN THE UK: ROLLS-ROYCE LIMITED AND QUEEN MARY COLLEGE

by Tsu-Wei Chou. Dr. Chou is Professor of Mechanical Engineering at the University of Delaware.

This is the seventh in a series of articles reporting research on fiber composite materials in the UK. Research at Rolls Royce and Queen Mary College is featured this month.

Rolls-Royce Limited

According to Dr. J.W. Johnson of the Non-Metallics Laboratories in Derby, composite materials research and development were extremely active at Rolls-Royce during the sixties. The company did much pioneering work in silicon and carbon fiber, and in composites based on metal and resin materials. Carbon composites were applied to jet engine fan blades (see *ESN* 22-9:237-39 [1968]). However, the failure of the composites to resist impact loading resulted in a major setback to the R&D effort at Rolls-Royce; there was considerably less research on composite materials during the early and mid-seventies. In retrospect, it is clear that the technology then was not mature enough for such applications.

Recently, the composite material R&D at Rolls-Royce has progressed more steadily. There are now 28 people involved in R&D and 100 in production. Soon there will be further expansion of activities in composites. There is strong interest in the use of high-strain carbon fibers; the evaluation of polyetheretherketone (PEEK)-based fiber composites; application of the aligned

short-fiber composites developed by the UK's Propellants, Explosives, and Rocket Motor Establishment (PERME); and compression molding of composite components. Most of the work has focused on jet engines. It is thus natural to expect that when the workers start to examine the hot part of the engine, metal matrix composites will be seriously considered.

Queen Mary College

Composite materials research at Queen Mary College, University of London (London E1 4NS), are conducted in the Department of Materials. (See *ESN* 33-2:41-44 [1979] for Willard D. Bascom's discussion of work on polymers and surfaces at Queen Mary College.) Prof. W. Bonfield, the Head of the Department, has been doing research on metal matrix composites for many years. The *Journal of Material Science*, which is edited by Bonfield, has given increasing emphasis to fiber composites based on polymer and metal matrices. The department has nine academic staff, 12 research associates and post-doctorates, and 20 research students.

A major emphasis of Bonfield's research is on composites of carbon fiber and metal matrix. The stress-rupture characteristics of individual carbon fibers coated with tin, aluminum, copper, silicon, or various aluminum alloys have been measured under vacuum, at temperatures up to 650°C. Experimental "microcomposites" have also been prepared by a hot pressing procedure in a controlled atmosphere. The overall objective of the research program is to produce an "optimized" carbon fiber-metal matrix composite suitable for application at 200 to 500°C. This article highlights findings in the study of aluminum- and copper-coated carbon fibers.

Vacuum evaporation techniques have been used to coat type II, polyacrylonitrile (PAN)-based carbon fibers with either 180-μ films of aluminum or 90-μ films of copper, and with various duplex coatings of copper and aluminum. On individual coated fibers, Bonfield performed room temperature tensile tests after heat treatments (at 450 to 625°C, for 100 hours) in vacuum ($<10^{-5}$ Torr), and stress rupture tests in vacuum at similar temperatures.

Aluminum-coated fibers showed a reduction in their ultimate tensile strength (UTS) at room temperature after heat treatment at temperatures above 450°C, an effect attributed to aluminum carbide formation. A reduction in the room temperature UTS of copper-coated fibers after heat treatment at 625°C was associated with fiber-surface pitting arising from localized oxidation. The UTS of duplex-coated fibers progressively decreased as the heat treatment temperature was increased above 450°C. Again, a pitting mechanism is suggested, possibly connected with whisker-like growths.

Uncoated fibers remained intact after 500 hours at 625°C under stress levels up to 89 percent, and on cooling to room temperature. Aluminum-coated fibers remained intact after testing under stress levels up to 80.5 percent at 400°C for 100 hours. At temperatures above 450°C, aluminum-coated fibers fractured both at constant temperature and on cooling, an effect associated with aluminum carbide formation. If copper-coated fibers survived the initial, thermally induced stresses during the heating up, they generally remained intact after 100 hours at either 550°C or 625°C under stress levels up to 75 percent, and on cooling. A thin (2-μm) copper interlayer did not protect the fibers against attack by aluminum at 550°C. However, thicker copper films (90 μm) provided limited protection to fibers under stress levels up to about 70 percent at temperatures above 450°C, although some strength degradation was still observed.

In the case of aluminum-alloy coatings, high tensile strength carbon fibers have been coated with 46 nm of Al 6 weight percent Sn or Al 15 weight percent Sn, and heat-treated in vacuum temperatures from room temperature to 650°C. The mechanical properties of the coated fibers were unaffected by the coatings and subsequent heat treatments at temperatures below 250°C. The UTS of Al 6 weight percent Sn alloy-coated fibers increased with an increase in heat treatment temperatures above 275°C, with a maximum (+17 percent) in the UTS after heat treatment at 300°C. The UTSs of Al 6 percent Sn and Al 15 percent Sn coated fibers heat-treated at temperatures of 275°C to 550°C were generally higher than those for uncoated fibers heat treated in the same temperature range. This effect was related to enhanced wetability of the alloy coatings. Some preliminary assessments of the effect of heat treatments on tin- or silicon-coated high modulus (HMS) fibers also have been performed.

Also in the Materials Department, Dr. R.J. Young has been studying the morphologies and defect structures of extended-chain polydiacetylene (PDA) crystals. PDAs may be prepared as macroscopic single crystals by the solid state polymerization of diacetylene

monomer crystals. The polymer backbone has the structure

$$\left[\begin{matrix}R\\ |\\ C\end{matrix}-C\equiv C-\begin{matrix}C\\ |\\ R\end{matrix}\right]_n$$

where the sidegroup R may be any one of many chemical groups. By selecting appropriate solvents, Young and coworkers have demonstrated that a number of diacetylene monomers can be prepared as needle-like single crystals up to 50-mm long and with diameters of 10 to 100 μm. The resulting monocrystalline polymer fibers have the molecules completely extended and aligned parallel to the fibers' axis.

Young has also studied the mechanical properties of partly and fully polymerized single crystal fibers of a substituted PDA. In particular, the Young's moduli, fracture stresses, and creep properties have been measured. The Young's modulus increased with conversion from monomer to polymer up to a maximum value of 62 GPa. The fracture stress varied with both the degree of conversion and fiber diameter. Strengths of up to 1.4. GPa have been determined for fully polymerized, 20-μm-diameter fibers. Young has not detected any creep or time-dependent deformation for the fibers. The variation of the mechanical behavior with conversion from monomer to polymer has been explained in terms of the Voigt and Reuss models and related to the structure of the crystals. The presence of defects on the surface of the crystals can account for the dependence of the fracture stress on fiber diameter.

Galiotis and Young's studies of the mechanical strength and deformation properties of PDA fibers have suggested that the fibers might have applications in composites. A useful composite can only be formed, however, if a strong bond is made between the PDA fiber and the matrix. This is the aim of a recent research program led by Young. Resonance Raman (RR) spectroscopy was used to determine the frequencies of the vibrational modes of the PDA backbone and the dependence of those frequencies on tensile strain. The knowledge of the strain dependence of the vibrational modes makes RR spectroscopy a potentially valuable technique for the study of PDA fiber composites in situations where the matrix is reasonably transparent. The resonant enhancement is so strong that RR spectra may be taken of PDA fibers covered by several millimeters of matrix.

For such a composite, then, one can determine the strain in the fiber at any point along its length simply by measuring the vibrational frequencies. Thus the PDA fiber acts as its own internal strain gauge. Young has investigated the properties of the PDA/epoxy resin bond by subjecting PDA fibers joined by an epoxy resin lap joint to tensile stress (Galiotis and Young, "Solid State" and "Resonance"). Potentially, this technique could be used to examine a number of interesting problems involving the interactions among fibers, as well as interactions between fiber and defects in a model composite.

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9/2/83

Ni_3Mo IN Ni-Al-Mo SUPERALLOY MATERIALS

by R.W. Armstrong. Dr. Armstrong is the Liaison Scientist for Materials 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.

Prof. M.H. Loretto (Department of Physical Metallurgy and Science of Materials, University of Birmingham, Edgbaston B15 2TT, UK) heads up a first-class electron microscope facility. There is a 1 million volt (high voltage) electron microscope, a scanning transmission electron microscope (STEM), and analytical electron microscope equipment. With M.J. Kaufman, J.A. Eades, and H.L. Fraser (University of Illinois, Materials Research Laboratory, Center for Microanalysis of Materials), Loretto has obtained convergent beam (electron) diffraction (CBD) and energy dispersive (x-ray) spectroscopy (EDS) results on the presence and nature of Ni_3Mo in Ni-12Al-15Mo and the ternary eutectic Ni-12.8-22.2 Mo (atomic percent) superalloy materials (Kaufman et al., 1983). The CBD and EDS techniques

Figure 1. Multiple diffracted beams with wide angle electrons.

Figure 2. Symmetry pattern within a single diffracted beam.

were applied to determining the structure and composition, respectively, of the orthorhombic Ni_3Mo phase.

The presence of stacking faults and antiphase boundaries within the Ni_3Mo phase in the ternary alloys obscured the diffraction symmetry of the Pmmm space group for the orthorhombic structure. Consequently, relatively fault-free stoichiometric Ni_3Mo material was specially prepared for CBD analysis. The CBD patterns for the reference material were used in the interpretation of patterns obtained on the ternary alloys. Two CBD patterns are shown at low and high magnification in Figures 1 and 2. Raghavan, Koo, and Petkovic-Luton [1983] have described how such patterns are obtained with a Philips EM400T TEM, the instrument used to produce the figures. The symmetry properties of the fine line structures within the CBD images are used to identify the point and space groups for the crystal structure-type.

The orthorhombic Ni_3Mo occurs as part of the cellular phase transformation product at grain boundaries in the ternary eutectic alloy aged at 760°C. After prolonged aging of the superalloy, selected area diffraction analysis was used in combination with phase identification by CBD and EDS to specify the following orientation relationship for the precipitating Ni_3Mo phase and either the γ' or γ face-centered cubic (fcc) matrix alloy:

$$(010)_{Ni_3Mo} \parallel (\bar{1}11)_{fcc} \text{ ; and,}$$

$$[100]_{Ni_3Mo} \parallel [110]_{fcc}$$

The current results relate to the development of advanced alloys for gas turbine components. (see *ESN* 37-1:21-24 [1983] and 37-7:266-271 [1983]). With US Naval Air Systems Command support, F.D. Lemkey and colleagues at United Technologies Research Center (East Hartford, CT 06108) have pioneered work on unidirectionally solidified alloys composed of α-Mo fibers within the fcc matrix material. More complicated structures involving several reported Ni_3Mo phases have resulted from other work on rapid solidification processing. The occurrence of Ni_3Mo by means of a cellular phase transformation has been associated with a loss in ductility. Unambiguous identification of the orthorhombic structure-type should contribute to an eventual understanding of the ternary superalloy properties.

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9/2/83

THERMOMECHANICAL PROPERTIES OF EXPLOSIVE MATERIALS

by R.W. Armstrong.

The thermomechanical properties of energetic (explosive) materials used in propellant or weapons systems were the subject of a recent UK symposium at the Royal Armament Research and Development Establishment (RARDE), Fort Halstead, Sevenoaks, UK. The meeting was chaired by J. Connor (RARDE). J. Perkins reported on materials research activities at RARDE in *ESN* 33-1:6-8 [1979].

The purpose of the symposium was twofold: to promote communication among persons having diverse experience with the chemical, physical, mathematical modeling, or engineering properties of explosive materials, and to provide information to persons potentially interested in characterizing and testing the performance of such complex materials. The meeting was attended by about 75 persons from a number of UK universities and Ministry of Defence agencies.

After a welcoming address by P.J. Deas (RARDE), Connor spoke about the concern for safety; energetic materials are hazardous from their initial manufacture or formulation, through storage and subsequent operations, until either being ignited as propellants or being fired in weapons systems. The concepts of sensitiveness and explosiveness were described for secondary explosives--those whose chemical decomposition is initiated by other primary agents (Connor, 1982). Sensitiveness refers to the capacity of an explosive for being initiated, and explosiveness refers to the consequent output or extent of response of the system. High safety and high performance are desired. The sensitiveness of energetic materials has been assessed in various tests for powders and charges. The RARDE Small Burning Tube Test for assessing relative explosiveness was described; about 350 g of explosive is ignited within a confined mild steel tube of 6-mm wall thickness, and the time for rupture of the tube, number of tube fragments, and fraction of consumed explosive are measured. Sensitiveness is measured in a number of impact tests involving measured drop heights for the start of reaction.

Considerable military developments have occurred since the historical manufacturing of gunpowder (Gray, Marsh, and McLaren, 1982). Many explosive and propellant mixtures are of current interest, including plastic bonded explosives containing RDX (cyclotrimethylenetrinitramine, $C_3H_6N_6O_6$) and HMX (cyclotetramethylenetetranitramine, $C_4H_8N_8O_8$) materials. Boggs (1982) has given a comprehensive survey of the thermal behavior of these materials. Elban, Armstrong, and Hoffsommer (1983) have reported on the crystal morphologies and microhardness properties of RDX explosive crystals grown from solution in acetone. Palmer and Field (1982) have described the twinning and cleavage properties of monoclinic HMX crystals grown by the same procedure. Derr (1982b) has reported on the production of RDX and HMX materials in the Explosives Division of Dyno Industries, near Oslo, Norway. In *ESN* 36-9:199-201 (1982), he described the Thirteenth Annual Conference of the Fraunhofer Institute for Propellants and Explosives, entitled "Use of Plastic Materials for Propellants and Explosives." In *ESN* 36-9:206-8 (1982), V.T. Stannett reported basic polymer chemistry research activities at the Propellants, Explosives, and Rocket Motor Establishment, Waltham Abbey, PERME(WA), Essex, UK.

K.N. Bascombe, PERME(WA), spoke about brittleness frangibility effects in rocket motor vulnerability studies. Ballistic penetration tests have been done on large tubular housings containing high performance extruded double-base (EDB) propellants; the results have ranged from simple penetration to tube bursting and extreme fragmentation. The temperature dependence of the system response has been studied because an increasingly violent response seems to be measured for lower test temperatures of the contained propellants. The temperature and strain rate sensitivities of the mechanical or rheological properties of propellant systems are being studied.

A.J. Kinloch, PERME(WA), reported on the fracture mechanics testing of crack propagation in propellant materials. Kinloch and R.J. Young (Department of Materials, Queen Mary College, London) are co-authors of "Fracture Behavior of Polymers" (1983), which emphasizes the use of fracture mechanics. A rubbery polymer propellant, such as hydroxy-terminated polybutadiene (see *ESN* 36-9:206-8 [1982]), may show values of stress intensity for crack growth, K, between, say, 4 and 10 $MPa \cdot m^{\frac{1}{2}}$. This compares with 40 $MPa \cdot m^{\frac{1}{2}}$ for aluminum.

Values of K between 0.26 and 2.2 MPa·$m^{\frac{1}{2}}$ have been measured for an EDB propellant composed of nitrocellulose (53 percent), nitroglycerine (42.2 percent), dibutylphthalate plasticizer (2.8 percent), plus stabilizers and ballistic modifiers (Kinloch and Gledhill, 1981). The viscoelastic properties of the material gave temperature-dependent and strain-rate-dependent stress intensities, particularly, for testing in plane stress.

Tod and Kinloch (1983) have reported more recently on the fracture and cyclic fatigue behavior of rubbery composite propellants. There is concern about the growth of small cracks in propellant systems and about the importance of crack branching at measured crack velocities approaching 1000 m/s. Measurements are obtained at different velocities so as to extrapolate the results to the highest velocities conceivable. In a related study, Dick (1982) reported on the plane shock initiation sensitivity of pentaerythritol tetranitrate (PETN) crystals also subjected to γ-irradiation.

R. Bird reported on a joint effort with C.E. Whatmore (Atomic Weapons Research Establishment [AWRE], Aldermaston, Reading) on the influence of materials properties on hazard response. High power, low hazard response was sought for material containing as much as 95 percent HMX. Manufacturing of the material included powder molding of different particle sizes and isostatic pressing, as well as charge machining, handling, and assembly. The charge sensitiveness was measured by the oblique impact test, modeled after an accidental drop during handling. As expected, the impact sensitiveness appeared to correlate better with the dynamic--as compared with static--strength properties of the charge material. The drop-height sensitiveness decreased as the dynamic strength increased. The explosiveness of the charges was measured in a "Susan" high velocity impact test of the confined charge. A strong particle-size effect was observed at low strike velocities: 40 percent colloid-milled material within the charge gave a strong blast effect, while charges composed of 91 percent particles of (smaller) micron sizes gave a weak blast. However, at high strike velocities the results became similar, giving a gradually increasing blast with increasing strike velocity--although not achieving the same high blast effect as for the lowest strike velocities on colloid-milled material. The material strength, particle size, and sensitiveness were shown to be interrelated. Future work was proposed to involve higher material strain rates, detailed examination of microstructures, and models of the fracturing processes.

A.S. Dyer (RARDE) measured the explosiveness of triaminotrinitrobenzine (TATB) in the oblique impact test, which includes the effect of frictional heat generated from sliding on impact. The angle of impact was found to be very important, even extending up to 76 degrees of being normal to the impact surface. Other factors were investigated, such as roughness of the target surface and the temperature of testing. The results are to be applied to the design of munitions and handling of bare or lightly encased charges. A thermal (Arrhenius) model is being developed to describe the temperature dependence of the sensitiveness results. A high ratio of dynamic to static strength correlates with the sensitiveness measurements. Impact tests are to be done with hemispheres and analyzed according to the Hertzian contact theory. Sharma, Hoffsommer, Glover, Coffey, Santiago, Stolovy, and Yasuda (1983) have reported effects of impact, ultraviolet, heat, and electron beams on molecular fragmentation of TATB material.

H.R. James (AWRE, Foulness) described his work on extensions and limitations of hydrocodes based on the Walker-Wasley criterion for shock effects produced by flying metal plate impacting of bare heterogeneous explosives. The criterion of a critical shock energy per unit area being required for detonation has been extended to the case of slender rod impacts. However, the total analysis is limited by being essentially independent of microstructural considerations and consequently must be applied with care. An equivalent criterion for cased charges needs to be determined.

M.M. Chaudhri (Cavendish Laboratory, University of Cambridge) discussed estimating the mechanical hazards of solid explosives based on the extensive work done by the Physics and Chemistry of Solids group at Cambridge (see "Breaking Molecules in Solid Explosives," *ESN* 37-7:290-1 [1983]). The plastic flow of individual grains, homogeneous adiabatic deformation, and friction between particles are topics being investigated. J.E. Field, heading the Cambridge group, pointed out that the various mechanisms of mechanical initiation need not all show the same sensitiveness dependences, and that better testing procedures were needed

for studies of the shear deformation of explosive materials. He emphasized the importance of making real-time photographic observations of explosive events. He spoke of the complementary work which could often be done jointly by university and government researchers. The universities, though limited to experiments with small quantities of explosives, could make detailed studies of basic phenomena. Government laboratories had facilities for the safe handling of kilogram quantities of explosives, but were more involved with development, testing, and solving immediate practical problems. Regular contact between universities and government laboratories was mutually beneficial.

Other discussions were by B.D. Goldthorpe and P. Lee (RARDE) on the usefulness of a fracture mechanics approach to characterize mechanically induced initiation events; by James on the incorporation of chemical energy considerations into a shock criterion such as Walker-Wasley; by Connor on the use of computer modeling of real lattice processes involved especially in proposed mechanical initiation processes--because of the very practical consideration of the appreciable cost of testing new molecular systems at PERME; and by D. Hull (University of Liverpool), Field, Kinloch, and Bird on the pros and cons of studying analog material systems for propellant and explosive material properties. C.W. Dickinson (Energetic Materials Division, US Naval Surface Weapons Center, White Oak Laboratory, Silver Spring, MD 20910) spoke briefly about US propellant and weapons systems activities. Derr (1982a) has pointed out that several groups in NATO are actively involved in cooperative studies relating to detonation hazards with solid propellant rocket motors and weapons systems. Deas and Lee said that many years of work will be required for understanding the subject in the depth desired and that the current meeting and discussion seemed to be a constructive step toward developing a coordinated research effort.

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9/1/83

MATHEMATICS

NUMERICAL COMPUTATION CONFERENCE HONORS PETER HENRICI

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.

Several new computational procedures were presented at a conference in Zürich celebrating the 60th birthday of Switzerland's Peter Henrici, one of the leading figures in computational mathematics throughout the past 25 years. Speakers also described new theoretical results in this area, reflecting Henrici's role as a lucid analyst as well as an inventor of methods.

Some 150 people attended the Symposium on Numerical Analysis and Computational Complex Analysis held from 15 through 17 August 1983 at the Swiss Federal Institute of Technology (ETH-Zentrum). There were six invited 1-hour addresses and about 75 contributed 20-minute papers. Generally the papers concentrated on areas of Henrici's own interest: complex analysis, differential equations, linear algebra, and approximation theory. Since no proceedings of the conference will be published, this article presents abstracts of five talks of special interest; readers should contact the speakers for further information.

"A Fast Direct Method for Solving Poisson's Equation on General Two-dimensional Regions," by Dr. W. Liniger, IBM Research Center, Box 218, Yorktown Heights, NY 10598. A direct (noniterative) second-order finite difference method was proposed for solving Poisson's equation on general two-dimensional regions. This algorithm, a variant of the marching method, is fast, requires a small amount of storage, and is much more stable with respect to the accumulation of round-off errors than the conventional marching method. Consequently, it can be applied on grids with a large number of grid points (and thus marching steps) without resorting to multiple shooting. The algorithm was tested successfully on regions with complicated geometries, including multiply connected ones.

"Computational Complexity of Some Problems of Numerical Algebra," by Dr. V. Strassen, Institut für Angewandte Mathematik, Universität Zürich, Rämistrasse 74, CH-8001 Zürich, Switzerland. The "simple" problem of determining and evaluating at x the polynomial P of degree n interpolating given values $y_o, \ldots, y_n$ at distinct given points $x_o, \ldots, x_n$--so that $P(x_i)=y_i$ for all i--was discussed as an illustration of the interaction of numerical analysis and computational complexity. The minimal computational effort to determine and evaluate P was shown to grow like $n \cdot \log_2 n$, and procedures were described to attain this growth. The problem for numerical analysts is to find numerically stable procedures which exhibit this behavior.

"Numerical Solution of Non-linear Diffusion Equations in a Moving-Boundary Domain: Application to the Microelectronic Technology," by Dr. Y. Depeursinge, Lab. Suisse de Recherches - Horlogères, Rue Bréguet 2, CH-2000 Neuchâtel, Switzerland. The phenomenon on which the integrated circuits technology is based is the coupled diffusion of several implanted impurities in silicone substrate under oxidizing conditions. The simulation of this process involves solving a set of nonlinear second order parabolic equations in a moving-boundary domain. The numerical solution of this transient problem is obtained by the finite element approach. The time discretization is treated by the third order Gear scheme, and the nonlinearity by a fixed point algorithm coupled to an iterative method for solving the system. The displacement of the boundary of the domain is governed by an oxide-growing law. The results obtained agree well with experimental measurements on test wafers.

"IMPACT--Interactive Mathematical Program for Automatic Control Theory," by M. Rimvall, Institut für Automatik und Industrielle Elektronik, ETH-Zentrum, CH-8092 Zürich, Switzerland. The software package IMPACT is described; it is a new system implementing special data structures and operations to formulate and solve problems in automatic control. IMPACT is intended for use in computer-aided control-system design: the use of the computer as a tool in designing and testing automatic control devices for real systems.

"A Jacobi-like Method for Computing the Schur Decomposition of a Matrix," by Dr. G.W. Stewart, Computer Science Department, University of Maryland, College Park, MD 20742. The Schur decomposition $A = Q^*RQ$ of an $n \times n$ matrix A displays the eigenvalues of A on the diagonal of the upper-triangular matrix R; an iterative method based on the Jacobi method (for symmetric matrices A) is described and shown to have good

local convergence properties. Moreover, it is shown how the n^3 operations required in a full pass of the method can be implemented on n^2 parallel processors in only n steps per processor, thus raising the possibility that the method will be more efficient than the QR-algorithm on such a system. (This is a preliminary report of work just recently begun.)

8/19/83

OCEAN SCIENCES

MARINE SCIENCE IN ICELAND

by F.A. Richards. Dr. Richards, formerly Chief Scientist at ONRL, is Professor of Chemical Oceanography at the University of Washington.

Some 85 percent of Iceland's foreign exchange arises from fisheries, so it is not surprising that the Icelandic Research Fleet is operated by the Marine Research Institute, which is an agency of the Ministry of Fisheries. (Unlike the comparable agency in the UK, the ministry does not include agriculture, emphasizing the importance of fisheries to Iceland.)

Institute Divisions

The Marine Research Institute has divisions of physical and chemical oceanography, marine geology, phytoplankton and primary productivity, zooplankton and benthic organisms other than fish, pelagic fish, benthic fish, flatfish, and fishing gear; there is also a computer department.

Much of the institute's function is in basic science, although the ultimate purpose is to improve and control the fishery. The staff comprises some 70 professional and technical people, including approximately 30 scientists at the PhD or equivalent level.

Physical oceanographic studies are under the leadership of Svend-Aage Malmberg, who has a staff of four to six. Although most of the work in physical oceanography consists of routine surveys designed to follow changing oceanographic conditions, the group is also concerned with measurements of overflow over ridges, short-term oceanographic changes along the south coast of Iceland, and studies of fjord circulation. The studies extend to the waters east and south of Greenland, to Jan Mayen, the Irminger Sea, and south to the Faroe Islands.

The chemical oceanography group is led by Jon Olafsson, who took his DSc under Prof. J.P. Riley of the University of Liverpool. Olafsson is primarily interested in trace metals, especially mercury and manganese. He has developed improved analytical techniques for both elements. For the Interventional Council for the Exploration of the Sea (ICES) and the Intergovernmental Oceanographic Commission (IOC), Olafsson recently headed an intercalibration study of the methods for estimating mercury. Olafsson's objective is to use trace metal distributions in pollution studies and to trace the effects of submarine volcanic activity. The chemical oceanography group also makes routine observations of the standard chemical variables: dissolved oxygen and nutrients, as well as DDT, polychlorinated biphenyls, and tarballs.

The marine geology group is headed by Dr. K. Thors, who has a staff of three. They are using side-scanning sonar to chart the upper layers of the sediments. They are particularly interested in the distribution of carbonate sediments, which are of considerable commercial interest. Iceland has no limestone deposits, and deposits of seashells on the sea floor are mined, by pumping, to supply the calcium carbonate required for cement manufacture. The building of a plant for sea salt recovery, using geothermal energy, is also under consideration. But for such a plant to be economical, it would probably also need to produce magnesium, which would in turn require a cheap source of calcium carbonate. The geological question is whether or not the deposits around Iceland are extensive enough to support such industries.

The productivity group (three permanent staff plus two or three technical assistants) is led by Dr. Thorunn Thordarsdottir, who was a student of Prof. Trygve Braarud of the University of Oslo. Much of the work of the group is academic, with taxonomic studies designed to determine the main phytoplankton species of the area. One aim is to map the distribution of annual primary productivity around Iceland. The observations include natural fluorescence and water transparency and the measurement of cyclic changes at a single point from an anchored ship.

The zooplankton and benthic animals group has some 10 professionals plus staff and is led by Dr. I. Hallgrimsson. The research is basic in that it concerns the identification of the main

zooplankton species and their basic biology and ecology, but the group is mainly interested in the role of the zooplankton as food for benthic organisms of commercial importance. The main species are shrimp (smaller animals in the bays and shallow waters, larger species in deeper waters), scallops, the horse mussel, and the so-called Icelandic lobster (*Nephrops norvegicus*).

Most of the other groups at the institute are concerned with traditional commercial fisheries research, including fishery biology and the acoustic estimation of stock sizes, which can now be done with a high degree of accuracy. The biology and ecology of herring and capelin are receiving particular attention from Dr. Jakob Jakobsson, the deputy director of the institute, and Dr. Hjalmar Velhjálnisson. Gear technology is being studied by Dr. G. Thorsteinsson.

Dr. Unnsteinn Stefánsson was on the staff of the Marine Research Institute but is now a full-time member of the chemistry department of the university. Although he is an authority on the physical and chemical oceanography of the waters around Iceland, his current research is on the very unusual chemistry of Icelandic lakes and embayments. Stefánsson is also responsible for the formal teaching of oceanography at the university, where two semesters of general oceanography are offered in cooperation with other specialists. The courses cover physical, chemical, geological, and biological oceanography, as well as marine pollution and the uses of the ocean. The biology department offers a course in marine ecology that includes units on marine plants, icthyology, invertebrate zoology, and embryology. In addition, the university offers a lecture series on the environment that is required of all civil engineering students and is elective for students in marine ecology. There are two 2-hour lectures a week by various experts.

Research Vessels

The Marine Research Institute operates four major research vessels:

1. *Bjarni Saemundsson*. Scientific party, 11. Tonnage, 777. Length, 55.9 m; width, 10.6 m; depth, 6.01 m. Speed, 11 kn. Crew, 15. Built 1970. Action radius, 4000 nautical miles. Special laboratories for physical, chemical and biological studies. Equipped with standard Technicon AutoAnalyzer®, acoustic assessment measurement devices, primary productivity laboratory, and experimental fishing gear. Her mission is mainly basic but includes applied fishery research.

2. *Arni Fridriksson*. Scientific party, seven. Tonnage, 449. Length, 40.42 m; width, 9.8 m; depth, 4.30 m. Speed, 11 kn. Crew, 12. Action radius, 3000 nautical miles. Built 1967. Special equipment: well equipped for acoustic evaluation of fish stock sizes. Includes equipment for routine physical, chemical, and biological investigations. Although her mission is primarily applied, some basic science is carried out.

3. *Hafthor*. Tonnage, 793. Length, 60.4 m; width, 11.32 m; depth, 6.21 m. Speed, 14 kn. Crew, 18; eight scientists. Action radius, 4000 nautical miles. Built in 1974, converted to research in 1979. Equipped for routine hydrographic and fisheries research.

4. *Dröfn*. Tonnage, 75. Speed, 9 kn. Length, 26.2 m; depth, 2.35 m; width, 5.80 m. Action radius, 800 nautical miles. Crew of five, space for three scientists. Built in 1961, converted in 1973. The ship is used principally for inshore biological work and limited hydrography.

Given Iceland's support of research facilities and programs, it is evident that the country understands the importance of a scientific basis for the management of its fisheries. The Marine Research Institute is responsible for advising the government on matters of fisheries management and conservation. The research methods are clearly mission-oriented, but they are scientifically sound and are based on the most up-to-date advances.

9/2/83

PHYSICS

ACOUSTICS IN LYON, FRANCE

by G.L. Wilson. Dr. Wilson is Associate Professor of Acoustics at the Pennsylvania State University.

The Institut National des Sciences Appliquées (INSA) and École Centrale de Lyon are centers for acoustics research in France. Lyon is also the headquarters for a government-sponsored high-tech industry dealing with acoustics.

The acoustics group at INSA comprises three laboratories associated with different major undergraduate

teaching departments. Prof. C. Lesueur is Director of the Laboratoire de Vibrations-Acoustique, which has about 10 regular staff; five student candidates for the diploma in acoustics and 20 final-year students also work in the laboratory. The work is partly theoretical and computational, but also largely experimental. The principal theme has been the transmission of vibration in complex structures, such as buildings. The researchers are now working on transmission through shells to gain an understanding of transfer phenomena and the influence of factors such as shape, stiffening, and damping; the goal is to predict the performance of new designs. In an anechoic chamber I saw a scale model of a section of an aircraft hull; the laboratory is studying the hull's transmission properties for Airbus Industries.

The Laboratoire de Traitement du Signal et Ultrason is headed by Professors R. Goutte and C. Guillaud, with a permanent staff of about 20 people. It has projects on the generation and propagation of ultrasound, acoustic emission, detection of ultrasound of bubbles in liquids and biological tissue, signal processing and image processing (particularly oriented toward medical ultrasonics), and on artificial intelligence. Acoustic emission is also studied by the Laboratoire de Metallurgie Physique, headed by Prof. P.-F. Gobin.

Other laboratories at INSA also have work related to acoustics. For example, the Laboratoire de Mécanique des Structures, headed by Professors M. Lelanne and P. Trompette, and with a permanent staff of about 15 people, has a research program devoted primarily to using the finite element method to predict the static and dynamic behavior of mechanical structures. The researchers are interested in rotor dynamics and bladed disk assemblies such as turbines and compressors, and are developing optimization procedures to minimize weight by modification of the blade shape. They are also working with composite structures, including viscoelastic damping, and are studying temperature effects. Viscoelastic damping materials and their properties also are studied in the Laboratoire des Matériaux Macromoléculaires. It is headed by Prof. J. Golé, who, after retirement, is to be succeeded by Prof. J.P. Pascault.

At the École Centrale de Lyon, there are several research teams associated with the teaching departments. Prof. G. Comte-Bellot is in charge of a team of about 12 people working on aeroacoustics in the Laboratoire de Mécanique des Fluides, whose director is Prof. J. Mathieu. The main themes of the research are turbulent flows and turbomachinery, including jet noise and fan noise. The team has experimental setups for measuring noise emitted by various solid profiles placed near a nozzle; for jet noise, at velocities up to 120 m/s, a hot wire in the jet is used for measurement. The team is interested in propagation in a turbulent medium and is doing for Electricité de France a project on predicting the plume from a cooling tower. A transverse system is used to measure the velocities and intensity of turbulence. The team is trying to simulate these factors on a computer. In addition, the researchers are measuring noise from turbine motors in a high speed wind tunnel, and are using laser doppler interferometry to investigate for Renault the flow field inside automobile mufflers.

Next to the campus is the headquarters for Societé pour la Mesure et le Traitement des Vibrations et du Bruit (METRAVIB), a government sponsored high-tech industry. The company employs about 200 people in three departments: research and development, technical assistance (consulting engineering), and manufacturing (of specialized measuring equipment). The research department is supported primarily by government contracts, with the French navy accounting for more than a third of these; the navy is concerned with the noise problems of surface ships, submarines, and torpedoes. The department is mostly involved in passive reduction of radiation, and is developing methodology in instrumentation and calculations. The researchers hope to be able to transfer their findings to problems in industry, including off-shore oil rigs, nuclear and chemical plants, and even space vehicles. I was shown a large, low-frequency hydrophone array for identifying and measuring noise sources. The array is 3 m by 2 m, has more than 30 units, and operates at up to 8 kHz. The research department has a project for developing high-temperature, glassy damping materials. The researchers are developing finite element models of structures and are measuring the vibration of naval structures to confirm the calculations.

For the civilian sector, the researchers have developed an array of intensity microphones (three for high frequencies) arranged in two planes. The array can measure the directivity and hence determine the power of noise sources; the system is now on the market. The company also sells a system for analysis and experimental modeling

of the vibratory behavior of mechanical structures. The system uses a 120-point nodal synthesis, by which one can make measurements on existing structures and models and evaluate the effects of modifications. The company recently performed a fatigue test for new Metro lines. In conjunction with INSA, METRAVIB developed a new viscoelastometer for measuring the elastic properties of damping materials; the measurements can be automated by computer control.

9/2/83

A UK FREE ELECTRON LASER

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.

A major new free electron laser (FEL) project has received approval by the UK Science and Engineering Research Council (SERC). The project, funded at roughly $1 million spread over 3 years, is a collaboration between the Kelvin Laboratory of the University of Glasgow, Heriot-Watt University in Edinburgh, and the Daresbury Laboratory in Warrington. First experiments are planned for the end of this year.

The ambitious project hopes to demonstrate high gain and power tunability over the 2.0- to 20-μm region of the infrared (IR) spectrum for applications to laser photochemistry, isotope separation, and solid state physics. In this article, the operation and applications of FELs are briefly reviewed, current research efforts are outlined, and the UK experiment and research program are described.

FEL Basics

Of the many types of lasers currently under investigation, the FEL is the only one that does not involve a lasing medium such as a semiconductor, dye liquid, gas mixture, or plasma. For most media, laser action is limited to a few lines of precise wavelength, and in some media, the wavelength can be tuned over a narrow range by varying the composition. Applications for such lasers therefore depend on matching the narrow portion of the electromagnetic spectrum emitted by them to targets and processes. Since it is not tied to any atomic or molecular level structure, a primary attraction of the FEL is continuous tuning over a wide wavelength band.

Tunability in an FEL is provided by changing the electron energy, the amplitude, B, or wavelength, λ_w, of a periodic "wiggler" magnetic field that causes the electron orbits to oscillate. The oscillating electrons emit dipole radiation, which can interfere constructively at the output wavelength, λ, given by

$$\lambda = \lambda_w(1+K^2/2)/2\gamma^2. \qquad (1)$$

In equation (1), γ is the relativistic factor, $K \sim \lambda_w B$ is proportional to the angular deviation of an electron from the wiggler axis and is in the range of 1 to 3.

Two types of wigglers are currently popular: an electromagnet producing a helical periodic field, and a double array of permanent magnets producing a planar periodic field. For either type, the laser-light gain increases as N^2--the square of the number of magnet periods. Energy extraction from the beam is limited to about 1/2N of the initial electron energy per pass in order to maintain proper phasing over the full length of wiggler. However, high output powers are still possible because of the high peak power of electron beams, and the high gains predicted for sufficiently long systems.

Gain can be reduced by line broadening due to energy spreading and angular spreading of the beam and to magnetic field inhomogeneities. These mechanisms require the electron gun, accelerator, beam transport, and magnet systems to provide a highly monoenergetic and bright beam. FEL operation at shorter wavelengths than visible light is difficult to achieve because of these requirements. For example, short λ_w requires a small active magnetic field region, so beam brightness requirements become severe.

FEL Applications

Tunable, picosecond-pulse-length lasers can be major research tools for laser photochemistry and dynamic nonlinear optics. The wavelength range of 2 to 20 μm contains the vibrational frequencies of many molecules and the energy gaps of many compound semiconductors. With FELs in this regime, high enough peak power should be attained to excite nonlinear processes in molecules

and solids. The average power available and the predicted high efficiency of operation should make processing on an industrial scale economical. The achieveable linewidth (about 0.1 cm^{-1}) is sufficiently narrow to select single vibrational states.

A major problem in state-selective chemistry is that once energy is pumped into a molecule, it can rapidly distribute among many available modes. FEL pulses can be shorter than the molecular relaxation times so that bond selective chemical processes can be controlled much more precisely than by conventional pyrolysis. The short pulse capability also allows the study of new dynamical, nonlinear, optical processes in semiconductors. Such studies could lead to low power, nonlinear switching and amplifying devices based on band gap resonant effects in a variety of semiconducting compounds and alloys.

The wide tuning capability makes FELs useful for laser isotope separation and enrichment--many elements become accessible whose excitation wavelengths are outside the bands of existing high power lasers. The potential high efficiency of FELs is important for large-scale isotope separation, where energy costs are important. FELs using kiloampere currents of a few megavolt electrons from pulse line generators produce intense bursts of microwave radiation for missile vulnerability studies. FELs are also under study for other directed energy applications.

Current Research Efforts

Free electron lasers are now in a developmental phase as oscillators and amplifiers in the US and Europe. Devices operating in the visible and IR regions use electron beams extracted from conventional accelerators. The wigglers are either in a linear accelerator beam line or in the circulating beam path of storage rings. In such devices operating as oscillators, the time structure of the electron beam produced by the accelerator radio frequency (RF) fields is synchronized with the transit of photons between the reflecting surfaces of the optical cavity.

The Stanford superconducting linear accelerator (linac) operating at 24 MeV with a helical superconducting wiggler was the first experiment to demonstrate gain at 10.6 μm (Elias et al., 1976), and in a follow-up oscillator experiment at 43 MeV, 7-kW power output at 3.4 μm was observed. A permanent magnet wiggler in conjunction with a 20 MeV, several-ampere microtron beam are used to study FEL operation in the 25- to 35-μm range at the Comitato Nazionale Energia Nucleare laboratory in Frascati, Italy (Dattoli, 1981). A major FEL development program has begun at the Los Alamos Scientific Laboratory. Using a 20-MeV linac and permanent magnet wiggler as an amplifier for a high power CO_2 laser, the effort is devoted to the production of high power, efficient devices. The Defense Advanced Research Projects Agency (DARPA) supports the Los Alamos work in addition to similar efforts at TRW Inc. and Mathematical Sciences Northwest Inc. The long term goal of the TRW work is demonstration of a high-power, efficient FEL operating in the visible region (Boehmer, 1982). An RF linac permanent magnet wiggler experiment is now in construction in the Optical Sciences Division of the Naval Research Laboratory. The device will use thin foil mirrors through which the electron beam passes in order to maximize the amplifying volume.

There are three FEL experiments currently mounted on European storage rings. The ACO ring in Orsay, France, has recently demonstrated low gain in the visible region with a 150-MeV beam and a short, superconducting wiggler. For oscillator experiments, the permanent magnet wiggler was recently configured as an optical klystron (Deacon et al., 1981). This device can give higher gain but only in certain wavelength bands. An optical klystron was also installed on the VEPP3 storage ring in Novosibirsk, USSR, for experiments in the visible regime. The LELA (for Libre [free] Electron Laser in Adone) experiment on the ADONE storage ring at Istituto Nazionale di Fisica Nuclere in Frascati, Italy, uses an electromagnet and a 600-MeV beam to operate in the visible range with wide tuning provided by the variable magnetic field. In the US, FEL experiments will be carried out on the vacuum ultraviolet ring of the National Synchrotron Light Source at Brookhaven. A permanent magnet and several-hundred megaelectronvolt beam will be used for oscillator experiments at short visible wavelengths.

A different type of FEL operation is achieved with high power, 100-ns pulse line generators producing kiloampere-and-above currents of few megaelectronvolt electrons. At such beam currents, collective electron effects become important, and much higher gains become possible. Also, since the technology can produce terawatt power levels (10^{12} W) and pulse durations approaching 1 μs, very high energy operation may be possible. However, experiments are complicated by axial

magnetic guide fields for beam transport and gain limitations imposed by low beam emittance. Pulse line generators are appropriate for long-wave IR and microwave FEL operation. Collective (or Raman) FEL operation was first demonstrated on the Versatile Electron Beam Accelerator (VEBA) device at the Naval Research Laboratory in collaboration with Columbia University (Granatstein, 1983). Experiments on similar devices have been performed on the TONUS pulse line in Tomsk, USSR, and at the Ecole Polytechnique, Palaiseau, France. Beam studies for this type of FEL are also carried out at the Hebrew University in Jerusalem.

An ONRL report on European FEL experiments is available (Neighbours, 1983).

The UK Facility

The UK effort is a collaboration between three research groups, each responsible for specific aspects of the construction, operation, and experimental programs. Responsibility for all aspects of accelerator operation, the vacuum system, and component assembly rests with J.M. Reid, D. Land, and M. Kelliher of the Kelvin Laboratory. Wiggler magnet construction at the Daresbury Laboratory is under the direction of M.W. Poole. S.D. Smith and C.R. Pidgeon of Heriot-Watt University are responsible for optical cavity construction and laser experiments. W.J. Firth of Heriot-Watt is in charge of the the theoretical support effort. Individuals from the following institutions are also expected to contribute: Essex University; St. Andrews University; Strathclyde University; the Max Plank Institute for Quantum Optics in Garching, Federal Republic of Germany; the Universities of New Mexico and Arizona; Imperial College, London; Warwick University; and the Hirst Research Center.

The electron linac at the Kelvin Laboratory has been operating reliably for a number of years at energies up to 165 MeV. It will now be dedicated to FEL activities for 3 days of operation per week. The klystron modulators are being modified to stretch pulses from the present 3.5 μs to about 8.5 μs, thereby allowing for increased power build-up during oscillator experiments. With an average pulse current of about 250 mA at up to 100 MeV, the RF system will produce peak currents of about 15 A in 6-ps bunches. The present beam emittance is acceptable for most FEL experiments (2 mrad-mm with 0.1 percent energy spread) but will limit the shortest operating wavelength.

A plane magnet wiggler was chosen for its design flexibility and ease of access to the vacuum chamber. A full three-dimensional computer optimization was performed to design a permanent magnet system composed of two linear arrays of samarium cobalt blocks. A maximum field of 0.36 T for a 25-mm separation of the two arrays can be obtained. The field can be continuously decreased by increasing the separation. Gain calculations for the 5-m wiggler length indicate that a magnet period of 65 mm provides near maximum gain in the 2- to 20-μm range of operation. With this period, a reference FEL wavelength of 10.6 μm is obtained at 53 MeV with a single-pass gain of about 30 percent, corresponding to average powers of tens of watts and peak powers of several megawatts. This reference wavelength for initial experiments is a popular choice because of the availability of seed CO_2 lasers for amplifier studies, good optics, and a well-developed detector technology. The choice of reference energy near the center of the accelerator-operation regime assures broad tunability.

Electrons will be transported from the accelerator to the wiggler by dipole and quadrupole magnets. Small deflection magnets will guide the beam into and out of the optical cavity and around the cavity mirrors. The two mirrors to be used in oscillator experiments are separated by 7.56 m and are of different composition: the first is a 100-percent reflectivity gold surface; the second is coated with ZnSe to provide 1-percent transmission coupling at 10.6 μm and 40-percent transmission for the He-Ne alignment laser. The layout of the experiment is shown in Figure 1.

Status and Program Plans

Mike Poole of the Daresbury Laboratory discussed the status of system construction with me. Modifications to the linac beam line should have been completed in October. A new electron gun for the accelerator is being tested. The new gun, a triode design currently used at Daresbury, will allow the pulse to be stretched to 10 μs. Peak current will be maintained by subharmonic RF modulation of the grid-cathode assembly. A spectrometer to measure the electron-energy distribution at the end of the beam line and to determine energy changes due to passage through the FEL has been designed. The instrument should provide measurements of electron momentum change with 0.02-percent accuracy by the end of the year. The wiggler magnet is fully designed and

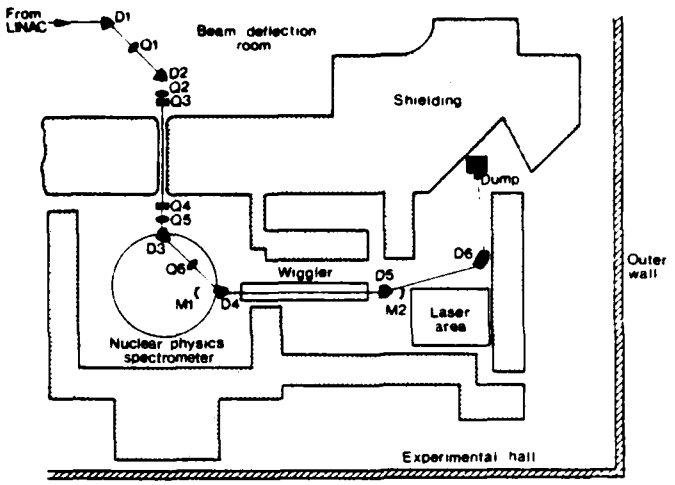

Figure 1. Layout of FEL experimental area (D = dipole magnet, Q = quadrupole magnet, M = mirror).

awaiting delivery of 70×20×10-mm $SmCO_5$ blocks from Hitachi. American suppliers apparently could not meet the uniformity specification required for the precise magnetic field configuration. Even so, individual blocks will be placed in the two arrays to compensate for existing block-to-block variations. Heriot-Watt University is constructing the optical cavity and developing the diagnostic equipment. The experiment is to be assembled at Kelvin this fall, and first experiments are anticipated before the end of the year.

The first phase of FEL diagnostic experiments will begin with installation of the wiggler. The optical gain as a function of electron energy will be measured using a 40-W continuous-wave CO_2 laser to prove the basic design. Gain will then be determined for a range of linac parameters and other laser probe wavelengths in the 9.3- to 10.8-μm band. Spontaneous emission measurements will establish the broad band tuning characteristics of the FEL. The first phase will be completed with strong-signal gain experiments using a 10-MW transversely excited CO_2 laser to determine gain saturation, the laser time-structure, and (with the electron energy analyzer) the electron-radiation coupling efficiency.

The objective of the second phase of experiments is the demonstration of an FEL oscillator that is continuously tunable in the 2- to 20-μm range with bandwidth limited power. The optical cavity will be seeded with a probe laser and then turned off to demonstrate free running FEL operation. Tunability will be demonstrated by varying electron energy, and laser output characteristics will be determined across the tuning range. The FEL's application potential will then be assessed by one photochemistry or solid state experiment before expiration of the 3-year grant period. Completion of the above experimental program would prove the importance of FELs to chemical and solid state applications and provide a boost to an area of research with few good experimental results.

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9/1/83

FAST DENSE-PLASMA-FOCUS EXPERIMENTS

by John D. Sethian. Dr. Sethian is Research Physicist in the Plasma Physics Division of the Naval Research Laboratory in Washington, DC.

The dense plasma focus is a simple and efficient device for generating an intense flux of neutrons. A modification of the conventional mode of operation has been developed that produces a tighter focus and greater neutron yield.

A conventional plasma focus consists typically of two coaxial electrodes separated at one end by a dielectric insulator and connected across a capacitor bank (Figure 1). At the other end, the outer electrode is considerably longer than the inner one. The focus is filled with deuterium to pressures of 2 to 7 Torr. After the capacitor bank is discharged, breakdown occurs across the insulator surface, and a plasma sheath is formed (see point a in Figure 1).

Driven by the J×B force, the sheath propagates axially away from the insulator (b and c) until it reaches the end of the inner electrode, where it is compressed radially (under the influence of the strong self-azimuthal magnetic field) to a tight pinch (d). In this pinched phase, the plasma emits x-rays and energetic electrons, ions, and neutrons. It has been shown empirically that the neutron yield, Y, is proportional to I^4, where I is the actual current flowing in the focused pinch.

To visualize how to maximize the pinch current, consider a simple capacitor bank of capacitance C_0, charged to voltage V_0, with impedance Z, and inductance L_0, driving a load with constant $\dot{L}$ (the pinch inductance increases linearly with time). Since the maximum short-circuit current of the bank is

$$I_{cs} = V_o\sqrt{C_o/L_o} = V_o/Z \quad , \qquad (1)$$

the bank inductance should be kept to a minimum. Since $Z \ll \dot{L}$ in a conventional device, the current at compression is given by

$$I_{focus} = V_o/\dot{L} \ . \qquad (2)$$

In other words, the bank acts as a constant voltage source, and the pinch current drops off at the precise moment it is most needed--i.e., when the plasma is focused. The result is a larger diameter pinch and less neutrons than could be produced if the current were held constant.

The above mode is that of a conventional plasma focus device. At the University of Dusseldorf (Federal Republic of Germany), a second mode of operation is chosen (Decker et al., 1983). In that experiment, a relatively high impedance bank is used, $Z \gg \dot{L}$ so that the constant current source prevents current dropoff at compression. Since $\dot{L}$ near compression can be quite large (typically 20 mH), this high value of bank impedance can only be achieved by minimizing C_o, since L_o has already been minimized to provide maximum current. This implies that the voltage must be larger than in conventional schemes (see equation [1]), and that the rate of current rise, $\dot{I} = V_o/L_o$, will be larger as well.

In fact, these changes also are beneficial when focus dynamics are considered; high values of V and $\dot{I}$ tend to produce a thinner, hotter sheath, which leads to a tighter plasma focus. The device built by the University of Dusseldorf uses a high impedance (160 mΩ), high voltage (200 kV), fast ($\dot{I} = 5\times10^{12}$ A/s) capacitor bank (Decker et al., *Proceedings*). First experiments with the device have demonstrated neutron yields of up to 2×10^{10} (over 10^6/J of capacitor bank energy) and currents of 600 kA (30 A/J). These numbers are to be compared with those of a conventional plasma focus device: 2×10^5 neutron/J and 20 A/J.

The details of the implosion have been studied with electrical measurements and schlieren photographs. At a filling pressure of 4 Torr, a very thin and hot plasma sheath is generated within the first 50 ns after voltage appears on the electrodes. Typical sheath thickness, just before compression (some 400 ns later) is about 0.66 mm. The final pinch has a diameter of

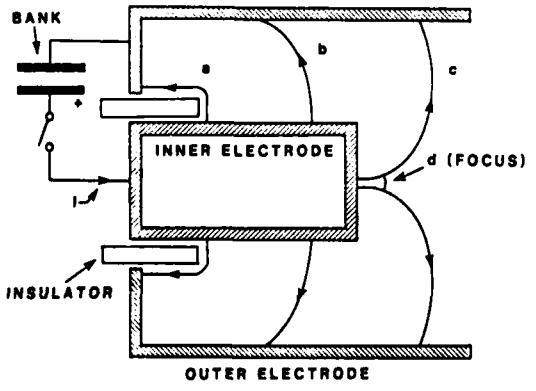

Figure 1. Conventional plasma focus.

0.2 mm and a length of 10 mm. The radial velocity of the current sheath is almost constant at 3×10^7 cm/s during compression. Decreasing $\dot{I}$ or V, or increasing the fill pressure, degrades the focus. The sheath widens; final plasma current drops; the plasma is not as tightly pinched; and, due to the prolonged breakdown time resulting from such changes, neutron output is decreased. (Note that to operate at higher pressure, in order to increase the neutron yield, one has to increase both V and $\dot{I}$.)

Compression takes place at constant magnetic flux, which indicates that there is no induced pinch voltage due to sheath motion. In all cases, no gross change in the current can be detected, which demonstrates the exceptional capability of this high impedance bank to stabilize the current during the pinching phase. As discussed earlier, this is in marked contrast to the conventional low-impedance focus devices that exhibit significant current reduction at the very beginning of the radial compression, and consequently reduced neutron yield. The maximum neutron yield per capacitor bank joule is five times higher on the Dusseldorf device than on conventional machines.

Reaction particle measurements (flux, fluence, fluence anisotropy, spectrum and spatial resolution) reveal that two entirely separate pressure-dependence sources contribute to the total yield. One, from the inside of the pinch itself, is correlated with the pinch dynamics, and, as expected, starts emitting when the pinch radius is at a minimum. At low pressures (2.5 Torr), the particles are emitted isotropically. But at high pressures (5 to 7 Torr), particles are emitted in a more conventional plasma focus mode, with the maximum intensity observed when looking end-on into the focus. The second source is axially extended; its contribution depends strongly on the filling pressure and pinch voltage. At low pressures (2.5 Torr) almost 60 percent of the total yield is due to this source, whereas at 5.5 Torr the contribution is negligible. The difference between these modes and that of a conventional plasma focus is again attributable to the rise time of the bank.

Encouraged by these very successful preliminary experiments, the Dusseldorf group has started building a larger capacitor bank; its parameters are V = 300 kV, W = 180 kJ, $\dot{I} = 2\times10^{13}$ A/s, and Z = 160 mΩ. This experimental facility is expected to be completed during the fall of 1983.

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8/31/83

INFRARED ATMOSPHERIC TRANSMITTANCE

by David Mosher.

Electro-optic communications and detection systems require accurate means of determining the infrared (IR) atmospheric transmittance in the 2- to 15-μm wavelength band under a variety of climatic conditions. Important information has been obtained experimentally for 16 km and shorter transmission lengths, and attenuation predictions based on known atmospheric properties have been obtained using the LOWTRAN computer codes developed by the US Air Force (McClatchey et al., 1972). Limitations of the LOWTRAN models become important at longer path lengths, where otherwise minor effects become appreciable, and deviations from simple exponential attenuation with distance occur. Better data for long transmission lengths are therefore required.

Long-term experiments in the Department of Physics of Technion--Israel Institute of Technology (Haifa, Israel) are designed to test code predictions and improve the data base for long path transmission in the 2.8- to 14-μm regime. The research, supported by the Israeli Ministry of Defence and industrial contracts, was described to me by S.G. Lipson, project head and Physics Department chairman. The experiments cover distances of up to 44 km and are carried out with mobile source and detection equipment in a number of widely different climates. Israel is a good base of operations for this work because climates ranging from temperate maritime to subtropical desert are within easy reach of the laboratory.

The experimental method is straightforward. A large, intense blackbody source transmits a beam to the distant measuring system. Measurements are made at two distances: about 1 km to determine the source spectrum, and long distance for transmitted spectrum data. The aim is to determine

transmittance with a maximum error of 5 percent. The problem is noise background from a number of sources. At IR wavelengths of interest, radiation from the ambient temperature environment greatly exceeds that of the distant radiator, so the source must be chopped and synchronously detected to separate its signal from the background. Turbulence and inhomogeneities modulate the received signal, imparting to it a noise power spectrum which falls rapidly with frequency. The chopping frequency is therefore chosen to be as high as mechanically feasible. On the receiving side, the entrance aperture of the detector is large to maximize the signal, and the angular field of view is only 1.9 mrad to minimize background noise. The radiator intensity is limited by the electrical power of the mobile generator. Although several types of IR lasers are much brighter at selective wavelengths, only a blackbody radiator covers the spectral range smoothly and continuously. (The UK free electron laser described earlier in this issue could cover the range when it begins operating, but it is not portable).

Figure 1 is a schematic drawing of the radiation source. The radiator is a 2-cm-diameter cylindrical annulus of graphite heated to about 2500°K by a 500-A current flowing through it. A stream of dry nitrogen flows over the heated element to prevent rapid oxidation. (The region around the element cannot be evacuated since any window would absorb radiation in some wavelength bands.) Radiation through a 5-mm-diameter aperture is collimated by Cassegrain optics to a beam of 10-mrad divergence with an exit aperture of 64 cm. Outside a radiation shield, an air-turbine driven, rotating double blade chops the beam at 450 Hz. A small fraction of the chopped radiation is collected by a photodiode to modulate a 10-W VHF transmitter for synchronization with the detector.

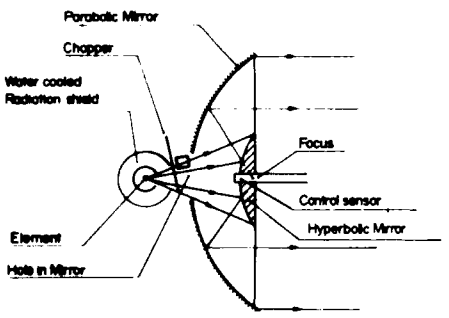

Figure 1. The radiation source and its collimating optics.

The primary detection system consists of an Exotech spectroradiometer with continuously variable interference filters covering the 2.8- to 5.5-μm and 7- to 13.6-μm bands, and cryogenically cooled InSb and CdHgTe detectors. Wavelength resolution of 1.5 percent is achieved, and a spectrum takes from a second to a minute to collect. A Meda multichannel analyzer (manufactured in Haifa by Elscint Ltd.) allows a number of spectra to be accumulated and averaged. A 100°C blackbody surrounded by boiling water is used to calibrate the instruments in the field at the beginning and end of each measurement.

Calculating the atmospheric transmittance from the data is not straightforward because the spectral resolution is insufficient to resolve detailed rotational fine structure. Each line of the rotational spectrum is attenuated exponentialy with its own decay constant, so the attenuation of the sum of states observed with the spectroradiometer varies with distance in a complex fashion. The transmittance at the short distance is first measured, and LOWTRAN is used to infer the source spectrum at wavelengths where transmittance is high (so that errors in extrapolating back to the source are small). Since the source spectrum is a smooth function of wavelength known to a constant factor, the data are sufficient to determine the spectral intensity at all wavelengths. The long distance data are then used to determine spectral transmittance.

The experimental procedure was carried out for a variety of climatic conditions and compared to LOWTRAN predictions with programmed meteorological parameters adjusted to those of the experiment. Figure 2 shows the results of experiments carried out on a 6-km range in an urban coastal area northeast of Haifa in winter. The LOWTRAN calculation used an urban coastal model. On the whole, agreement with the prediction was fairly good, although the predicted structure in the 2.9- to 3.2-μm range is missing, and transmittance in the 4.4- to 5.5-μm region is less than predicted. The higher-than-expected absorption around 5 μm was also observed in a series of 44-km range experiments in a rural environment under conditions of varying humidity. At the highest humidity (69 percent), transmittance in the 4.5- to 5.5-μm regime disappeared completely, although LOWTRAN predicted about a 7 percent peak in this region. Measurements were also performed in the range of 8 to 14 μm along 14-km paths across bays to verify the dependence on water vapor content. Two experiments in

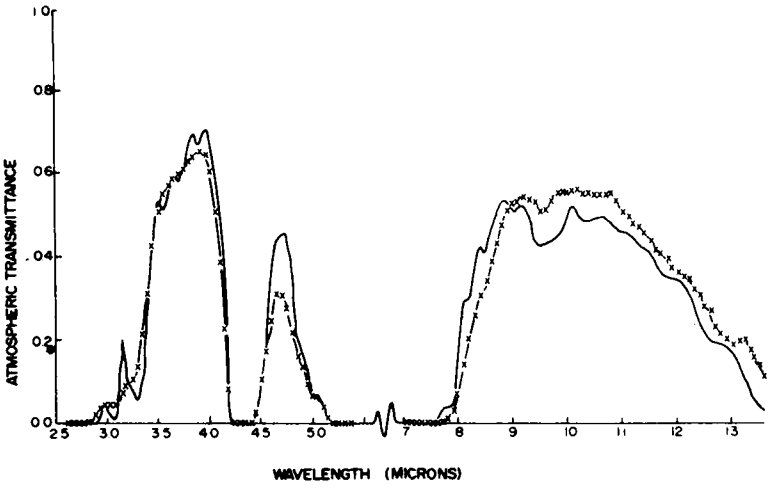

Figure 2. Transmittance measurements in an urban environment: curve-code, crosses-experiment.

the presence of sea winds were carried out: one across the Mediterranean and the other across Red Sea. Both experiments showed higher transmittance than expected from LOWTRAN.

The disappearance of structure in the 2.9- to 3.2-μm regime indicates that LOWTRAN used inaccurate spectroscopic data for the region. It is believed that the lower-than-expected transmittance between 4.4 and 5.5 μm is connected with aerosol scattering from water drops in conjunction with a water absorption band centered at 4.8 μm. Current research is concentrating on the importance of scattering processes to the observed transmittance. In a recent experiment, agreement was achieved between two types of measurements. In the first, longitudinal (along the beam) scattering was measured as a function of wavelength. In the second, the dependence of scattering on the angle to the beam direction was determined at a fixed wavelength. The measurements were then used to infer two distributions of scattering particles. Agreement between them was particularly satisfying because the scattering processes are quite different for the two types of experiments.

The Technion group has also carried out extensive related measurements of spectral radiance of the sky for code comparison in the same IR bands investigated for transmittance. These measurements are important for solar energy applications and provide IR background data for astronomy and electro-optical applications. In the LOWTRAN codes, atmospheric radiance is determined by summing emission contributions from various layers of the atmosphere and attenuating them along the line of sight. A study of the dependence of sky radiance on the observation angle, season of the year, and time of day was carried out to provide data for code verification (Ben-Shalom et al., 1981). Results of the experiments point to an optimal division of the contributing layers in a manner different from that employed in the codes. The Technion method gives better agreement with the experimental data, especially for long optical paths in the lower layers of atmosphere.

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9/1/83

INTERNOISE '83

by Alan Powell. Dr. Powell is Technical Director of the David W. Taylor Naval Ship Research and Development Center, Bethesda, MD.

The International Institute of Noise Control Engineering (INTERNATIONAL/INCE) was founded in 1974 as a nonprofit organization to promote

international cooperation in research on noise control and the application of engineering techniques for the control of noise.

INTERNATIONAL/INCE is supported by an imposing array of organizations from 21 countries interested in noise control engineering. There are two national INCE organizations, INCE/USA and INCE/Japan. INTERNOISE '83, the annual conference of INTERNATIONAL INCE, was held in Edinburgh, Scotland, from July 13 through 15.

This twelfth conference was attended by nearly 700 people representing over 30 countries. The largest numbers came from the UK (over 250), the US (over 50), and Denmark, Japan, and Sweden (over 40 from each). Such participation indicates the broad interest today in the relatively new subject of noise control--a field that barely existed before the introduction of the aircraft gas turbine. Jet noise turned out to be a major nuisance. At first, scientists were interested in its generation, reduction, and propagation; flight pattern and airport environs planning; and associated regulatory activities. Later, attention focused on aircraft compressor and similar noise. Yet these issues were almost completely absent from INTERNOISE '83. Instead, noise pollution has become widely recognized and now embraces a range of activities; the participation in the conference indicates the general agreement that noise pollution has an impact which can no longer be ignored.

The areas the conference covered help sketch the range of interests (Table 1). Not apparent from Table 1 is the activity of the national and international standards organizations and the very extensive regulatory activities, which are providing considerable stimulus.

Two areas received notable emphasis. One was sound intensity measurement; that is, the measurement of the vector of sound power per unit area. The other was active noise reduction, variously called active acoustic absorption or active acoustic cancellation. From the physical point of view, there is little novel in either of these areas--the acoustical physical principles have been known for decades. In both cases, the microcomputer has made possible, in a compact volume, what could only be achieved very imperfectly, if at all, by analog circuitry. Compact, lightweight, and reliable sound-intensity meters are readily available commercially, and the interest now lies in developing the appropriate measuring techniques and interpretation.

The sound power radiated by a device can be estimated by integrating the measured sound intensity over an enclosing volume. This may be done in any reasonable space, including that for machinery in many *in situ* locations. It is a very different matter to deduce the sound power from sound pressure measurements in an anechoic or an effectively free field space, or sound power from the steady reverberant levels attained in a reverberation chamber. Also, the location of the sources of acoustic radiation on a complex machine or structure may be determined. As might be expected, the interest in interpretation has generated a flurry of interest

Table 1
Conference Topics

1. Effects of Industrial Vibration on Man
2. Occupational Noise
3. Structural Response & Vibration Analysis
4. Machine Noise & Vibration
5. Diagnostics, Including Monitoring
6. Noise in Industry, Including Planning
7. Noise Control in Buildings & Building Services
8. Opencast Mining & Quarrying
9. Ships and Offshore Noise & Vibration
10. Transportation Noise Control
11. Community Noise, Including Aircraft
12. Diesel Engine Noise
13. Low Frequency Noise
14. Instrumentation and Measurements
15. Active Noise Reduction
16. Outdoor Noise Propagation

in the numerical computation of the intensity vectors. As is so often the case, interpretation of the measurements may be more complex than it appears at first.

There is also considerable interest in active noise reduction. Simply put, sound at a point from one small source may be canceled by introducing another of an amplitude and phase that cause cancellation at the point. If the two sources are close together and of the same amplitude but of opposite sign, almost complete cancellation occurs in all directions (there being a residual source of higher order and of much lower efficiency). One might ask what happens to the sound energy of the original source. The answer, of course, is that the impedance of the space into which each source radiates is changed by the pressure of the other source, becoming nearly totally reactive. The sound-power radiation into the surrounding space simply does not occur.

Two principal schemes for active noise reduction are unfolding. The first is easily visualized in the case of a one-dimensional duct, which is the popular application now. The sound field to be canceled is sensed and used to drive the canceling source at a position slightly "downstream" from the source. There are a number of variations on this; one of them is the obvious extension to three dimensions by using an array of sensors and an array of "canceling" transducers. This is still in the experimental stage, the idea having been demonstrated over a solid angle of a steradian or so. As one might expect, there was a significant "shadow" of relative silence on the side away from the original noise source. Of course, these are feedback systems, and the trick is to avoid feedback oscillations when the system is broadband.

The second scheme is pertinent to signals which are periodic, or nearly so--such as the noise generated by a diesel exhaust. Here the noise signal of a whole firing cycle is sensed and stored, and used to drive the "canceling" system for a subsequent cycle. A microprocessor is used to update the signal for each subsequent cycle, so the system is effective for nearly repetitive situations. This small "black box"--known as the "Essex Synthesizer"--is evidently of a general purpose character. A timing signal taken from the diesel engine itself synchronizes the process: the usual feedback path is thus broken. If the speed is variable, the process takes just a few cycles to adjust to the changing period. The system was used, for example, on the top of the stack of a small freighter to reduce the noise level on the bridge. An experimental version proved successful, and a permanent installation is undergoing sea trials. There are obvious applications to vibration control, where the prospect for "active vibration mounts" is tantalizing. There was a bench-top demonstration at the conference and a laboratory system, but no applications were described. One clear need is the development of the active mount itself; schemes for the configuration of such a mount were shown. Researchers are trying to remove the large oscillation an engine makes as the speed passes through the resonant frequency of the engine-mount system.

The technology is in its infancy. Development of the present, rather elementary-appearing systems, has taken some 5 years. But the 20 papers on the subject indicate that the long-known potential is well recognized; microprocessors have helped increase interest in an appealing but frustrating area. In some situations, "active cancelation" probably will be an attractive and practical solution.

INTERNOISE '83 brought together individuals from several disciplines and many countries. The wide international flavor of the conference showed that the need to control noise is now recognized even beyond the most heavily industrialized nations.

9/2/83

SPACE SCIENCE

THE EXTENSION OF THE AURORAL ZONE INTO SPACE

by R.L. Carovillano. Dr. Carovillano is the Liaison Scientist for Space Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until June 1984 from Boston College, where he is Professor of Physics.

The scientific study of the aurora essentially began with the pioneering work of Birkeland and Störmer near the turn of the century. Birkeland made observations during Arctic expeditions and suggested surprisingly insightful mechanisms for the origin of auroras, and Störmer conducted analytical studies

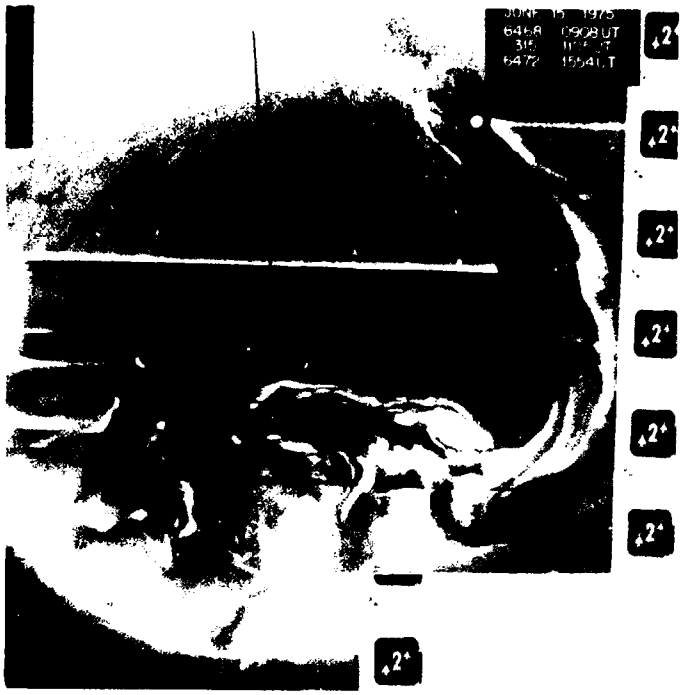

Figure 1. The aurora shown was taken by a DMSP satellite in 1975 during a traversal of the southern hemisphere. The south geomagnetic pole is slightly above center toward the top of the figure (which is local noon). Dayside aurora at the top of the figure differs significantly from nightside aurora in appearance and physical characteristics. The image most sensitively portrays infrared and long wavelength visible radiation. The white smear at the upper left and the horizontal streaks are due to instrumental effects.

of charged particle motion in a magnetic dipole field. Today we know a great deal about the aurora, but many basic questions remain unanswered. Auroral studies, which are conducted by almost all nations active in space research, involve ground observations, rocket and balloon campaigns, and space missions.

The aurora occurs in both hemispheres at high latitudes in an annular-shaped zone within nearly circular boundaries. Because the centers of the circular boundaries are offset by a few degrees, the auroral zone is thicker on the nightside of the earth than on the dayside. The aurora is caused by the precipitation of particles, principally electrons and protons of magnetospheric origin, which collisionally excite atoms in the upper atmosphere. The excited atoms return to their ground, or normal, state through the spontaneous emission of light that constitutes the aurora.

Early work on the aurora was based mostly on visual observations. More recent studies have taken advantage of far more sensitive techniques using, for example, ground-based photometers, rocket and balloon measurements, satellite imaging and particle data, and radar observations. The most important satellite observations of auroras have been made by the US Air Force Defense Meteorological Satellite Program (DMSP) series and L. Frank's (University of Iowa) imaging experiment on Dynamics Explorer (DE), which was launched in 1982. Although in visible light the aurora appears to be concentrated near local midnight, satellite and sensitive ground-based photometric observations have established that the aurora occurs essentially all of the time and normally extends 360 degrees about the geomagnetic poles (Figure 1).

Morphological characteristics of the aurora have been carefully catalogued, and many magnetospheric dynamical processes have been related to auroral location. At the August 1983

meeting of the International Union of Geodesy and Geophysics (IUGG), M.S. Gussenhaven (Boston College) and D.L. Hardy (Air Force Geophysics Laboratory [AFGL]) reported on the statistical characteristics of auroras based on more than 14 million electron precipitation spectra. At the same meeting, Frank showed images of the so-called theta aurora. It consists of the usual display encircling the geomagnetic pole and located in the auroral oval, plus a sun-aligned auroral arc that extends completely across the polar cap. Theta auroras have been observed only when the interplanetary field is northward and suggest a bifurcation of the plasma regimes in the geomagnetic tail. Dynamical features related to auroral location include magnetic-field-aligned currents, electric fields, acceleration of ionospheric plasma, and kilometric radiation.

A major question is how the auroral oval maps physically upward into space. To help deal with the issue, a Working Group on the Auroral Oval and its Extension into Space (WGAO) was established by the International Association of Geomagnetism and Aeronomy (IAGA). The goal of the WGAO is to develop symposia and to help workers in the field organize and communicate. About 40 scientists attended the WGAO's meeting at the IUGG in August. The participants included representatives from many nations, ground-based observers, a variety of satellite experimenters, and theorists. A vote was taken to continue the work of the WGAO, to encourage intensified activity, and to nominate a slate of officers (a chairman and three vice chairmen) representing different nations and scientific approaches. Nominees were from Finland, France, Japan, Norway, and the US.

Several participants said they anticipated exciting results in the coming years because of developments in radar observations, particularly from EISCAT and the Sondre Stromfjord facility; the satellites DE, DMSP, and HILAT, which provide unique auroral coverage; and continued operations of established ground-based stations and networks. The HILAT satellite was launched in June 1983 with a circular orbit at 830-km altitude and an 82-degree inclination. The spacecraft is a modified US Navy TRANSIT navigation satellite. HILAT is a program of the Defense Nuclear Agency, with cooperation from AFGL and the National Research Council of Canada.

For future IAGA meetings, the WGAO is considering a symposium on the dayside cusp and on the remote mapping of the auroral regions. The dayside of the magnetosphere occurs at high latitudes in each hemisphere with a longitudinal breadth of about a couple of hours on each side of local noon. The cusp region is a domain of diminished magnetic field intensity at the magnetopause, and thus allows direct access of solar wind plasma into the magnetosphere. Plasma entering through the cusp is believed to produce the dayside aurora and to be a significant source of magnetospheric plasma because of convection and energization processes. EISCAT and, especially, the Sondre Stromfjord facility will provide unique radar observations of the cusp region that will be complemented by ground observations and high latitude satellite coverage.

The symposium on the remote mapping of the auroral regions would use results from DE, DMSP, and HILAT in conjunction with auroral observations from low altitudes and from the ground. Empirical models of auroral flux observations and magnetic field line extension into the magnetosphere would be important topics.

Additional conferences of special interest to the WGAO include the recent symposium on magnetic reconnection (Los Alamos, NM, October 1983) and the symposium on the polar cap (University of Alaska, August 1984).

9/2/83

STATISTICS

STATISTICS IN IRELAND

by D.R. Barr. Dr. Barr is the Liaison Scientist for Statistics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until December 1983 from the Naval Postgraduate School, where he is Professor of Statistics and Operations Research.

Most statisticians are familiar with the story of how W. Gossett developed the distribution of statistics proportional to a ratio of the sample mean over the sample standard deviation. The story reports that Gossett published his results under the pseudonym "Student," because he was fearful his employer wouldn't appreciate such use of his time. It is not so widely known, however, that Gossett did this work as

an employee of the Guinness brewery in Dublin, Ireland. We should expect that a country in which such a central development in statistics occurred would have plenty of statistical activity today.

The Republic of Ireland (i.e., "southern" Ireland, which I shall refer to as "Ireland" in what follows) has a small but active group of statisticians centered primarily in the Dublin area; there are also important activities in other cities, such as Cork. In spite of efforts such as those of Gossett and Roy Geary (who, in his eighties, is still active as a consultant to the Economic and Social Research Institute in Dublin), one gets the impression that statistics in Ireland is in its infancy. The university programs in statistics in Ireland were established in the late 1960s and early 1970s, for example. The organization of statistical activities in Ireland seems just now to be developing. For example, there have been several conferences of Irish statisticians in recent years; on the other hand, I was told there is not yet a chapter of the Royal Statistical Society in Ireland (there is one in Northern Ireland, however).

Irish industry in general has been slow to recognize the usefulness of statistics. Historically, Irish industry hasn't spent much on research and development; businesses are concentrated in "medium tech" areas such as foods, tobacco, and textiles. US and Japanese "high tech" industries have invested heavily in Ireland in recent years, partially in response to government tax and other financial incentives. But these industries (such as electronics and computer manufacturers) are generally based abroad, and the tendency has been to use Irish labor, without corresponding demands on the Irish scientific community.

For statistics in particular, the result is that interaction with local industry--such as consulting, research support, and hiring of graduates--has been slow to develop. There has been substantial progress nevertheless, and there are currently small but good statistics programs at Trinity College, Dublin, and University College, Cork. The statistics departments at these universities have attracted active researchers, and both have promising young faculty members, such as Adrian Raftery at Trinity College and Gabrielle Kelly at University College. Of course, there are significant statistical activities at other institutions, such as those of I.G. O'Muircheartaigh at University College, Galway.

Trinity College

The statistics department at Trinity College has developed under the leadership of Prof. Gordon Foster. Roughly one half of the department's activity is in operations research; the statistics work is quite applied. Most department members work with its statistical consulting laboratory, and thus are involved in projects with other departments and, increasingly, with Irish industry.

Foster's research interests include queuing applications and systems performance evaluation. He has recently developed the conditional expected response time in the M/G/1 processor-sharing system. The model Foster considers concerns a single-processor system in which all jobs present simultaneously share the fixed capacity of the processor. He defines the response time of a job to be the total time the job is in the system, whereas the processing time is the response time it would have if it were always alone in the processor. Jobs are assumed to arrive in a Poisson stream with rate λ, and processing times are assumed to be independent and identically distributed with general distribution function F and mean $1/\mu$, where $\mu > \lambda$. The problem is to obtain the conditional expected response time of a job, given that it meets n jobs on arrival and requires processing time t. (The case for exponentially distributed processing times had been obtained previously.) Foster noted an interesting property of this system: the expected number of jobs in the system and a specific "tagged" job, unconditional on the number of jobs the tagged job met in the system upon its arrival, remains constant throughout its sojourn time in the system.

John Haslett at Trinity College has been working with the Irish government on a project concerned with estimating the wind energy available in Ireland. The problem is to use noisy data from a few specific locations to predict the power available over the whole country. Haslett is also interested in mineral resource estimation and geostatistics, involving spatial statistics. Adrian Raftery at Trinity College is also working on the wind-energy problem, as well as use of solar energy for domestic space heating. Raftery's interests extend to point processes, time series, and geometric probability. He has recently been working on the use of social mobility measures which allow cross-national comparisons of social mobility. Especially for societies whose gradations from the top to bottom effectively form a continuum, the

measures overcome traditional obstacles, such as use of different methods of social stratification.

Let us consider Raftery's model. Assume individuals can be ranked in descending order of occupational status (with ties allowed), scaled with highest at 0 and lowest at 1. Let a respondent's rank be Y and the father's rank be X, so (X,Y) has a bivariate distribution with joint cumulative distribution function Q, assumed to be jointly discrete or absolutely continuous with density q. Because X and Y relate to ranks, differences between X and Y, called "rank mobility," are independent of the margins. Further, q summarizes all the movements which take place and thus provides a basis for cross-national comparisons. This helps establish a family of mobility measures which are insensitive to the margins, independent of the occupational categories used, and take into account not only all the mobility which has occurred, but also the size of the movements.

If $\rho(X,Y)$ is any measure of the difference between X and Y, such as $|X-Y|$, then the expected value of $\rho(X,Y)$ is a useful mobility measure. Computation of this value is carried out with respect to an estimate $\hat{Q}$ of the distribution obtained with data from a sample survey in which respondents are asked to give their occupations and those of their fathers. Raftery has carried this out for data from 19 countries, from which he found that mobility rates at different levels in the social hierarchy are not very highly correlated. His results also suggest that circulation mobility is positively correlated with structural mobility for industrial countries and negatively correlated for nonindustrial countries.

University College, Cork

The statistics department at University College, Cork, is somewhat more mathematical than that at Trinity College. Prof. M.A. Moran, chairman of the department, is interested in multivariate methods, and particularly estimation of odds in discriminant analyses. Discriminant analysis is concerned with the correct allocation of an observation x to one of a given number of populations to which it may belong. In the case of two populations and equal prior probabilities for membership in either, the log-odds in favor of the first population, π, is $\ln[f_1(x)/f_2(x)]$, where $f_i(x)$ is the density function for population π_i. An observation may be allocated to π_1 or π_2 on the basis of the sign of the log-odds.

In practice, f_i is unknown and must be estimated. Parametric methods include the "estimative," in which unknown parameters are estimated, and the "predictive," in which a Bayesian model is used to obtain a predictive density for x. A nonparametric approach is the use of kernel density estimators. Using simulation for the classical case of two multivariate normal populations having common unknown covariance matrix Σ, Moran has compared the parametric and nonparametric approaches to estimation of log-odds. His results indicate the product kernel approach is better when the variables are independent; for moderately correlated variables, the methods give about the same correct allocation rates.

Patrick Bourke of University College is interested in randomized response designs. Randomized response is a survey technique for eliminating evasive answers by respondents to sensitive or embarrassing questions. Such techniques have enjoyed recent attention as a way of avoiding invasion of the respondents' privacy; the techniques were originally intended to avoid bias due to untruthful responses to embarrassing questions.

Bourke believes that randomized response designs should be such that the respondent's answer will not suggest to the interviewer which category the respondent is actually in. Bourke has extended designs for dichotomous questions to situations involving several possible responses, or "multi-proportions" situations. As an example, consider the problem of estimating the proportions of women belonging to the three classes:

C1: Women who have never had an induced abortion
C2: Women who have had one induced abortion
C3: Women who have had two or more induced abortions.

Directly asking women which category they are in would likely lead to overestimation of the proportion π_1 in C1 and underestimating the proportions π_2 and π_3 in C2 and C3. Suppose that instead of asking each woman in the sample which category she belongs to, one asks her to give a response based on selection of a bead at random from a box containing proportion p_1 red beads, p_2 blue beads, and p_3 white beads. The color of the bead is noted by the respondent in such a way that the interviewer cannot know what it was. Then the respondent gives a "coded"

Table 1

Response Codes

Category of Respondent	Color of Bead		
	Red	Blue	White
C_1	S_1	S_3	S_2
C_2	S_2	S_1	S_3
C_3	S_3	S_2	S_1

response to the interviewer, in accordance with Table 1, where S_i stands for "say class C_i."

Let n_i denote the number of respondents in the sample of n women giving response S_i, and let λ_i denote the probability of getting response S_i from a randomly selected woman in the population sampled. Then $P\Pi = \Lambda$, where P is the matrix

$$\begin{matrix} p_1 & p_2 & p_3 \\ p_3 & p_1 & p_2 \\ p_2 & p_3 & p_1 \end{matrix}$$

and Π and Λ are vectors of the π_i and λ_i. Now if Λ is known (and if P is nonsingular), the desired proportions would be given by $\Pi = P^{-1}\Lambda$. In the sampling problem, Π is estimated by estimating Λ from the responses,

$$\hat{\Lambda}' = \frac{1}{n}(n_1, n_2, n_3).$$

Then $\hat{\Pi} = P^{-1}\hat{\Lambda}$. P can be thought of as the "design" of this randomized response survey. P is nonsingular if the p_i's are distinct. Bourke recently has been investigating extensions of this type of survey approach to include multistage randomization, which he believes increases the level of respondent cooperation.

It is clear that statistics is alive and well in Ireland. There is a very bright future for Irish statisticians as interaction with industry continues to improve.

9/7/83

NEWS & NOTES

EXERCISE SEDGEMORE

The US Navy and the UK Royal Navy recently collaborated on a submarine rescue exercise called SEDGEMORE. The main objective of the August exercise was to simulate a submarine emergency and then use current operational procedures to maintain and rescue survivors aboard the submarine.

The US Navy has developed the Deep Submergence Rescue Vessel (DSRV) to rescue crew members in a sunken submarine. The DSRV is basically a small submersible carrying a crew of four and capable of taking up to 24 passengers. It can be transported by air to the general area of an accident and can move by sea to the specific site. The DSRV can then locate and attach to the sunken submarine and transfer survivors either to another submarine or to a surface vessel. In theory, the DSRV is available for use by NATO and Commonwealth nations; accordingly, it is vital to test the system in various locations, if only to highlight the geographic and international aspects of a rescue operation.

Exercise SEDGEMORE involved the DSRV; HMS/M *Opossum*, the simulated sunken submarine; and HMS/M *Revenge*, the simulated rescue submarine. On signal from the Royal Navy, the DSRV was flown from its base in San Diego, CA, to Prestwick, Scotland. It was transported by road to the location of the rescue submarine and placed piggyback on *Revenge*. *Revenge* then proceeded to the general location of *Opossum*, which was on the sea bottom near the Isle of Arran. The DSRV detached from *Revenge* and used navigation and scanning equipment to locate and attach to *Opossum*, which was about 400 feet below the surface.

During the exercise, the DSRV successfully made five rescue trips. On one of the missions, Lord Trefgarne, the Undersecretary of Defence, made a transfer from *Revenge* to *Opossum*. On another mission, the first-ever transfer under pressure between submarines was successfully accomplished. If a submarine sinks, the pressure inside can be greater than one atmosphere; the survivors can suffer from decompression sickness if they are not transferred under pressure.

Another aspect of SEDGEMORE was a survival trial carried out while *Opossum* was simulating a sunken submarine. Thirty-two persons were placed in one of the escape compartments and used the survival rations for 48 hours. The rations consisted of 500 ml of water and 200 g of barley sugar per man. During the survival trial, the atmosphere in the compartment was kept habitable by a foot-operated scrubber that uses lithium hydroxide as the chemical agent. The system was developed at the Admiralty

Marine Technical Establishment Physiology Laboratory in Alverstoke. The scrubber maintained the carbon dioxide concentration in the atmosphere at adequately low levels.

CDR A.R. Manalasay, USN
9/8/83

UK CONTINUES AGGRESSIVE COMPUTER LITERACY PROGRAM

Ken Baker, UK Minister for Information Technology (IT), announced on 23 August 1983 that the UK is the first nation on earth to have equipped all of its secondary schools with computers for student use. Furthermore, over half of the primary schools have computers, and the rest are expected to follow soon. He also announced a new £2.5 million ($3.75 million) initiative to use computers to enable handicapped persons to become more productive members of society; this is believed to be the first such government-backed program. Clearly, Britain intends to maintain its claim to being the most computer-literate nation.

M.N. Yoder
8/29/83

DUTCH GROUP USES SPIN TO SPAN METAL-SEMICONDUCTOR CONDUCTIVITY RANGE

Heusler alloys composed of nonmagnetic materials such as magnesium, arsenic, and silver have been investigated for many years. A Dutch team of investigators at the Philips Research Laboratories in Eindhoven and at the Research Institute for Materials in Nijmegen has modified the alloy formula to obtain new properties. Using an alloy of antimony, nickel, and magnesium provides an interesting and potentially useful new property. Whereas most materials are characterized by conduction electrons having fixed net spins which are UP, DOWN, or both (i.e., magnetically compensated), the spin state of the new alloy is thought to be switchable as a function of applied magnetic field. Thus it should be possible to externally control the material between a state in which it has semiconducting properties and a metallic state. The effective transconductance of a device made from such a material could be several orders of magnitude better than that of the best semiconductor switches. If the switching speed is found to be fast, then the speed-degrading line-charging problems of very large scale integrated circuits may be addressed by the new Heusler technology.

M.N. Yoder
8/17/83

MEMEBRANE ELECTRODE DEVELOPED AT IMPERIAL COLLEGE

Prof. W. John Albery and Peter Barron (Department of Chemistry, Imperial College of Science and Technology, London SW7 2AY) have developed a new membrane electrode for the determination of CO_2 (Albery and Barron, 1982). To prevent its interference, oxygen is reduced by a second metallized electrode. The quantitative reduction permits the simultaneous determination of O_2 and CO_2.

The reponse time of the electrode depends on the membrane thickness and can be as little as 0.3 second. The electrode is sensitive to 1 to 2 percent CO_2 and is light--less than 500 g. The sensitivity to CO_2 can be increased by removing the O_2 with another membrane. The process is somewhat hazardous because dimethyl sulfoxide is used as the solvent, but the danger can be reduced if the solvent is put into a gel form. The power requirement is about 2.5 mW.

The electrode is good for breath-to-breath monitoring--i.e., the CO_2 and O_2 content of the breath at each exhalation. This has clear implications for use with breathing apparatus of various kinds. Further research is being done on using the electrode for measurements of the ambient environment. There is great interest in the instrument in medical circles.

Albery has made arrangements for Sensors International (50 Milk Street, Boston, MA 02109) to handle the electrode.

Reference

Albery, W.J., and P. Barron, "A Membrane Electrode for the Determination of CO_2 and O_2," *Journal of Electroanalytical Chemistry*, 138 (1982), 79-87.

Vivian T. Stannett
F.A. Richards
9/1/83

A HISTORY OF SONAR IN THE ROYAL NAVY

Scientists and engineers engaged in research and development tend to underestimate the value of a definitive history of their field of specialization. But researchers may begin to appreciate such a document if they take the time to reflect on what they have learned from the book and on how often it is used as a reference. The first book-length scholarly history of sonar, written by a professional historian, is to be published within the next few months. US scientists should find it a valuable source of information.

Dr. Willem D. Hackmann, Assistant Curator of the Museum of the History of Science, Oxford University, has written *Seek and Strike: Sonar, Anti-submarine Warfare, and the Royal Navy 1914-1954.* It is scheduled for publication by Her Majesty's Stationery Office (HMSO), London, during the spring of 1984. The book will comprise approximately 400 pages of text, plus 75 plates of photographs and drawings, 26 tables, several appendices, and an extensive bibliography, glossary, and index. The printing run will be 3000 copies, and the estimated cost will be less than £20.

Preparation of the book began in 1976, when the UK Ministry of Defence (MOD) invited Hackmann to prepare a technical summary of sonar development in the Royal Navy (RN). He proposed to expand the scope of the work to a complete history, which would attempt to answer questions about why certain courses were taken and to interpret the results of decisions. Such coverage involves much more than a review of technical reports; government policy, politics, strategy, and tactics play equal or greater roles. The MOD agreed to the broader scope, and for the next 2 years they funded Hackmann and a research assistant, both full-time. In 1978 the support ceased (the funding of history projects being just as uncertain as that for R&D), and the book was not completed until 1982, being a part-time effort for Hackmann.

For source material, Hackmann made extensive use of the UK and US Naval Archives, the libraries in several MOD R&D establishments, patent files, papers published in various journals, and interviews with some 65 people. He was given a security clearance in both the UK and US for this project. Although the book is primarily a history of sonar in the RN, it was deemed desirable to include material on US developments. In 1978 Hackmann, his research assistant, and Peter Ward (then recently retired from the Admiralty Underwater Weapons Establishment) visited the US for a month to do archival research and interviews. Because of funding limitations, their US visits were restricted to the Washington area and the Northeast. The 42 US interviews listed compose two thirds of all the interviews.

Hackmann carries three themes through the book. About a third of the text is devoted to the technical history of devices and systems such as transducers, domes, electronics, and complete sonars. Another major theme is the development and evolution of the organization to carry out research and development on sonar for the RN, primarily the Royal Naval Scientific Service. The third theme covers the impact of government policy, politics, and operational strategy, and tactics on technical developments.

Chronologically the book covers pre-World War I, the period between the major wars, World War II, and the post-war period to 1954. The cutoff was the launching of the USS *Nautilus*, an event which resulted in a major change in undersea warfare. (Also, it becomes increasingly difficult to write an unclassified history on a topic of military technology as one approaches the present.)

The book deals mostly with submarine and antisubmarine sonar, both active and passive. The coverage of torpedo acoustic homing sonar and mine-hunting sonar are mentioned only briefly. Hackmann has prepared a number of useful charts and tables which trace the development and evolution of various major sonar systems.

I recently had the opportunity to browse through the manuscript of the book during a visit with Hackmann. The book seems to contain a wealth of interesting and useful information, and I predict that it will be used extensively in the US. When it is published we can rush out and buy a copy, read it quickly, and proceed to proclaim loudly to our colleagues that: (1) the author has left out the really important events, or (2) has the story all wrong. Certainly in part that is bound to be the case. Although I have not yet read the book, I am thankful that it has been written.

Chester McKinney
8/25/83

IAGA TO ASSEMBLE IN PRAGUE

Prague, Czechoslovakia, has been chosen as the site for the 5th Scientific Assembly of the International Association of Geomagnetism and Aeronomy

(IAGA). The symposium will be held from 5 through 17 August 1985 on the campus of the Prague University of Technology. Questions about the symposium should be sent to Mr. Vaclav Bucha, Geophysical Institute of Czechoslovak, Acad. Sci. Bocni II, 14131 Praha 4, Czechoslovakia. The last IAGA assembly was held in Edinburgh, Scotland, in 1981.

IAGA covers a considerable range of interests in geophysics and space science. Disciplinary coverage relates to IAGA's five divisions: I, Internal Magnetic Fields; II, Aeronomic Phenomena; III, Magnetospheric Phenomena; IV, Solar Wind and Interplanetary Field; and V, Observatories, Instruments, Indices, and Data. Numerous symposia will be held in each division at the IAGA assembly; many symposia are interdisciplinary and interdivisional. For example, we now realize that the coupling between the magnetosphere and ionosphere is so extensive that few ionospheric considerations can be made independently of important magnetospheric effects or constraints. Thus, joint symposia between divisions II and III, and similarly between III and IV, are assured.

In addition to divisional symposia, IAGA activities include divisional business meetings, business meetings of special commissions and working groups, and other meetings accommodated by the large international collection of scientists that typically attend IAGA assemblies.

R.L. Carovillano
9/2/83

ANNIVERSARY CONFERENCE SET FOR ROYAL STATISTICAL SOCIETY

The Royal Statistical Society has published a provisional program for its 150th Anniversary Conference, to be held at Imperial College, London, 4 through 6 April 1984. The first meeting of the Royal Statistical Society, then called the "Statistical Society of London," took place in London on 15 March 1834. The main object of the society was "to examine facts calculated to illustrate the condition and prospects of society." Among founding members were Charles Babbage, Thomas Malthus, and Adolphe Quetelet. In 1840, Prince Albert, who had been tutored in probability by Quetelet, became the society's first royal patron. A royal charter was granted to the Statistical Society in 1887.

For the anniversary conference, a number of prominent British statisticians have been invited to give papers on a wide range of statistical topics. The society is planning an exhibition featuring the growth of the society and statistical applications in various fields. Further information and application forms can be obtained from the Secretary, Royal Statistical Society, 25 Enford Street, London W1H 2BH.

D.E. Barr
9/7/83

NEW RELEASE: SOLAR-TERRESTRIAL PHYSICS

Solar-Terrestrial Physics: Principles and Theoretical Foundations has been released by the publishers, D. Reidel Publishing Company of Dordrecht, The Netherlands, and Boston. The book was edited by Dr. R.L. Carovillano, Liaison Scientist for Space Physics at ONRL, and J.M. Forbes, both members of the Department of Physics at Boston College. The work is an addition to the Astrophysics and Space Science Library, a series of books on recent developments in space science, general geophysics, and astrophysics. The series is published in connection with the journal *Space Science Reviews*.

Space-Terrestrial Physics is based on the proceedings of the Theory Institute held at Boston College, 9 through 26 August 1982, and chaired by Dr. Carovillano.

The book is available from the publishers only.

D. Mott
9/6/83

UNESCO BIBLIOGRAPHY PUBLISHED

Quarterly issues of the *UNESCO List of Documents and Publications* (ULDP) and an annual cumulation are available free of charge from the following address:

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D. Mott
9/6/83

AUGUST MAS BULLETINS

The following *Military Applications Summary (MAS) Bulletins* were published by the ONR London Military Applications Division during August. 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 *MAS Bulletins*, by number, from ONR London.

Bulletin Number	Title
98-83	European Aerospace Updates
99-83	Ferranti's Helmet Target Acquisition Designation System (HTADS) for Helicopters and Ground Vehicles
100-83	Norwegian Coast Guard Ship K/V *Andenes*
101-83	Fourth Symposium on Turbulent Shear Flows
102-83	A New British Earth Anchor With Applications to Troop and Helicopter Operations in the Field.

ONRL REPORTS

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

C-13-83: *The 19th International Symposium on Applied Military Psychology*, by N.A. Bond, Jr. The symposium dealt with issues such as women in the armed forces, leadership and management, training, combat reactions and stress, decision aiding, and the role of psychologists in the military.

C-14-83: *The 10th International Thermal Spraying Conference*, by H. Herman. In thermal spraying, protective coatings are formed through high velocity melt-spray deposition of a wide range of materials (plastics, metals, ceramics) onto substrates to be protected. The high temperatures for melting are achieved through combustion, with an electric-arc, or within a plasma. The conference examined the scientific bases of the processes as as well as a number of active applications, including corrosion/oxidation and wear and erosion resistant coatings, gas turbine engines, and a number of high temperature applications.

R-7-83: *Applied Psychology in Europe: An ONR Perspective*, by N.A. Bond, Jr. This report is intended to alert American researchers to European developments in applied psychology. The following areas are examined: interactive man-machine interfaces, combat reactions and stress, memory enhancement, large digital simulators, and human performance models.


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