++

HELLO, MY NAME IS SCHOLAR. I WILL HELP YOU IN REVIEWING THE GEOGRAPHY OF SOUTH AMERICA. THIS IS ABC REGIONAL HIGH SCHOOL. TODAY IS 04/30/70.

IF YOU HAVE CAREFULLY STUDIED YOUR INSTRUCTIONS, WE MAY BEGIN THE REVIEW NOW.

WHEN YOU ARE READY TO START, TYPE READY --- REMEMBER TO TERMINATE WITH AN ASTERISK * FOLLOWED BY A CARRIAGE RETURN.

REDY

NOT READY YET? LET ME KNOW AS SOON AS YOU CAN START.

READY

PLEASE TYPE YOUR NAME --- MR., MISS, OR MRS. FOLLOWED BY FIRST NAME, MIDDLE NAME OR MIDDLE INITIAL, AND LAST NAME.

MR. JONATHAN K. O'MALLEY

NAME OF YOUR INSTRUCTOR, PLEASE:

MR. NORTHERLAND

LET'S BEGIN OUR DISCUSSION NOW, MR. O'MALLEY.

++

SELECT AN ALTERNATIVE FROM THE LIST:

VENEZUELA
URUGUAY RIVER
EUROPE
SOUTH AMERICA

TO FILL THE BLANK BELOW:

PARAGUAY IS LOCATED IN ---.

VENEZUELA

NAVAL RESEARCH

REVIEWS

OCTOBER 1971

PROFILES IN SCIENCE

Dr. Joanne Simpson

Dr. Joanne M. Simpson, one of the nation's foremost meteorologists, was the first woman in the United States to receive a Ph.D. in meteorology. Her principal preoccupation in research is cumulus convection and its role in the general circulation of the atmosphere. As the principal investigator on an ONR contract with the WHOI for many years she devoted her efforts to identify and understand the main sources of energy for the global circulation (the trade wind circulation of the tropics and the trade wind cumulus cloud regime).

She is still concerned with the export of energy from the tropics that drives the general circulation and with the primary meteorological energy transfer mechanism, the trade wind cumulus cloud. Today she is Director of the Experimental Meteorological Laboratory of the National Oceanic and Atmospheric Administration located at the University of Miami. One of her important tasks in this position was to direct Project Stormfury. The aim of this project is to ameliorate the destructive force of a hurricane by redistributing the storm's energy through seeding its component great cumulus clouds which are the building blocks of the storm.

Dr. Simpson, who was a Guggenheim fellow in 1954, is a fellow of the American Meteorological Society, the Royal Meteorological Society.

SCHOLAR—A New Approach to Computer-Assisted Instruction

Jaime Carbonell
Bolt, Beranek and Newman, Inc.
Cambridge, Massachusetts

The traditional approach to computer-assisted instruction (CAI) may be called conventional ad-hoc frame-oriented (AFO) CAI. This refers to the fact that the system involves the construction of frames including questions with anticipated correct and wrong answers. The data are formed by specific pieces of text and detailed questions with their predicted answers, errors, and anticipated branching, all of which must be entered in advance by the teacher.

The AFO system has basic limitations. The student has little or no initiative; he cannot use natural language in his responses; and systems look fairly rigid to him. The teacher has a considerable burden in the preparation of questions, answers, keywords, keyword groups, and branching. From a system point of view, the system controls the student and is in turn tightly ad-hoc programmed by the teacher; the system has no real initiative or decision power of its own; and, of course, it has no real "knowledge."

In most CAI systems of the AFO type the computer does little more (if any) than what a programmed text can do, and one may wonder why the machine is used at all. Some systems allow some degree of processing of unanticipated answers, permit time to be measured, and statistics to be collected in most cases, but not much more.

In contrast to the AFO system, a new approach to CAI has been devised which can be defined as being information-structure-oriented (ISO) because it is based on the utilization of a data base that is a complex but well defined structure in the form of a network of facts, concepts and procedures. We call this system SCHOLAR.

The SCHOLAR program was originally developed at Bolt, Beranek and Newman supported in part by the Office of Naval Research. We were recently awarded a new contract by ONR for further improving the program. The overall goal of ONR is to obtain for the Navy advanced automated instructional systems that will speed up, improve the efficiency and reduce the cost of the technical training of Navy personnel.

A basic feature of SCHOLAR is its semantic network. Semantics is the science of meaning. In linguistics, semantics is concerned with the deep structure of sentences, *i.e.*, with what words and the modifiers stand for, and how different words affect each other at that level; on the other hand, the way they are organized sequentially within a sentence is in the domain of the syntax. A semantic information structure is an organization of units of information in terms of their meaning and mutual relationships. When each unit in the set may refer to other units within the set, and so on, with possibility of loops and cross-references, we have a *semantic information network*. The experimental program utilizes the subject of geography.

SCHOLAR is capable of generating out of its information network the material to be presented to the student, the questions to be asked of him, and the corresponding correct answers. SCHOLAR can also utilize its information network to answer questions formulated by the student. As a consequence, SCHOLAR is capable of maintaining a mixed-initiative dialogue with the student, i.e., questions may be initiated by either side and answered by the other. The dialogue takes place in a rather comfortable subset of English and, in the present implementation, has as its goal to review the student's knowledge in the context of the subject matter. SCHOLAR is only the first prototype of an ISO CAI system, but is being built with a large degree of modularity in both program and data base, and it should generalize with little trouble to many other examples and fields of application.

In a specific protocol, SCHOLAR starts typing after being called. The student's turn comes after an asterisk, and can be a response to a question by SCHOLAR, a question to SCHOLAR, or a command. The student returns control to SCHOLAR by typing another asterisk and a carriage return.

SCHOLAR can prompt the student, indicate when it does not understand him, detect misspellings, and answer the student's questions using acceptable English.

The goal of artificial intelligence research has been defined in the following way: "to construct computer programs which exhibit behavior that we call 'intelligent behavior' when we observe it in human beings." The development of SCHOLAR is, to a large extent, an effort in this direction, and can be legitimately considered to be in the field of artificial intelligence. We are referring now to some of SCHOLAR's capabilities like answering questions not specifically anticipated, constructing questions on given topics, and generally carrying on a mixed-initiative contextual dialogue with a human in a rather free and comfortable subset of English.

How Does SCHOLAR Learn?

The question has arisen many times: "How does SCHOLAR learn?" A standard response is, "SCHOLAR learns what it is told." In SCHOL-

AR we have followed an approach that involves constructing a program that we think reasonably performs some conversation and teaching functions so far considered the privilege of human beings, instead of trying to develop *a priori* a theory of learning, or teaching, in a formal way. We think that with the selected approach we have learned at least as much as with a more formal one.

Developed in SCHOLAR is a true "knowledge" of the subject matter as exhibited by human teachers. The computer in AFO CAI systems has no "knowledge"; it merely regurgitates text, questions and answers that have been specifically entered in advance. SCHOLAR, however, has a semantic network which utilizes and processes knowledge in a manner quite similar to a human teacher. This does not mean that it is attempting the construction of formal models of teachers' behavior, but simply that a close look at human teachers could be beneficial.

Communication Between Man and Computer

A very interesting issue which arises in a discussion of CAI is the importance of natural-language communication between man and computer. The importance of such communication for CAI has been somewhat exaggerated. This is especially so in the case of researchers who have neglected other aspects to concentrate on natural-language understanding. In SCHOLAR, however, we have been able to achieve a large degree of freedom, better than our early hopes, both in input and output. This has been obtained by taking a pragmatic approach which has proved very successful. First of all, we have restricted student answers to SCHOLAR questions to certain types, namely numerical, atomic, and lists of atoms, though other words like auxiliary words can also appear. The underlying reason has not been difficulties in parsing complete sentences, but judging their acceptability as answers.

The case where complete sentences have been allowed with a large degree of freedom is that of questions asked *by* the student of SCHOLAR. "How" and "Why" questions are not answered by SCHOLAR, but then no program we know of has properly handled these questions. However SCHOLAR can handle: (a) yes-no, and true-false questions; (b) multiple-choice questions; (c) WH type questions (these questions involve a constructed response through the use of words like "What," "Which," "Where," and "When"); (d) fill-in questions; and (e) imperative statements like "Tell me ..." or "Give me ... ." SCHOLAR can also handle another important aspect of questions: quantification through modifiers like "some," "all," "everything," "something," "more," and "most." The system is also equipped to accept misspelled words, approximations, and synonyms. SCHOLAR can also separate the correct and wrong parts of a question requiring a series of answers.

In the CAI program, there are two levels at which interaction can take place. The *first* level is the interaction between teacher and computer. The teacher-computer interaction should occur in three phrases:

1. Preparation of the data base, be it in the form of questions and frames in AFO CAI, or a semantic network in ISO CAI.
2. Setting conditions for student-computer interaction, *i.e.*, defining the system parameters necessary to stimulate the conditions of that interaction.
3. Collection of results in the form of scores, statistics and general history of the student-computer interaction after it has taken place.

The *second* level of interaction occurs between computer and student. Before his initial involvement with the computer, the student is provided with directions. He types his name and the name of the instructor after SCHOLAR "introduces" himself. The student's input is rather free compared to earlier systems, *i.e.*, SCHOLAR is able to handle not only model inputs but variants as well (inputs containing misspelled words, approximations and synonyms).

Processing Student Input

Several stages are necessary to process student input. The first stage takes care of compounding words like "tell me" into "tell/me," and also of separating punctuation marks from words. In the next stage the student input is checked for input courtesy words (like "please" and "kindly"), and there is a check to see if the student input is the name of one of the modes of operation. The transformed input is then analyzed in an attempt to find unbound words (words which have no meaning for SCHOLAR).

The next procedure is to determine if the student input is a question by checking for the presence of one or more interrogative words or the presence of a "blank" word indicating a fill-in question. If not, the statement is considered as a response. In cases in which the statement cannot be properly interpreted by SCHOLAR, it declares that it is incapable of understanding the statement, and asks the student to rephrase it.

If SCHOLAR cannot obtain an answer for a question which it considers well-formed and which contains no undefined terms, it assumes that the requested information is not part of its semantic network. In that case, SCHOLAR confesses its ignorance by typing out a message like "Sorry, I don't know."

An important routine associated with reading by SCHOLAR is called PABLO. It handles the changes in control from SCHOLAR to the student and vice versa. It operates by calling the basic reading routine RD. While waiting for input, PABLO measures elapsed time; if this exceeds a given delay, PABLO prompts the student to respond, and records the excessive delay.

Example of SCHOLAR Protocol

++

HELLO, MY NAME IS SCHOLAR. I WILL HELP YOU IN REVIEWIN(
THE GEOGRAPHY OF SOUTH AMERICA. THIS IS ABC REGIONAL
HIGH SCHOOL. TODAY IS 04/29/70.

IF YOU HAVE CAREFULLY STUDIED YOUR INSTRUCTIONS, WE
MAY BEGIN THE REVIEW NOW.

WHEN YOU ARE READY TO START, TYPE READY --- REMEMBER
TO TERMINATE WITH AN ASTERISK * FOLLOWED BY A CARRIAGE
RETURN.

READY

PLEASE TYPE YOUR NAME --- MR., MISS, OR MRS. FOLLOWED
BY FIRST NAME, MIDDLE NAME OR MIDDLE INITIAL, AND LAST
NAME.

MR. JAMES R. JONEES↑S↑ES

NAME OF YOUR INSTRUCTOR, PLEASE:

MR. BROWN

LET'S BEGIN OUR DISCUSSION NOW, MR. JONES.

++

WHAT IS CHILE?

A COUNTRY

THAT'S FINE.

SELECT AN ALTERNATIVE FROM THE LIST:

214000.
800300.
49883.
63690.

```
FOR THE QUESTION:

  APPROX WHAT IS THE AREA OF CHILE?

*800300*

 YOUR ANSWER IS INCORRECT.
 THE CORRECT ANSWER IS: 214000.


 THE POPULATION IN CHILE IS APPROX 8500000. PEOPLE.
 TRUE OR FALSE?

*TRUE*

 YOU ARE CORRECT.


 USE ONE OF THE FOLLOWING:

 SUCRE
 FRENCH
 ARGENTINA
 SPANISH

 TO ANSWER THE QUESTION:

   WHAT IS THE LANGUAGE IN CHILE?

*
 YOU ARE TAKING TOO MUCH TIME...

*SPANICH*

 YOU SHOULD HAVE WRITTEN "SPANISH".

 VERY GOOD.


 THE CAPITAL IN CHILE IS SANTIAGO.
 CORRECT OR INCORRECT?

*CORRECT*

 THAT'S RIGHT.

   APPROX WHAT IS THE AREA OF BRAZIL?

*2500000 SQUARE MILES*

 WRONG.
 PLEASE INDICATE IF THE FOLLOWING STATEMENT IS CORRECT
           OR INCORRECT:
```

THE AREA OF PARAGUAY IS APPROX 47432 SQUARE MILES.

WHAT IS THE AREA OF BRAZIL?

THE AREA OF BRAZIL IS APPROX 3600000. SQUARE MILES.

NOW ANSWER THE QUESTION YOU DIDN'T ANSWER BEFORE.

FALSE

REPHRASE YOUR STATEMENT. I CAN'T UNDERSTAND IT.

INCORRECT

VERY GOOD.

THE AREA OF PARAGUAY IS APPROX 157000 SQUARE MILES.

THE LANGUAGE IN BRAZIL IS FRENCH.
RIGHT OR WRONG?

WRONG

YOU ARE CORRECT.

THE LANGUAGE IN BRAZIL IS PORTUGUESE.
IS IT TRUE THAT THE CAPITAL IN BRAZIL IS BRAZILIA?

YES

THAT'S FINE.

APPROX WHAT IS THE POPULATION IN BRAZIL?

60000000.

APPROXIMATELY TRUE, BUT A MORE EXACT VALUE IS 70000000.

WHAT IS BRAZIL?

TELL ME SOMETHING ABOUT PERU.

WAIT A MINUTE. I'M CHECKING MY FILES.

LET'S PROCEED NOW.

PERU IS A COUNTRY.
IT IS IN SOUTH AMERICA.
THE POPULATION IS APPROX 7000000. PEOPLE.
THE CAPITAL IS LIMA.

NOW ANSWER THE QUESTION YOU DIDN'T ANSWER BEFORE.

Q/A

DO YOU WANT TO CHANGE THE GENERAL MODE OF THE INTERACTION
TO Q/A?
PLEASE ANSWER Y OR N.

Y

OK, MR. JONES. LET'S GO AHEAD.

PLEASE, TELL ME MORE ABOUT PERU.

THE AREA OF PERU IS APPROX 480000. SQUARE MILES.
THE LANGUAGE IS SPANISH.

HOW MANY SQUARE MILES ARE THERE IN BRAZIL?

THE AREA IS APPROX 3600000. SQUARE MILES.

WHAT IS THE PRINCIPAL RELIGION IN URUGUAY?

THE PRINCIPAL RELIGION IN URUGUAY IS CATHOLICISM.

*
WELL, HAVE YOU MADE UP YOUR MIND?

THE PRINCIPAL RELIGION IN PERU IS ---.

I'M AFRAID I CAN'T ANSWER THAT.

IS IT TRUE THAT THE AREA OF URUGUAY IS 70000?
THAT'S ABOUT RIGHT. THE EXACT ANSWER IS 79000.

*COULD YOU PLEASE INDICATE THE PRINCIPAL RIVERS IN
ARGENTINA?*

I DON'T UNDERSTAND YOUR WORD "INDICATE". I'LL GIVE
YOU ANOTHER CHANCE.

THE PRINCIPAL RIVERS IN ARGENTINA ARE ---.

THE PRINCIPAL RIVERS IN ARGENTINA ARE THE RIO DE LA PLAT
THE PARANA, THE URUGUAY RIVER, THE SALADO, THE
PARAGUAY RIVER, AND THE PILCOMAYO.

MIXINIT

DO YOU WANT TO CHANGE THE GENERAL MODE OF THE INTERACTI
TO MIXINIT?
PLEASE ANSWER Y OR N.

*Y**

OK, MR. JONES. LET'S GO AHEAD.

WHERE IS BRAZIL?

PLEASE HURRY UP. I'M WAITING FOR YOUR STATEMENT.

IN SOUTHAMERICA

I BELIEVE YOU MEANT TO TYPE "SOUTH AMERICA".

THAT'S RIGHT.

IS IT CORRECT TO SAY THAT THE CITIES IN BRAZIL ARE
SAO PAULO, RIO DE JANEIRO, BRAZILIA, PORTO ALEGRE,
BAHIA, RECIFE, SANTOS, MANAOS, AND BELEM?

YES

THAT'S FINE.

THE CITIES IN BOLIVIA ARE ----.

LA PAZ, SUCRE, BOGOTA, AND ACONCAGUA

AT LAST! ANYWAY, LET US SEE WHAT YOU HAVE JUST WRITTEN.

HAVEN'T YOU INCORRECTLY USED "BOGOTA" AND "ACONCAGUA"?
ON THE OTHER HAND "LA PAZ" AND "SUCRE" IS CORRECT.

THE COMPLETE ANSWER ALSO INCLUDES POTOSI, COCHABAMBA,
AND SANTA CRUZ.

SELECT AN ALTERNATIVE FROM THE LIST:

845600.
1033500.
-8297216.
4000000.

TO FILL THE BLANK BELOW:

THE POPULATION IN BOLIVIA IS APPROX --- PEOPLE.

*40
00 YOU ARE TAKING TOO MUCH TIME...

452-004 O - 71 - 2

```
*4000000.*

 THAT'S RIGHT.

 TYPE EITHER T OR F AFTER THE FOLLOWING STATEMENT:

 THE LANGUAGE IN BOLIVIA IS SPANISH.

*WHAT IS CORDOBA?*


     CORDOBA IS A CITY.
     IT IS LOCATED IN ARGENTINA.
     THE POPULATION IS 700000. PEOPLE.

 NOW ANSWER THE QUESTION YOU DIDN'T ANSWER BEFORE.

+++++++++++++++++++++++++++++++++++++++++++++++++++++

 TODAY'S REVIEW IS OVER.
 IT HAS BEEN A PLEASURE TO WORK WITH YOU, MR. JONES.

+++++++++++++++++++++++++++++++++++++++++++++++++++++
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Comparison of CAI Systems

We are now in a good position to establish a comparison between the classic ad-hoc frame-oriented CAI systems, and the information-structure-oriented ones we have just introduced. Let us first consider the capabilities of both types of systems. Both can present material and questions to the student. AFO can at this time ask more involved questions but these must have been formulated in all detail in advance by the teacher. Information-structure-oriented systems have better capabilities for analyzing unanticipated answers, which they can relate to their semantic memory. Because of this, ISO systems can be designed to have *diagnostic* capabilities which AFO systems can not possess; the latter can only work on specific errors anticipated by the teacher.

AFO systems do not allow students' questions; ISO systems can handily process and answer them. This leads to a true conversational capability, with questions from both sides that will depend on overall context, specific context, what has just happened in the previous question, *etc*.

SCHOLAR further shows that ISO systems exhibit the capability for handling relevancy and determining which information and how much information to present at a given time, either in response to a question or as new material. This capability is outside the realm of AFO systems.

Future SCHOLAR Plans

There are three areas in which it is planned to develop SCHOLAR further. A new program is now underway which will enable the computer and the teacher to converse with each other so that the teacher can program the computer without special training. It is also intended to give SCHOLAR the additional capability of detecting and correcting a student's underlying misconceptions about a subject as well as determining his previous knowledge of the subject under study.

One area of development is interactive construction of the data base, which would be concerned with the teacher's role of getting the information into the data base easily. SCHOLAR will be refined so it can accept simple sentences from teachers just as it now accepts questions from students. At the same time, SCHOLAR can use the information already stored to help the teacher to integrate new information into the network. SCHOLAR will be designed to accomplish this by asking the teacher questions on how these new concepts are related to the information already stored.

There would be the need to develop a conversational approach for questioning the teacher. The most logical alternative involves building a conversational program to help the teacher enter material. If the program can interrogate the teacher, then it can acquire the information it needs by asking specific questions that demand one or two word answers. Such a conversational routine, therefore, would not need a sophisticated parsing strategy. Furthermore, use can be made of semantically high levels, if they have already been entered in the data base. This can occur in two ways: (1) those concepts that are used in describing a new entry need not be defined if they are already entered, and (2) the concepts already entered can be used by the conversational routine to guide the questioning of the teacher.

To a certain extent, the teacher will have to adapt his coding to the form of the data structure, but he should be able to enter any desired property. To the degree he has to conform to the data structure, he will have to learn the relatively few conventions of the system.

The initial programming to question the teacher will not present any great difficulties. There is, however, the aspect of programming SCHOLAR to help the teacher express more complex properties in a form compatible with the data base. The object here is to avoid the necessity of having the teacher learn all the conventions of attribute-value notation used in the data structure.

The major problems in providing this kind of help are of two kinds. First, there is the problem of constructing a detailed enough framework so that there is a slot somewhere for any kind of information the teacher might want to enter. Second, there is the problem of recognizing that when a teacher tries to enter a certain fact he is referring to a specific category.

A second area of development in SCHOLAR would encourage correction of a student's misconceptions. SCHOLAR can serve as a model for developing a taxonomy of misconceptions in terms of the information stored in memory. Such a taxonomy can be used to investigate the relationship between the errors students make and their underlying misconceptions. This investigation would seek to determine what kinds of questions will pinpoint the misconception producing any given error. SCHOLAR then would be programmed to interrogate the student further when he makes a mistake in order to determine what underlying misconception is involved.

Using the structure of information in SCHOLAR as a basis, we can construct a preliminary taxonomy of misconceptions students are likely to have. This is certainly not complete, but a complete taxonomy probably can be constructed by extension from this beginning.

A general taxonomy of this kind has implication for education as a whole beyond those for development of SCHOLAR itself. The taxonomy provides a basis for understanding why some errors that a student makes are worse than others. How bad any error is depends on the number and type of the underlying conceptions which give rise to the student's mistake.

Ideally SCHOLAR should correct the underlying misconception whenever a student makes a mistake in answering a question. A human tutor can quickly find the misconception by asking one or two questions. It should be possible within SCHOLAR to develop strategies for asking the appropriate questions when a student makes a mistake. These strategies will have to be independent of the particular subject matter. This is one reason why it is important to develop a taxonomy of misconceptions independent of subject matter.

Attempts will be made to formulate a programmable strategy for asking questions to determine what misconception caused by error.

A third area of development would be concerned with questioning the student about his previous knowledge so that what is taught can be related to what the student already knows.

This can solve two problems in teaching that now exist—boring the student with material already familiar to him or confusing him by giving him material that is too advanced. Currently teaching machines handle this problem by starting at fairly low levels of material. The result is that students frequently spend large amounts of time going over material they already know or partly know, leading to boredom and frustration and a waste of valuable instruction time.

Before we can develop the capability of SCHOLAR to probe for previous knowledge, we must have an idea of what kinds of questions tutors ask to determine this.

One serious handicap in questioning the student is the fact that when he is questioned about previous knowledge he will probably respond with a lengthy paragraph, and SCHOLAR is not equipped to analyze text like this at the present time. It only accepts one- or two-word answers, although it can interpret and answer fairly long questions. Programming SCHOLAR so that it can interpret long passages is too difficult, given the present state of the art. It probably would be possible to allow the student to respond with short declarative sentences within fairly restricted formats. By restricting the statement forms more and more, the difficulties in programming SCHOLAR become easier. However, it is not clear that this is the best approach to approximating the tutor's strategy. If teachers can question students about their previous knowledge using only specific questions, then it might be a better solution to use a questioning strategy that asks specific questions rather than restricting the student's responses to more general questions.

There is a tradeoff between approximating the best tutoring strategy and implementing the strategy in SCHOLAR. The best solution will be tried within the constraints of this tradeoff.

In conclusion, it is important to emphasize that we are not advocating the complete elimination of AFO CAI systems. They will have their role for some time to come. We see them as convenient for cases in which the subject matter is very diversified, and the interactions with the students are planned to be brief. In that case the development of complex semantic networks is not justified. When discussion in depth is desired, when the student should have some initiative, when detailed anticipation is unwanted, then information-structure-oriented systems are to be preferred. And at the opposite end, when teaching sequences are extremely simple, perhaps trivial, one should consider doing away altogether with the computer, and using other devices or techniques more related to the nature of the instructional material and objectives.

Application of ONR Basic Research to Display Panel

Recently Owen-Illinois, Inc., announced that they are beginning commercial pilot plant production of their "Digivue" electronic digital display/memory panel. At the same time, Rome Air Development Center (RADC) awarded them a contract to (1) conduct an analysis of these display panels in the military airborne environment, and (2) to design and fabricate an experimental display terminal to interface with a current RADC's information processing system.

The present "Digivue" display product resulted from ONR funded research at the University of Illinois, during the mid 1960's; the more recent prototype development was funded by ARPA. The panel is expected to have universal applicability as a compact

(Continued on Page 21)

Recent Advances in the Study of Aseptic Bone Necrosis

Gillian Karatinos
Office of Naval Research

Aseptic bone necrosis refers to destructive sclerotic and cystic changes in bone which are not infectious (bacterial) in origin. Aseptic bone necrosis may occur in association with a variety of conditions such as chronic alcoholism, pancreatitis, sickle cell anemia, and pressurized environments. Navy interest in the ailment stems from the pressurization necessarily experienced by naval divers working in the underwater environment.

Historically, aseptic bone necrosis was known as caisson disease of bone because it was diagnosed chiefly in caisson workers. These individuals experienced a high incidence of bends (pain during or immediately following decompression, probably due to bubble formation somewhere in the body) as a result of inadequate decompression time. During pressurization, gases in the breathing mixture dissolve in the blood and tissues at a higher concentration than at sea level. Decompression is the process whereby underwater workers are brought up from depth in accordance with a time schedule calculated to allow the venting out through the lungs of the excess dissolved gases from the tissues and blood stream in a manner gradual enough to prevent significant bubble formation.

The first investigator to link aseptic bone necrosis with caisson disease was Twynam in 1888, who described a caisson worker whose abscessed right knee necessitated amputation and revealed necrosis throughout the shaft of the femur. In articles in 1909, 1911, and 1912 Bornstein and Plate discussed 500 cases of the bends in builders of the Elbe Tunnel in Hamburg. Among them were 9 cases with changes in the bones. These changes were accompanied by pain, and consequent x-rays. showed decreased bone density and/or deformity. Bornstein and Plate suggested that gas bubble formation led to blockage of blood nutrition to bone. Similarly, Bassoe, reporting 161 case histories of bone and joint manifestation of compressed air disease in 1913, suggested a relationship between the initial joint pain "bends" and later x-ray evidence of bone atrophy and sclerosis. More extensive information transpired in 1939 when Kahlstrom, Burton, and Phemister published autopsy findings on a case of aseptic bone necrosis of 35 years standing. The articular cartilage of the joints had broken down and had been replaced by a fibro-cartilage similar in appearance to that seen in arthritis. While there were necrotic areas in the long bones, some replacement by new bone had occurred. The authors attempted but failed to induce bone necrosis in dogs by injecting air into the femoral artery. Therefore, they suggested that bone lesions, rather than being due to intravascular emboli, were due to gas liberated in the interior of the bone under enough pressure to asphyxiate the tissue.

It appeared that aseptic bone necrosis could occur after only one severe compression/decompression exposure as pointed out in studies by Coley and Moore in 1940 and Taylor in 1943. Taylor emphasized that a time period must elapse (several months) between time of exposure and symptoms in joints. He noted that shaft lesions are usually asymptomatic and may be replaced to some extent by new bone growth. But in the weight-bearing joints where constant pressure is exerted by the weight of the body, bone lesions eventually cause collapse of the joint.

In 1966 McCallum and Walder reported that 19% of 241 tunnel workers suffered from aseptic bone necrosis. Frequency of decompressions, attacks of bends, and amount of pressure exposure were listed as factors related to likelihood of incurring bone lesions. A surprising finding was that x-rays do not always reveal bone lesions that are present. Conversely, there may be x-ray evidence of bone necrosis when no symptoms are reported (Behnke 1967).

The etiology of aseptic bone necrosis still has not been unequivocally demonstrated. It seems to have the highest incidence in workers who have used inadequate decompression tables or who have experienced the bends on one or more occasions. Lesions may appear anytime from 2 months to 5 years after exposure. Usually no complications arise if the lesion is present in the shafts of the long bones as shown in the photomicrograph in Figure 1. If it arises in the joints, the consequences are serious. Some revascularization of bone may take place as the drawing of Figure 2 illustrates.

In Figure 3 is shown an x-ray of an incipient lesion of the femoral head (upper thigh bone). A photomicrograph of the same lesion is illustrated in Figure 4. Unless all weight bearing is suspended for many months so that scar tissue can develop, the lesion will grow progressively larger, as may be seen in the enlarged dark area of the x-ray in Figure 5. Eventually, collapse of the bone results (see Figure 6). The victim is then a cripple in the portion affected. He has recourse to an artificial joint fashioned by surgeons, but these joints are not always functionally successful.

The U.S. Navy has not experienced the high casualty rate that commercial diving organizations have with regard to aseptic bone necrosis. With the advent of saturation diving, however, there is some indication that aseptic bone necrosis may become a Navy problem. Surveys of incidence among divers are now being made by and within the Navy.

Figure 1 — Distal femur with infraction shown by arrows

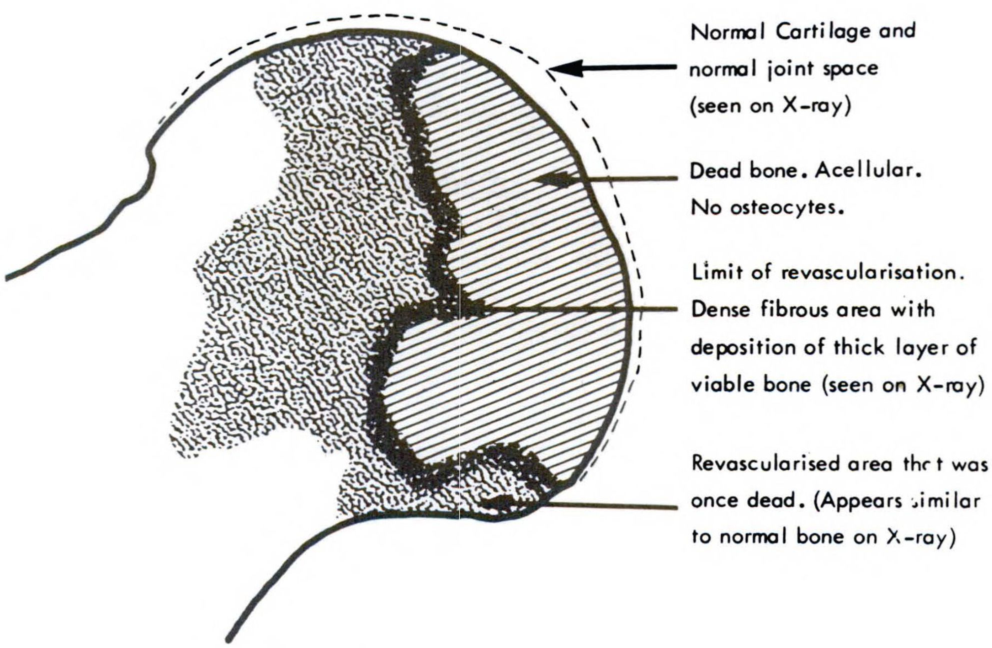

Figure 2 — Limit of revascularization of necrotic bone at a joint

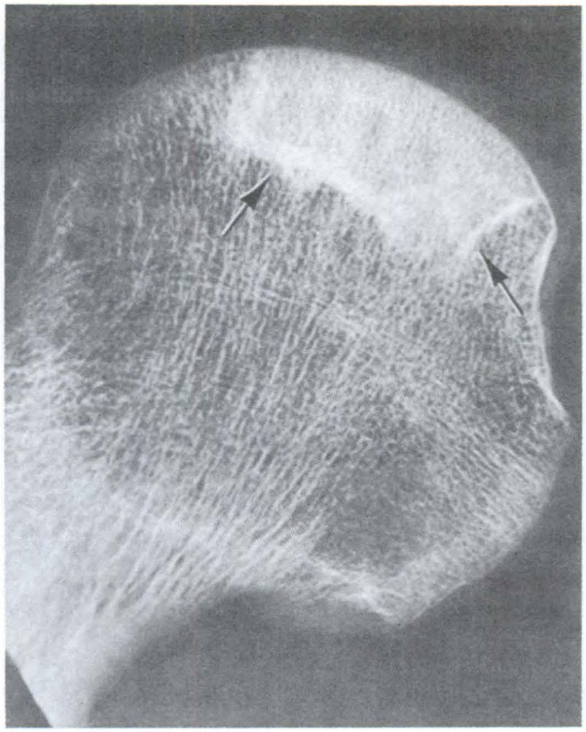

Figure 3 — X-ray of early femoral head necrosis (white area outlined by arrows)

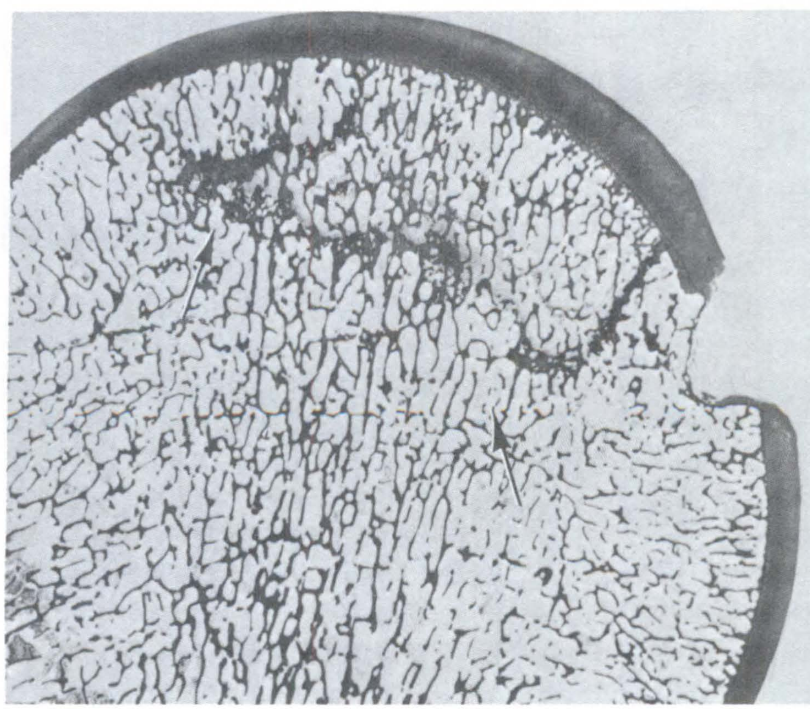

Figure 4 — Photomicrograph of early lesion in x-ray in Figure 3

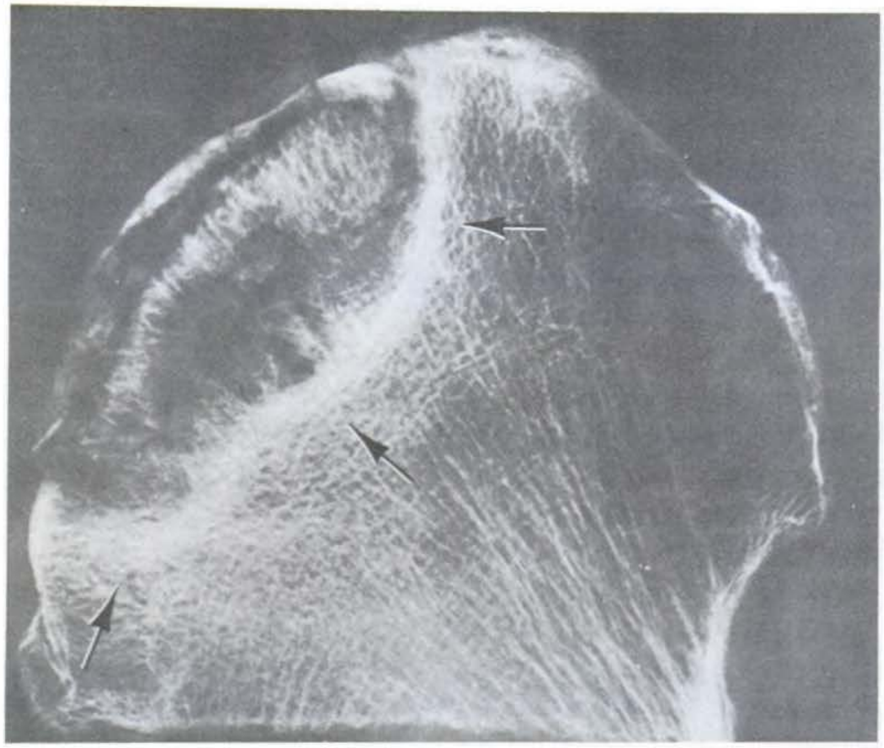

Figure 5 — X-ray of late avascular necrosis of femoral head

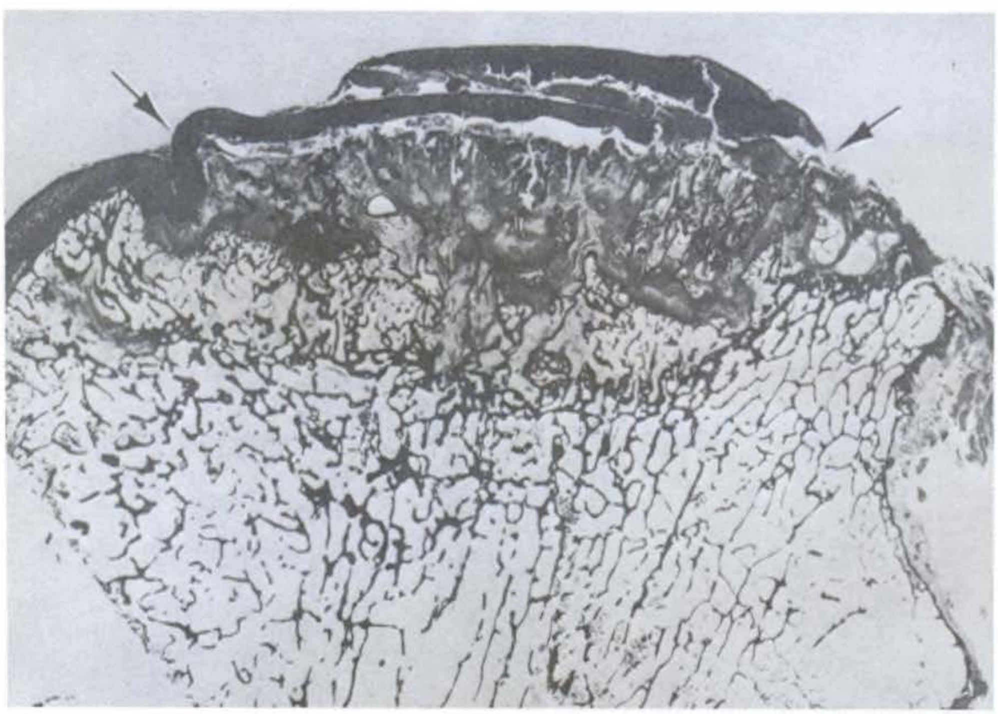

Figure 6 — Photomicrograph of collapse of the bone (arrows) in advanced aseptic bone necrosis of the femoral head

At a recent Navy-wide workshop (May 18-20, 1971) held at the Naval Submarine Medical Center, Groton, Connecticut, aseptic bone necrosis was among the problems discussed. The workshop, co-sponsored by the Office of Naval Research and the Bureau of Medicine and Surgery, was attended by representatives from Navy in-house laboratories and by Navy contractors working on pertinent research problems. Five speakers on aseptic bone necrosis delineated the current status of the problem and developed new concepts as to basic mechanisms underlying the disease state. A summary of each of these presentations follows.

Surgeon Cdr D. H. Elliott, an exchange officer from the Royal Navy posted to the Naval Medical Research Institute at Bethesda, Maryland, reported on a three year survey of the incidence of aseptic bone necrosis in 350 full time divers in the Royal Navy. A 5% incidence was tabulated. Almost half of the divers who did contract the malady had "clean dive records" (*i.e.* used Royal Navy decompression tables only, with no evidence of decompression sickness). When all compressed air workers were included in the survey, a 26% incidence of aseptic bone necrosis was recorded. Sites of crippling were shoulder (head of humerus), pelvis (head of femur), and knee (distal end of femur). Possible etiologies considered included correlation of necrosis with compression rate, oxygen tension, decompression rate, number of exposures, and alcoholism.

Dr. Brian A. Hills of Duke University Medical Center reported on some of his experimental evidence to support his theory that excessive compression rates induce conditions leading to aseptic bone necrosis. An increased solution of gas molecules in the circulating blood during the compression phase causes an increase in the osmotic pressure of the blood. Because of this increase in osmotic pressure, he believes that a pressure gradient is set up between the blood and the bone tissue (interstitial tissue spaces of the bone) that is partially affected by the semi-permeable nature of the perforated, membranous head of the bone. In response to this gradient, plasma water is allegedly shifted from the blood vessels into the tissue spaces of the bone, thus choking off adequate bone blood flow. Dr. Hills has developed a technique for measuring blood flow directly in the heads of bones rather than in the shafts, as had been done previously. Using rabbits and dogs, he has measured a fall in bone blood flow during compression and a rise during decompression. Futhermore, bones were seen to act as excellent osmometers *in vitro:* the water pulled across the articular cartilage (one of two cartilaginous surfaces which comprise a joint) was directly proportional to osmotic pressure exerted. The rate of flow due to osmotic pressure was seen to be much higher than rate of flow due to simple diffusion; therefore, the gas gradient could not be eliminated by diffusion before appreciable quantities of plasma water had crossed from blood vessel to bone tissue space. Future studies will consist of measuring blood flow at the head of the femur while varying one of the following: rate of compression, time at maximum pressure, or rate of decompression. Dr. Hills stated that he felt aseptic bone necrosis is not a manifestation of decompression sickness but is a separate phenomenon.

One of the problems of studying aseptic bone necrosis has been the difficulty of inducing the ailment in experimental animals. Dr. C. Chryssanthou of Beth Israel Medical Center, New York found an animal susceptible to necrosis as an offshoot of his studies on a drug (PPCH or MA 1050) which protects against decompression sickness. While microscopically examining tissues of obese mice that had been compressed, decompressed, and then taken to altitude, he saw aseptic necrosis in the bones. In compression/decompression trials with several hundred of these mice, he deduced that the incidence of aseptic bone necrosis is not correlative with occurrence of decompression sickness, but rather, that the incidence is related to the number of compression/decompression episodes. The drug PPCH which is so effective in preventing decompression sickness in mice did not prevent development of bone necrosis, thereby strengthening the argument that aseptic bone necrosis is *not* an extreme of the spectrum of symptoms of decompression sickness. On this point the work of Dr. Chryssanthou agrees with the theory of Dr. Hills.

Another investigator, who is not working directly with aseptic bone necrosis, made some contributions to the subject as a corollary to his main work. Dr. Harry Sobel of Colorado State University, Fort Collins, while reporting on the effects of elevated oxygen pressure on collagen, a significant component of bone as well as of other body connective tissue, suggested a possible origin of aseptic bone necrosis. He had observed that mice exposed to 1.08 atmosphere O_2 (over 5 times normal oxygen partial pressure) for 3 days a week developed biochemically modified collagen. He raised the possibility that an accumulation in the bone of this oxygen modified collagen might (1) block blood flow to the bone and thus initiate aseptic bone necrosis or (2) might perhaps be part of the disease process of the softening and necrotizing of the bone. New studies will follow up on this possibility.

A concentrated effort on the problem of finding the best human analog for the study of the pathogenesis of aseptic bone necrosis has been launched by Dr. Kent Smith of Virginia Mason Research Center in Seattle. Dr. Smith made a study of the comparative circulatory anatomy of the head of the femur (thigh bone which forms part of the hip joint) in the sheep, the goat, and the miniature pig (minipig). He used a three-pronged methodology. (1) He injected the femoral blood vessels of exsanguinated animals with dental acrylic which would harden to form a cast model of the vasculature. The surrounding flesh was then removed by concentrated hydrochloric acid or by other means. (2) Radiographs (x-rays after injecting radiopaque dye) and serial tomograms (radiographs of only vessels in the same plane) were made of the vessels leading to the femoral head. (3) Angiograms (x-rays of moving "blood" using liquid radiopaque dye perfusion at typical blood pressure) were done *in vitro* on decalcified femoral heads to get an idea of dynamics of flow at the femoral head. In addition, literature surveys of femoral circulation in the human, rabbit, dog, rat, and goat were compared with the experimental findings. Because the minipig, goat, and sheep were found to possess femoral head vasculature very similar to each other and to the human, the final selection of the experimental animal was based on other physiological similarities to the human: total body mass, fat/water ratios, and generally observed decompression characteristics. Based on these criteria, the minipig was chosen for the induction of aseptic bone necrosis. Minipigs are now being exposed to long term hyperbaric pressure. The bones will be examined by the methods developed in the initial study. Biochemical tests of bone marrow stress are being performed to aid in detection of the initiation of the disease. To date, blood platelets (cell fragments originating in the bone marrow) of multi-dive minipigs are seen to be decreased, while reticulocytes (red blood cell precursors formed in the bone marrow) have tripled, indicative of bone marrow stress.

The saga of deciphering the pathogenesis and prevention/treatment of aseptic bone necrosis has only just begun. It continues to unfold in the laboratories of many Navy-sponsored investigators. The exchange of information and ideas on this subject that occurred during the Navy-wide workshop in high pressure biomedical research at Groton will probably be highly contributory to progress in overcoming this disorder.

(Continued from Page 13)

display unit. Typical naval uses would be aircraft cockpit displays, and command and control terminals.

The new RADC airborne environment test plasma panels will consist of 512-line plasma panels measuring 8.5 inches square and have a resolution of 60 lines per inch, plus the necessary addressing and sustaining circuitry and power supplies. The term "plasma" stems from the panel's unusual design: a 1/2-inch thick panel comprised of a sandwich of two glass plates separated by a gas which when ionized becomes similar to a plasma.

In the Digivue display/memory panels, metallic conductors are deposited on the two sheets of thin glass. A thin dielectric coating is applied over the conductors, and the plates are mounted opposite each other with their conducting lines at right angles to each other forming a matrix. Digital signals select the appropriate matrix intersection for illumination to form the alphanumeric characters and graphic symbols displayed on the panel. The panel is capable of displaying three colors—red, blue, and green.

Precision Time and Frequency

Robert Stone
Naval Research Laboratory

Of the three fundamental quantities, mass, length, and time, the most closely associated with electronics is time and its reciprocal, frequency. Most people have considered time and frequency separately for so long that they lose sight of the fact that they are inter-related. Time must be thought of in terms of epoch and time interval (frequency). Time and frequency are absolute necessities for all electronic systems and other naval operational requirements.

The Navy must keep time for navigational purposes. To assist in carrying out this function the Naval Observatory in Washington was established in 1843. Over the years the Navy has been instrumental in every major development in the field of precision time and frequency including precision oscillators, frequency meters, synthesizers, and all forms of precision time and frequency measurement controls and disseminating techniques.

NRL has been active in the field of time and frequency since the early 1920's. In the beginning years of electronics, time and frequency were thought of separately. Tuning forks and crystals were used to control frequency; pendulums and other similar devices were used to control time. In the past the state-of-the-art in time and frequency has been a factor of 10 greater in accuracy than was actually needed. Communication during this period was very simple and the time/frequency problems could be very easily met.

A major breakthrough in time/frequency techniques occurred with the advent of the ring crystal in 1930. By 1940, standards capable of maintaining frequency to parts in 10^{-8} and time to 1 msc were available. During this period, operational requirements for precision time and frequency were also increasing. Navigation systems, such as LORAN, were coming into being and digital communication systems required in teletype systems were being introduced. In the 1940's, a number of 0 temperature coefficient crystals were being developed, such as the GT cut crystal in 1942 and the AG cut in 1950.

About 1960, frequency synthesizers were developed which allowed a much more precise control of transmission frequencies. Concurrent with this was the development of stabilized single-side band systems. Prior to this point in history, the techniques which were used were simple and easily understood. Operation and maintenance were performed through intuition. All that was needed of precision time and frequency was sufficient frequency control to hold the signal within the band passes of the system employed.

About 1950, things began to change. More and more precision was being required in frequency and time. The intuitive approach to electronic operation and maintenance began to give way to a greater use of instrumentation. As more systems were developed (such as TACAN, OMEGA, LORAN-C in the navigation area; and use increased of the teletype, stabilized single-side band, higher band rates, and the use of multichannel operation in communications areas), the demand for more precision in time and frequency increased. Figure 1 shows an increase of about an order of 10 in precision for each decade up to about 1950. Somewhere between the 1950's and 1960's, there was an upswing, until the decade between 1960 and 1970 there was an increase of about three orders in the operational need of precision time and frequency. This need is still increasing. With the advent of satellite communication, spread spectrum frequency diversity, and integrated systems, it can be expected that eventually a day will come in which all the precision time and frequency which can be provided by the state-of-the-art will be utilized in operational systems. This point may be reached at some time in the next decade.

The aim of the time and frequency program at NRL is to provide a practical path by which users of precision time and frequency can refer to a common worldwide standard at the Naval Observatory. A hierarchy is envisioned in which the standards are maintained at the Naval Observatory; a long-range means of transfer is provided to various parts of the world; then, branching from these points, there is a short range means of transfer to local time distribution centers which serve the user systems. Any system which utilizes precision time or time interval also has a capability for the dissemination of time and time interval to the accuracy required in the system. The most economical way to transfer or disseminate time and frequency is to utilize those systems which require it. Such a system for long range transfer of time is the Defense Communications Satellite System (DSCS). Utilization of this system on a non-interfering basis will permit the transfer of precision time to about 1/10 microseconds anywhere in the world, which has the proper facilities. Following the same concept, short range and distribution of time and frequency would utilize available communication and navigation systems.

The worldwide dissemination of precision time, as anticipated by NRL, will be introduced into the DSCS satellite system *via* a microwave link from the Naval Observatory. This link at present goes from the Observatory to NRL and Waldorf, Maryland but when the system becomes operational, the link will go from the Naval Observatory to Brandywine, Maryland. Once in the DSCS satellite system, the transfer of time can be accomplished to virtually all major areas of the world. From these points, it is expected that other systems, such as LORAN-

C, OMEGA, VLF, HF, *etc.*, will be synchronized. Plans are being made to extend this hierarchy to the shipyard, the calibration center, and to ship and shore stations. One of the major problems in developing this hierarchy is to determine the users who should receive precision time and to set a system of priorities.

Short range transfer of time will be accomplished by cable, optical link, or microwave link. It is expected that the most extensive method will be the microwave link. Such a link has been established between the Naval Observatory and NRL. The hydrogen masers at NRL can quite effectively be compared with the standards at the Naval Observatory *via* this link. Both a time tick and a 1-megacycle signal are transmitted. Accuracies of 10 nanoseconds can easily be obtained. Although this link is devoted exclusively to the use of time frequency transfer, it is expected that comparable results will be obtained when the time transfer techniques are added to operational systems.

At present, NRL is investigating various operational systems which can be utilized for the short range transfer of time, and it plans to develop techniques to extend the time hierarchy through these systems to the various DOD users.

Ping Interval Found to Affect Sonar Operator Performance

A major goal of designers of active sonar systems is to obtain longer detection ranges, with the consequence being longer time intervals between transmissions. A study has been completed by Human Factors Research, Inc., for ONR in which the effects of transmission interval on operator target detection performance were investigated.

Three transmission intervals were studied: 5, 15, and 35 seconds. Other conditions which were varied were signal-to-noise ratio ("high," +2.6 db; "medium," +0.8 db; and "low," −0.5 db), and number of echoes appearing (2, 4, and 8) in a set of 8 transmissions. Performance measures were percents of targets detected and number of false detections. The study was performed on a general purpose sonar/radar simulator which presented target on a CRT.

Results showed that transmission interval had a significant effect on performance. As the interval increased, the mean percent of targets detected decreased slightly, and the number of false detections increased sharply, especially at low signal-to-noise ratios. A larger number of echoes improved performance, but in this case there was a greater effect on the percent detections than on the false alarms.

These results provide quantitative confirmation of the desirability of time-history or memory type displays with long-range active sonar systems to enhance operator detection performance.

On the Naval Research Reserve

NRRC 9-21, Denver, Colorado

Naval Reserve Research Company 9-21, Denver, Colorado, has structured a program that will better integrate the company into the overall Reserve Program and add to the contributory support role of the Research Reserves. The program includes such activities as:

1. Participation at State and International Science Fairs. Five officers of NRRC 9-21 participated as Navy Judges at the Colorado State Science Fair and two officers at the International Science Fair in Kansas City, Missouri.
2. Drills were increased from 24 to 36 with 12 additional drills through modified scheduling.
3. Sponsored several joint Services/Community drills which included several important members of the civic community, local Army, Navy and Air Force organizations and Reserve officers organizations.
4. Established "project officer" position to monitor and follow up on company and individual projects.
5. Increased recruiting in the civilian research community. (Increased recruiting efforts resulted in a membership increase from 11 to 22 in FY 71.)
6. More emphasis on the conduct of or participation in contributory support projects. Some of these projects are:
   a. Operations analysis (analysis of various aspects local reservists)
   b. Log information on Quick Retrieval System (local project)
   c. Investigate problems of Mandatory Drillers (local project)
   d. Explanatory listing of Naval Reserve Units in local areas (local project)
   e. Prepare History of N&MCRTC, Denver (local project)
   f. Identify elements of Coastal Environment (ONR project)
   g. Improvement of Human Relations Skills—Intergroup Racial Relations (ONR project)
7. Improved administrative procedures that provide for better utilization of members.
8. Other activities such as: Serving on Group Commanders Naval Reserve Policy Board and Counseling Board; dual participation by attending NROS classes; participation in annual competitive training exercises; and family night meetings.

This program and associated Naval Reserve Research Company activities have produced results. The Denver Company was awarded First Place in the Ninth Naval District and, subsequently, nominated for the national General Excellence Award.

Research Notes

Marine Aerosols

A global scientific study of marine aerosols (air-suspended particles in air masses) by the Naval Research Laboratory (NRL) scientists is expected to play an important role in man's future efforts to detect pollution, determine early climate changes, and give weathermen advantages in predicting the weather at sea, where there are few "weather stations."

Dr. Peter E. Wilkniss, principal NRL scientist involved in the effort made the report public, after research proved the chemical composition of the air near the air-sea interface, and marine aerosols, vary widely with geographic location and weather conditions.

By proper chemical identification, he related, different particles (dust, ash, salt) can be traced to their respective sources (continent, volcano, ocean) giving scientists a way to determine air mass movements over the oceans. These results, he added, will aid in weather forecasting and could play a role in weather modification. As an example of future weather modification, Dr. Wilkniss said that techniques developed under this program would enable one to follow the fate of silver iodide crystals used to seed hurricanes in order to weaken their fury.

The NRL scientist voiced an opinion in the report that the results of his current study may also contribute to the general knowledge of the concentration and movement of airborne particulates (aerosols) in the global atmosphere. He said, "In this time of growing controversy over pollution and an impending change of climate (greenhouse effect, new ice age), the chemical monitoring of the relatively clean marine atmosphere will play a significant role for an early detection of dangerous trends."

Activation analysis and atomic absorption spectroscopy, two of the most sensitive analytical techniques known today, are used by the NRL scientists to determine the chemical composition of research samples, sometimes so small they are barely visible.

The over-ocean sampling program by NRL's Ocean Sciences Division is supported by the Office of Naval Research (ONR) for the benefit of the Navy, but results are also said to affect problems of a socio-economic nature, as those noted by Dr. Wilkniss.

The research effort depends heavily on the use of aircraft and ships in the global sampling program. Remotely controlled air sampling equipment is suspended from the wings of Navy aircraft, flown by NRL pilots, to scoop up the samples.

The Laboratory's modified aircraft includes an SD2 which can perform routine sampling at altitudes as low as 100 feet above the ocean surface. The other aircraft, an EC 121, laden with scientific gear has worldwide capabilities in obtaining scientific data by a variety of techniques. Two oceanographic research ships, the USNS MIZAR and the USNS GIBBS, have been used in sampling operations in remote ocean areas and on extended cruises.

Bone Fracture Healing by Electricity has First Human Success

The February 1971 issue of Naval Research Reviews reported that animal experiments had demonstrated how electric currents can make bone fracture heal faster. The principal investigator, Dr. Carl Brighton, has now reported the first success of the technique with a human. The research is being conducted by the University of Pennsylvania Medical School in conjunction with the Philadelphia Naval Hospital under a contract with ONR, with funds provided by the Bureau of Medicine and Surgery.

The research study has revealed that the bone ends, where bone grows, are normally electronegative but that the rest of the bone is much less so and, in fact, the midpoint is slightly positive. When there is a fracture, however, this gives the entire bone surface a negative charge, which is strongest at the fracture site. As the bone heals, electrical activity returns to normal. It was found that the application of ten microamperes of electrical current—with the negative wire on the fracture—produced faster healing of fractures.

The technique was tried on a 51-year old woman who had fractured her ankle two years previously, but the ankle had failed to heal properly. A small negative wire was inserted into the fracture under local anesthesia and a positive wire taped to the skin. A cast was applied and the wires brought through the cast and attached to a 7.5 volt battery. The current was applied for nine weeks. After two weeks, the patient stopped using crutches and has had no problems since. This result occurred even though the fracture was displaced and separated by thick fibrous tissue. It is estimated that it will be at least a year before the technique can be perfected for general use.

ONR Appoints New Director of Research

Dr. Elliot H. Weinberg has been appointed Director of Research for the Office of Naval Research. He previously served for four years as Director of the Physical Sciences Division, ONR. Earlier assignments included service as Chief Scientist, ONR Branch Office, San Francisco, and scientific liaison officer, ONR London. His new position involves supervision of the ONR research program conducted under contract at universities and research laboratories throughout the country.

Dr. Weinberg received his Ph.D. in physics from the University of Iowa in 1953 following completion of B.S. and M.S. degrees at the University of Michigan. Prior to joining ONR in 1962, Dr. Weinberg served as Chairman of the Physics Department at North Dakota State University and earlier on the faculty of the University of Minnesota. His special field is laser research and technology.

ONR's New Comptroller

"One of the highest paid women in the government," said Secretary of the Navy, John H. Chafee as he congratulated Mrs. Mary H. Ferguson upon becoming the Navy's and ONR's first woman comptroller. Her promotion caps a 37 year record of government service that began in December, 1933, when she started as a clerk typist with the Farm Credit Administration.

As ONR's Comptroller, Mrs. Ferguson also acts as Special Assistant (Financial Management) to the Assistant Secretary Navy (Research and Development). In her new role she also becomes one of 93 "quota supergrades" within DoD according to ONR Personnel information. She also becomes one of 37 women in government with a GS-17 rating according to Civil Service Commission statistics for 1969.

Just recently, Mrs. Ferguson was selected "Woman of the Year in Comptrollership" by the American Society of Military Comptrollers at their annual symposium.

Infrared Detection by a Continuous Gas Discharge

A decrease in the light output from electrical discharge tubes filled with helium, neon, argon or xenon when the gas is irradiated with infrared has been observed by Professors H. Merkelo and L. Goldstein at the University of Illinois. Formerly, only infrared radiation incident on the gas after the excitation had been turned off was seen to have an effect:

it reduced the afterglow. Reduction of light output by a gas tube under *continuous* direct-current excitation greatly increases the usefulness of the effect because one has a continuous detector of infrared rather than one with only a pulsed duty cycle. Both effects have appeal since they provide infrared detection in a device which operates at room temperature, unlike photoconductive and photovoltaic detectors which require cooling by liquid nitrogen or liquid helium.

Navy Studies Moving Submarine Electronics Outside Pressure Hull

The Navy is studying the possibility of moving a submarine's electronic equipment into the space between the pressure hull and the outside shell or fairings. The concept requires that electronic hardware be made ultrareliable so that it would not fail during an entire mission since repair or replacement while underway would be impossible.

The study is being conducted by the Raytheon Corp. under a contract with the Office of Naval Research. The twofold objective is to investigate the apparent advantages offered by the concept and to examine some of the problems to be solved before it could become a reality.

The chief advantage of this concept would be the elimination of present space requirements needed to accommodate electronic equipment inside a submarine. There would also be no need of a cooling system to dissipate the considerable heat generated by electronic hardware. Since external components will not permit periodic preventative or corrective maintenance, fewer electronic technicians would be needed with a consequent reduction in crew size.

Another result of external components is a reduction in space requirements permitting a smaller pressure hull. This would contribute to the eventual design of submarines that are smaller, modular and capable of greater depths and speed. Other benefits would also result, such as added buoyancy and easier replacement of equipment and reduced turn around time while in port.

Preliminary results of the study indicate the concept is feasible. Several problems, however, remain to be solved, particularly in the area of achieving ultrareliability. This involves the design of electronic systems that not only are long lived but can also withstand shock and vibration and are unaffected by changes in pressure and temperature.

Gas Bearing Technology Development

A recent breakthrough in commercial computer development announced by the Ampex Corporation, is the direct outgrowth of air bearing technology evolved under two ONR contracts; one with Ampex Corporation and the other with Columbia University. The Ampex Terabit Memory System (TBM) is a massive digital memory system with a capacity of up to 400 billion bits on line (equivalent to that of 30,000 computer tapes). TBM uses standard 2-in. wide video tape, with data recorded in block format and each individual block identified by a unique address. Rapid random access to any record is achieved by performing block address searches at tape speed of 1000 inches per second—both forward and backward. The success of the system is keyed to the multiplicity of air bearings used throughout the system for the extremely high speed tape transport, tensioning devices (vacuum chambers), and read/write heads. The air bearing research under the above two tasks, coupled with Ampex video recording techniques, enabled the breakthrough demonstrated by the TBM system. It is felt that the TBM provides an economical approach to massive data storage and retrieval problems.

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Navy Study Makes Possible Improved Crash Helmets and Protective Padding

The design of a crash helmet that could greatly reduce head injuries has been made possible by a study conducted by a Navy scientist.

The study involved the development of a mathematical model of the forces that result in skull fracture. The model, developed by Dr. Nicholas Perrone of the Office of Naval Research, also predicts how different forces interact with different areas of the skull to produce the fracture.

Previously the design of efficient protective headgear has been stymied by the lack of such analytical data. The model now makes it possible to design greatly improved crash helmets as well as the padding of areas where the head may possibly impact, which should result in a reduction in the number of head injuries. The validity of the model was established by Dr. Perrone by comparing it with experimental findings on cadavers in which skull fracture was impact initiated.

Development of the model was spurred by Department of Defense and Navy concern over the great number of head injuries involving DoD Personnel, and the insufficient protection afforded by present headgear.

A great number of Navy Personnel, such as pilots and drivers, are potential victims of skull fracture. It is estimated that two out of three vehicular fatalities involve skull fracture. In the last decade, the Department of Defense has lost more men to head injuries than to combat action.

Although the wearing of protective headgear has diminished the number of head injuries, crash helmets now in common use afford limited protection. The reason is that their design is based solely on empirical experience and does not take into account the dynamics of skull fracture or the individual differences of people. For instance, a helmet that may afford good protection to an adult may be inefficient for an adolescent. Furthermore, even within an age group there are differences in head structure which should be accounted for in the design.

Besides providing the basis for design improved helmets as well as protective padding, the model may some day give the answer to reducing the number of "closed brain" injuries. These are injuries to the brain resulting from the shock of collision without resulting in fracture.

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 109, Office of Naval Research, Arlington, Va. 22217. Requests for subscriptions should be directed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.75 per year in the U.S. and Canada; $2.25 per year, foreign; $0.20 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

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