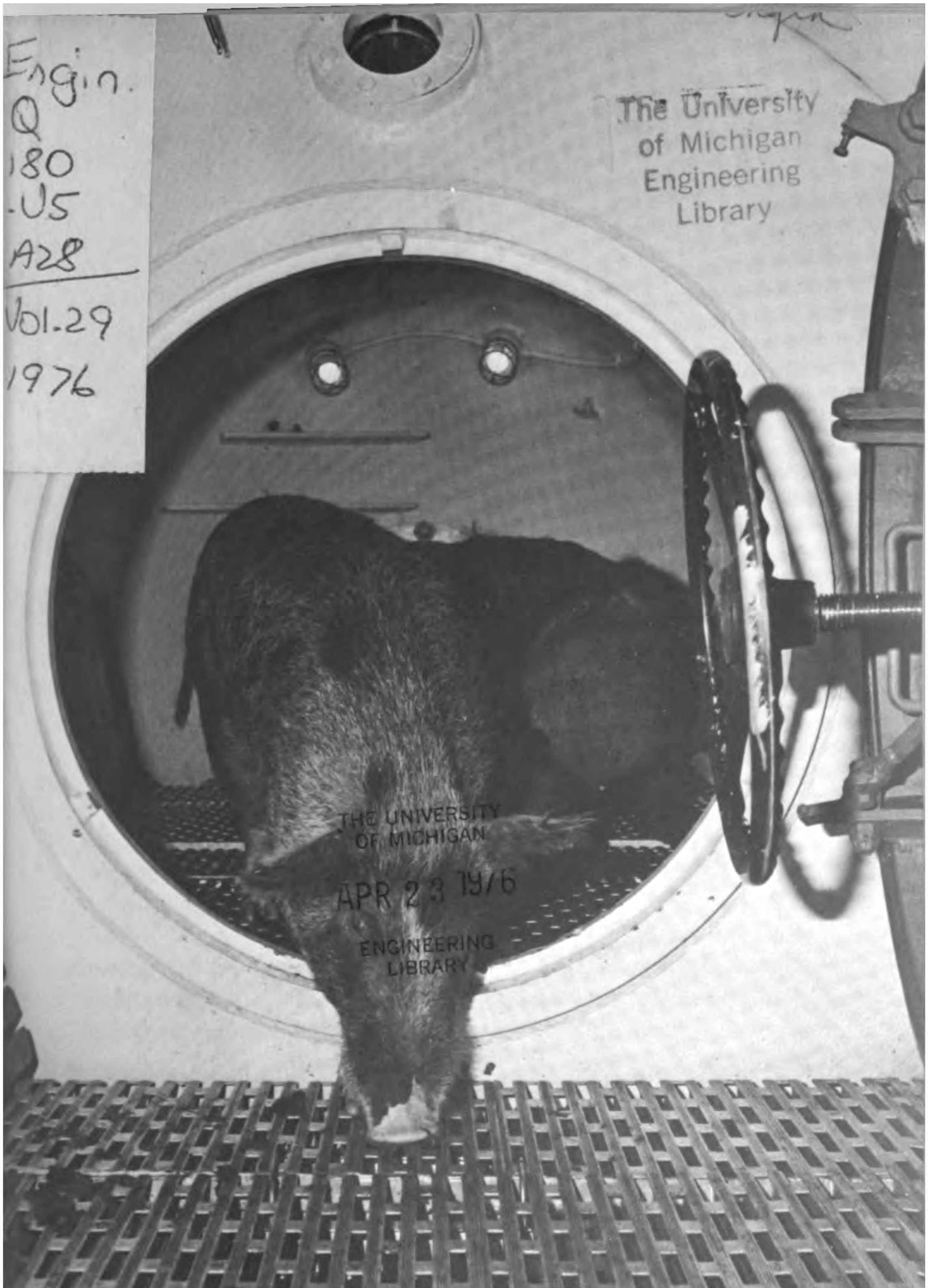
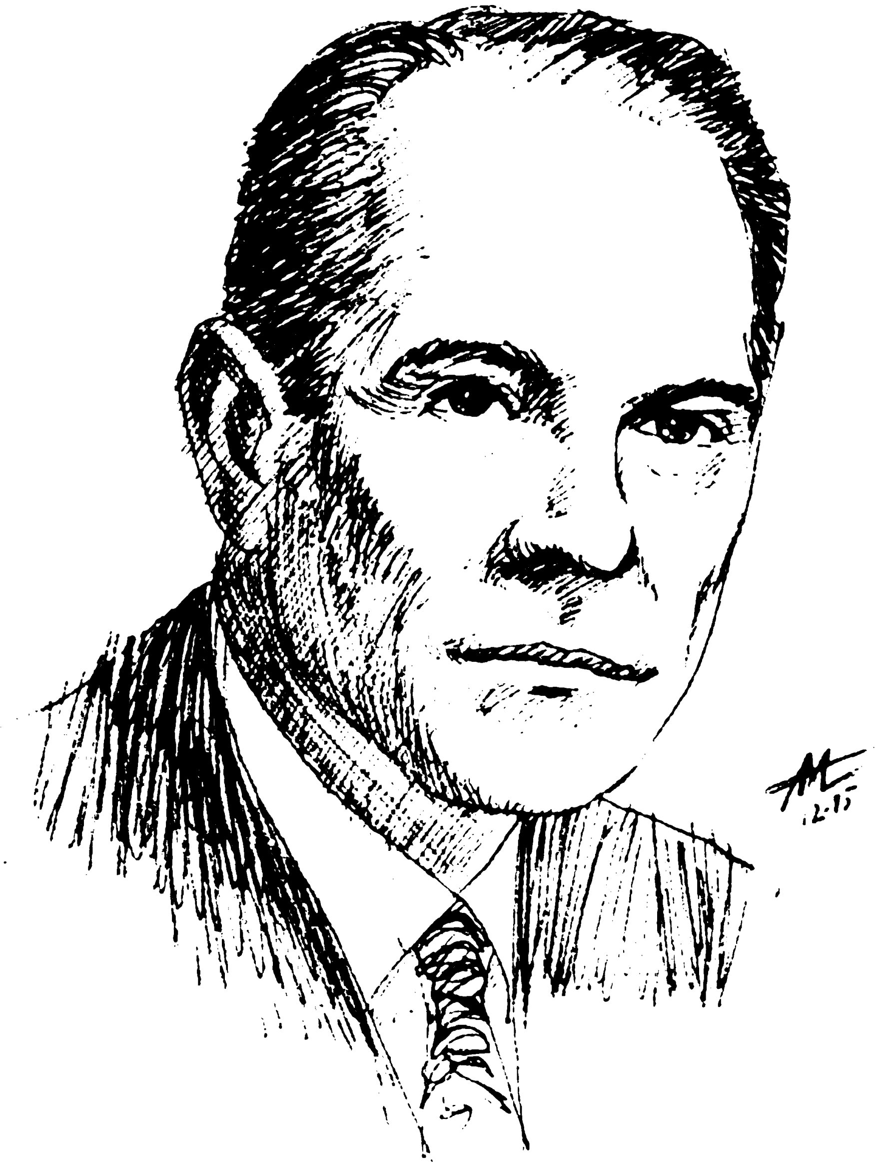


NAVAL RESEARCH REVIEWS

JANUARY 1976

PROFILES IN SCIENCE



Dr. Benton J. Underwood

Dr. Benton J. Underwood is Professor of Psychology at Northwestern University, Evanston, Illinois. His research has centered on problems of human learning and retention, with particular emphasis on the mechanisms involved in long-term forgetting. Underwood is credited with the discovery of the importance of proactive interference as a cause of forgetting. Along with two of his graduate students he developed what has become known as *frequency theory*, a theory found useful in accounting for performance on tasks measuring recognition memory. Since 1950 Underwood's research has been supported by the Office of Naval Research. This research has resulted in the award of the Warren Medal by the Society of Experimental Psychologists, the Distinguished Scientific Contribution Award by the American Psychological Association, and election to the National Academy of Sciences.

The Etiology and Course of Decompression Sickness

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The term decompression sickness applies to the abnormal signs and symptoms that may appear in man following reduction of his environmental pressure. Commonly known as the bends, this condition has in the past also been called caisson disease and compressed air illness. Each change of ambient pressure associated with diving brings problems of physiological and biochemical adjustment, some relatively inconsequential, some potentially serious. Even when the reduction of pressure, decompression, is carried out in a controlled manner, one or more of the wide range of symptoms known as decompression sickness may be produced. Few decompression profiles now in use can be considered absolutely safe in spite of many years of attempts to solve the perplexing decompression problem. Until the exact cause and the pathophysiologic course of decompression sickness are well defined, the solution to the problem will continue to be as elusive as it has been for the past one hundred years.

The situation is complicated by uncertainties which remain regarding inert gas uptake and elimination and appropriate ascent criteria. Diving profiles must be based on knowledge of man's physiology. Two questions must be answered: 1) how fast does the body take up and/or eliminate inert gases, and 2) how fast can the body be safely decompressed? Much current research, some of which is discussed below, focuses, in one way or another, on these two questions.

Although the fundamental physics and physiology of decompression have been generally understood, there still is insufficient knowledge and understanding to indicate the best practical approach to be used to formulate safe decompression procedures, and there is uncertainty as to how best to effect treatment. Recent evidence indicates that gas emboli ("bubbles") are present in divers using "acceptable" decompression schedules and that such separated gas has a variety of hematological, vascular and tissue effects, any of which may not be sufficient to produce symptoms.

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Pain in one or more large joints is the most common clinical manifestation of decompression sickness. As early as 1854 it was noted that these pains were relieved by returning the suffering person to the raised pressure environment and it was suggested that the pain was due to bubbles formed when the pressure was reduced (1). This hypothesis has not been invalidated to this date.

Whether the cause of an inadequate decompression is an error in decompression theory, an error in decompression practice, or an anomalous response of the individual, minute quantities of separated gas (bubbles) are thought to form, coalesce and grow, exert pressure on sensitive tissue, interact with the hemostatic mechanism, damage vascular endothelia and/or occlude some part of the circulation. The presenting symptoms may be sudden and dramatic, involving vital centers, or delayed, localized and merely uncomfortable. Secondary effects of tissue damage and edema may be superimposed on this picture.

Gas Uptake and Elimination

Since Haldane first proposed a systematic method for calculation of decompression tables, it has been assumed that the body saturated and desaturated "symmetrically," that is, both processes could be described by the same mathematical function. This was challenged by Hempleman (2) on the basis of a number of repetitive dive experiments with goats, which indirectly suggested the presence of "silent bubbles," a factor long suspected to require consideration. Theoretical predictions indicated that non-symmetry in uptake and elimination would be expected if bubbles were present during a decompression, because gas equilibration depends on the presence of a gradient in pressure, which bubble formation would eliminate.

Le Messurier and Hills (3) further stressed this idea, and cited both physical experiment and unusual diving practices of native divers in the Torres Straits as evidence (4). However, up until 1967 no experiments sufficiently direct to be conclusive had been undertaken on surviving animals or man to demonstrate either that gases were eliminated differently during decompression, or that bubbles were present in tissues and/or blood. Work in this laboratory from 1967 to 1974 has provided significant answers to both these questions.

Studies by Spencer and Campbell (5) demonstrated an effect of certain bronchodilation drugs in lessening the incidence of decompression sickness in guinea pigs. Although the decompressions were extreme, they demonstrated the importance of physiological and pharmacological variables in the pathogenesis of decompression sickness. Over the past three years our studies have provided estimates of gas uptake and elimination rates in awake dogs by direct analysis of mixed venous blood inert gas content after compression and decompression. It has been found that a decompression from saturation at only 33 feet of sea water (fsw) to the surface, previously supposed to be safe, produces a difference in the *apparent* rate with which N_2 is being cleared from the tissues to the blood. This is shown in Figure 1 where observed uptake and elimination rates are compared.

The result is of major significance to the formulation of decompression procedures, since it indicates that the decompression itself is decreasing the rate of gas elimination, thus "trapping" gas in the diver. While these studies were proceeding, other investigations were underway

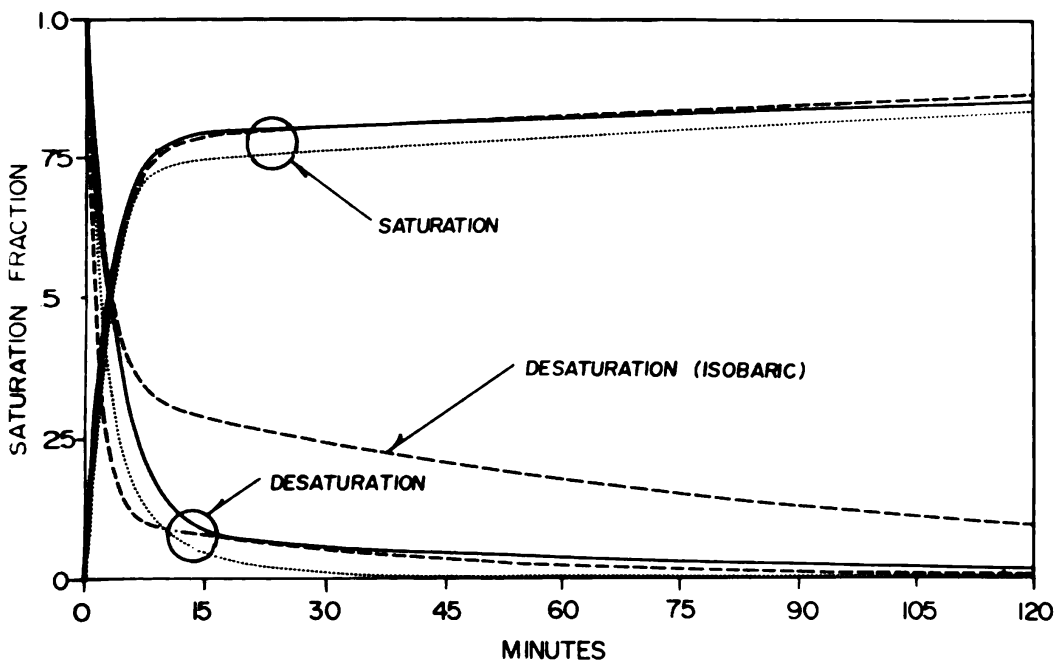

Figure 1 — Fractional state of N_2 saturation of mixed venous blood (V) sampled from the pulmonary artery of awake dogs versus time following compression to and decompression from 33 (-----), 66 (·····) and 99 (————) feet of sea water (fsw). Curves are based on computer fit of data to the equation

$$Y\ (= N_2\ \text{content}) = B_1 e^{-k_1 t} + B_2 e^{+k_2 t}.$$

The similarity of all uptake (increasing) curves and all desaturation (decreasing) curves in spite of the different pressures involved lends support to the data. The dissimilarity of saturation and desaturation curves as a group suggests the effects of decompression on desaturation. The mixed venous blood appears to desaturate much more rapidly than it saturates. However, calculation of the quantity of N_2 which could be removed by the venous blood in any given time indicates that much N_2 remains in the animal. The similarity of the form of the isobaric desaturation curve to the saturation curves indicates that decompression per se induces the alteration in elimination rate. In this case the absolute pressure was 33 fsw (1 atmosphere) and the desaturation was accomplished by suddenly switching the breathing gas to 20% O_2/80%He in a tracheostomized awake dog. Only the isobaric desaturation shows the theoretically predicted symmetry with saturation.

in this laboratory attempting to demonstrate the actual presence of bubbles.

Detection of Separated Gas

Since decompression sickness was identified with the unphysiologic evolution of gas from body stores in the form of bubbles, techniques for the ultrasonic detection of gas bubbles in tissue and blood were attempted that would allow their acoustic visualization. The presence of bubbles in an asymptomatic diver was suspected (6) but not demonstrated until their ultrasonic visualization (7).

Serendipity played a part in the initial usage of the doppler ultrasonic instrument in the detection of bubbles. During a visit to the United States in 1968 by Dr. Dennis Walder of the British Medical Research Council Panel on decompression, Dr. Merrill P. Spencer, then of the Virginia Mason Research Center in Seattle, Washington, was demonstrating a doppler ultrasonic blood flow monitoring device to Dr. Walder. Dr. Spencer's comment that bubbles present in the flow stream during blood flow measurement significantly disturbed the signal, alerted them to the potential for detecting the separation of gas in the bloodstream following decompression. Development of the instrument in several laboratories has taken place since that time (Figure 2) (7,8,9,10).

In early doppler studies, bubble signals were demonstrated in the large vessels returning blood to the heart of a sheep. These signals preceded any sign of decompression sickness (7). Other studies demonstrated that the longevity and sometimes the character of the "bubble signal" were not entirely consistent with the existing models of stability of bubbles in the vascular system (11). It was suspected that as a result of the interaction of whole blood and air, coagulation particles in the cardiovascular system were being detected by the doppler system. We have subsequently demonstrated in this laboratory that separated gas is indeed present in many "successful" decompressions and have observed other hematologic changes which suggest that this gas may have an effect on hemostatic function and possibly on the integrity of the blood vessels (12).

Blood-Bubble Interaction

Agglutination, or the clumping of red cells, in decompression sickness was considered as early as 1937 by Dr. Edgar End, but more recently it has been demonstrated that in severe decompression sickness with intravascular bubble formation, microthrombi involving blood platelet

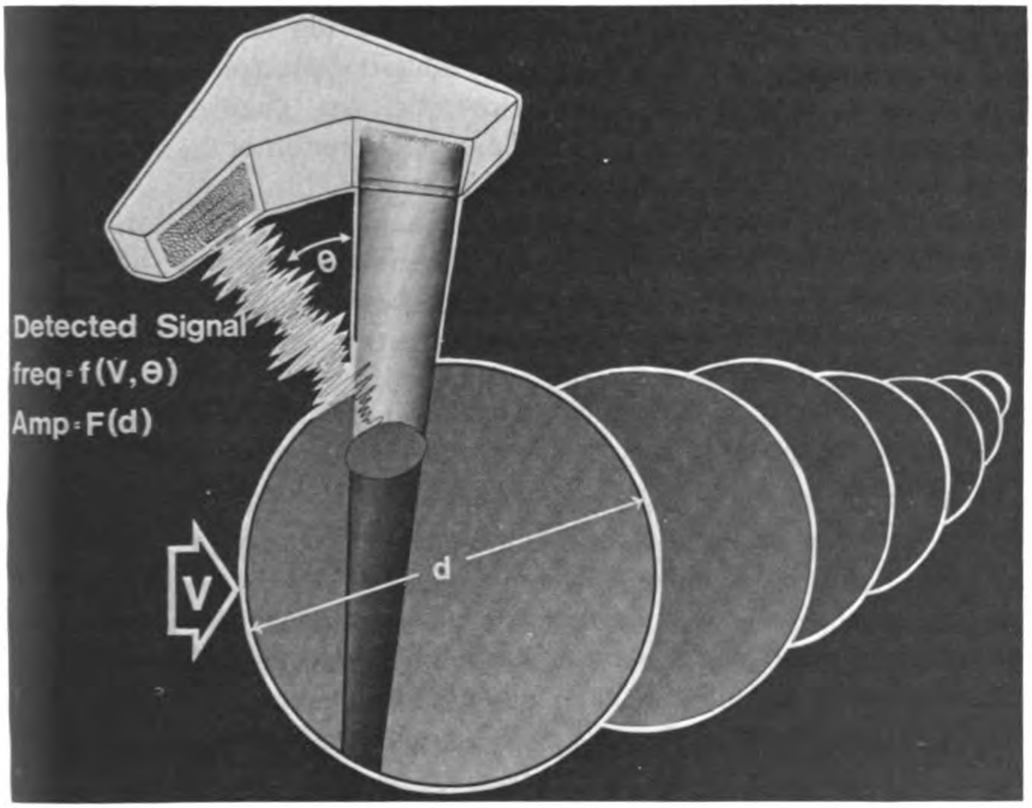

Figure 2 — Schematic illustration of ultrasonic doppler bubble detection of gas emboli in pulmonary artery or other vessel. Coherent ultrasonic energy at 5 mHz is shown beamed from one piezoelectric barium titanate crystal into the vessel through the body wall. Detection of the reflected signal of 5 mHz ∓ the doppler shift of 500 - 2000 Hz is accomplished by the other equivalent crystal mounted at an appropriate angle to the first. Appropriate electronic circuits detect and display the doppler shift frequency. The latter is a function chiefly of the incident angle and the velocity of the reflecting element, while the amplitude is a function chiefly of "d" and other geometric factors. When a bubble or particle of different acoustic frequency passes through the insonified regions, a characteristic frequency/amplitude combination or audible "chirp" appears in the reflected signal which depends on the particle size, velocity and position in the sonic field. These events can be detected electronically and—by imposing certain types of signal processing—counted. The result is a valuable tool for evaluating the safety of new and existing decompression procedures.

(minute circulating particles active in the formation of thrombi) aggregates occurred in a manner similar to that seen in disseminated intravascular coagulation (13,14,15). Platelet and red blood cell aggregates were seen in the vessels of rats that had decompression sickness and in pulmonary vessels of rabbits intravenously infused with air. Rats with artificially elevated platelet counts were shown to have an increased incidence of the bends following decompression (15).

Interaction of platelets with surfaces was thought to be an important stimulus in the initiation of coagulation when intravascular bubbles were present (16,17). Contact of platelets with surfaces has been shown to lead to release of their constituents, which causes platelet aggregation and production of a platelet mass without the precipitation of blood coagulation (18,19,17,20,21,22). However, the platelet mass may then serve as a focus for the initiation or acceleration of the coagulation mechanism and lead to the formation of thrombi (23).

Many constituents which may be released by the platelet, and air infusions into the blood stream can produce hypotension or a lowering of blood pressure (24). One of these, the vaso-constrictive substance serotonin, can be expected to play an important role in hemodynamics subsequent to lung vessel aero- or thrombo-embolism (25). The circulating gas bubbles from decompression sickness are surely destined to end up in some filtering organ such as the lung or liver and thus become emboli, causing local and systemic hemodynamic effects. These are now thought to be part of the overall pattern of decompression sickness.

Other hematologic studies have confirmed that hemostatic abnormalities occur following asymptomatic hyperbaric exposure (12,26). The finding of both increased platelet and fibrinogen (a blood protein which causes coogulation of the blood) utilization in the immediate post-dive period suggested that a condition of intravascular consumption of hemostatic factors was produced by diving. More than a single mechanism was suspected of producing the increased platelet and fibrinogen consumption because fibrinogen survivals returned to normal by the end of the first week following the hyperbaric exposure, and the continuing abnormality involved only platelet consumption. Since earlier in the study there was some histologic evidence of endothelial damage, the persisting shortened platelet survival was thought to be the result of response to vessel damage. The prolonged time necessary for platelet survivals to return to normal appeared to reflect the time required for healing of the damaged vascular endothelium or vessel lining.

The Lung and Blood-Bubble Interactions

The presence or absence of bubbles is clearly an important factor which must be considered as potentially modulating, physically and physiologically, the rate of gas elimination from the tissues and the lungs (4,8). There is also the possibility that separated gas in tissues can produce local reactions, not only changing local blood flow but also mobilizing whole body responses. Therefore, it is not difficult to imagine that the occurrence of pulmonary gas embolism, either from decompression sickness or aero-embolism, could cause the lung to change cardiovascular and ventilatory patterns. In addition, platelet aggregates and/or thrombo-emboli can also affect the lung in this way.

We should emphasize here the complicated interrelationship of both physical insult (the inadequate decompression) and physiologic response (the body response) which is taking place during decompression sickness. There is an urgent need for an integrated research approach to these problems.

Bubbles, Blood and Vestibular-Auditory Dysfunction

Diving induced deafness and vestibular dysfunction have recently been recognized as important problems in individuals exposed to compressed gas atmospheres, especially those involving deep exposures, especially when more than a single inert gas is employed (27,28,29,30). The condition encompasses, however, almost every phase of human diving from breath hold and shallow air scuba dives to deep saturation helium/oxygen dives. Hemostatic and thrombotic problems have been proposed as the potential causative factors.

In this context, it is interesting, with respect to the condition of aseptic bone necrosis described below, that hemorrhage in the fluid present in the inner ear, has been correlated with the incidence of vestibular attack and the subsequent cochlear-auditory dysfunction in dived animals (31). It was noted that animals subjected to the same helium/oxygen dive conditions, but not having attacks, did not show hemorrhage in the inner ear. Until such time as we know the cause of the hemorrhage or the gas exchange characteristics of these sensitive and important organs, vestibular and auditory problems will continue to be a diving hazard.

Aseptic Bone Necrosis

This condition, perhaps better called dysbaric osteonecrosis or avascular bone necrosis, is thought to be a latent sequela of inadequate decompression manifested by localized destruction of selected long bones in the body and is apparently associated in part with function of the hemostatic mechanism. This has been studied extensively in this laboratory (32,12,26). Coagulation studies, done on animals in which aseptic bone necrosis was produced by compression/decompression exposure, have demonstrated a significant reduction in platelet and fibrinogen survival times. Platelet function inhibitors (one of which is aspirin) and anticoagulants were used, attempting to prevent the hemostatic changes and the necrosis; however, in those treated animals avascular necrosis was produced in a shorter period of time with fewer compression/decompression episodes. One hypothesis possibly explaining this event includes a hemorrhagic infarct at the site of the lesion as the result of endothelial damage. This hypothesis is strengthened by the fact that aseptic bone necrosis is also a sequela in man to a variety of diseases unrelated to diving, including certain bleeding disorders.

The most common pain associated with decompression, deep bone pain, is also experienced by sickle cell crisis patients. In the latter individuals there is a known impairment in blood flow which is treated with some success by agents which appear to benefit decompression sickness victims. This blood flow impairment, due to a "sludging" of the blood elements, has been demonstrated in decompression sickness and has been successfully treated by the infusion of low molecular weight dextrans and heparin (33,13,34). These agents, by their diluting action, platelet function inhibiting action, anticoagulation function, and lipemic clearing action, can establish a more normal blood flow in the affected area and thereby reduce the pain and perhaps prevent further damage.

Effects of Pressurization

In addition to the problems of decompression, the response of the body to pressurization itself is not well understood. It has now been demonstrated that fluid and electrolyte balance between blood and tissues can be affected by compression and decompression. The precise mechanisms of these shifts are not yet known, and, although gas-induced osmosis has been suggested as a mechanism for such fluid shifts, experimental evidence is scant and open to alternative interpretations. It is probable that such changes in fluid balance can significantly affect the result of subsequent decompression, but again plausible mechanisms have only been suggested, not demonstrated.

While any of the above may not necessarily be life threatening or even produce a long term pathological consequence, they are nevertheless flags which should caution us lest we become too absorbed in our theoretical perambulations to acknowledge the fact that we don't know what is really happening. It therefore must be realized by the diver, his employer and society at large that decompression hazards are not necessarily the result of negligence but rather are the result of inadequate knowledge. This part of the risk and hazard of diving will remain until such time that certain fundamental concepts of inert gas uptake and elimination, bubble formation and the pathophysiological consequences of inadequate decompression are demonstrated, defined and understood.

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Natural Language Access to a Large Data Base

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Introduction

A prime obstacle for non-technical people who wish to use computers has been the need to either learn a special language for communicating with the machine or communicate via an intermediary. We feel that the time is ripe for computers to be equipped for natural language systems which can be used by persons who are not trained in any special computer language. In order for such systems to be of value to a casual user, the systems must tolerate simple errors, must embody a degree of "common sense," must have a relatively large and complete vocabulary for the subject matter to be treated, must accept a wide range of grammatical constructions, and of course must be capable of providing the information and computations requested by the user.

Researchers at the University of Illinois Coordinated Science Laboratory are developing such a system called PLANES (for Programmed LANguage-Based Enquiry System) under ONR sponsorship. PLANES includes an English language front end with the ability to understand and explicitly answer user requests and to carry on clarifying dialogues with him, as well as the ability to answer vague or poorly defined questions. We are also building a library of associated programs which includes functions for recognizing patterns within the data base and for alerting a user when certain patterns of data occur which are of interest to him. This work is being carried out using a subset of the Navy 3-M data base of aircraft maintenance and flight data, although the ideas can be directly applied to other record-based data bases, both military and non-military.

Historical Perspective

Systems which retrieve information requested in English from a data base have long been a subject of interest for computer scientists. For

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example, BASEBALL [1], written in 1961, answered questions about baseball data containing month, day, place, teams and scores for each game in the American League for one year. In this limited context, a very small vocabulary was sufficient, and relatively few types of questions could be asked at all. Furthermore, a user's language was severely constrained. Sentences could contain no dependent clauses, no logical connectives (like *and*, *or* and *not*), no constructions with relations like *highest* and *most*, and no reference to sequential facts, as in "Did the Red Sox ever win six games *in a row*?" Some examples of questions BASEBALL *could* answer are:

Who did the Red Sox lose to on July 5?
Did every team play at least once in each park in each month?
What team won 10 games in July?

BASEBALL operated by parsing its questions, and then transforming the parsed question into a standard "specification list." The question-answering routine took this canonical form as the meaning of the question. Thus "Who did the Red Sox lose to on July 5?" was transformed into the specification list:

Team (losing) = Boston
Date = July 5
Team (winning) = ?

Aside from its grammatical limitations within its domain of expertise, BASEBALL had the following limitations:

1. it could only be extended to new domains by extensive reprogramming,
2. it either understood a sentence fully, or did not understand it at all — no provision was made for saving partially understood sentence portions or for interacting with the user to ask clarifying questions,
3. it could not understand pronoun reference,
4. it had no ability to accept declarative information; it was not possible to add to its data base by telling it "The Red Sox beat the Yankees on July 10."
5. A user could not add procedural information, e.g. one could not add to its linguistic ability, nor could one give it advice in any form.
6. Because its universe of discourse was so limited, BASEBALL's writers simply never had to worry about handling ambiguous requests.

In contrast, there exist programs today which exhibit all of these abilities that BASEBALL lacked, at least to some degree. I will briefly describe two such programs, those of Woods et al [2] and Winograd

[3], and will then describe our work on PLANES. A number of references to other related work are provided at the end of this paper for readers interested in learning more about this area.

Woods' LUNAR System

The LUNAR system [2], written by William Woods and a number of coworkers at Bolt, Beranek and Newman, Inc., answers questions about a fairly large data base of samples of lunar rocks and soils. While the data base, like BASEBALL's data base, contains only a small number of data types, the LUNAR system is much more flexible than BASEBALL, most dramatically in its linguistic ability.

It is able to accept grammatically complex sentences, involving nested dependent clauses, comparative and superlative adjective forms and some types of anaphoric reference. As examples, Woods' system can answer all the following questions:

> What is the average concentration of aluminum in high alkalai rocks?
> Has the mineral alalcite been identified in any lunar samples?
> What are those samples?
> Give me all model analyses of lunar fines.
> List the rocks which contain chromite and ulvospinel.
> What minerals have been identified in lunar samples?
> What is the concentration of La in rock S10034?

LUNAR was demonstrated at a geology conference only six months after work had begun on the project; the system was able to answer 78% of the questions solicited from the audience, and was judged to be able to answer 90%, save for bugs remaining in the program code.

Woods' system uses an augmented transition network (ATN) to parse sentences [4], and then generates a formal query by patching together the code fragments which represent each phrase in the sentence. Like BASEBALL then, it attempts to produce something like a specifications list, except that it has a much large r set of lists to choose from, and is more clever about concatenating them.

Winograd's SHRDLU

A program called SHRDLU [3] completed in 1971 by Terry Winograd at the Artificial Intelligence Laboratory, MIT, is able to answer questions, some quite complex, about a simple data base representing a visual scene in a blocks world (see figure 1). SHRDLU can display its world on a CRT screen, and simulate the manipulation of blocks in the world

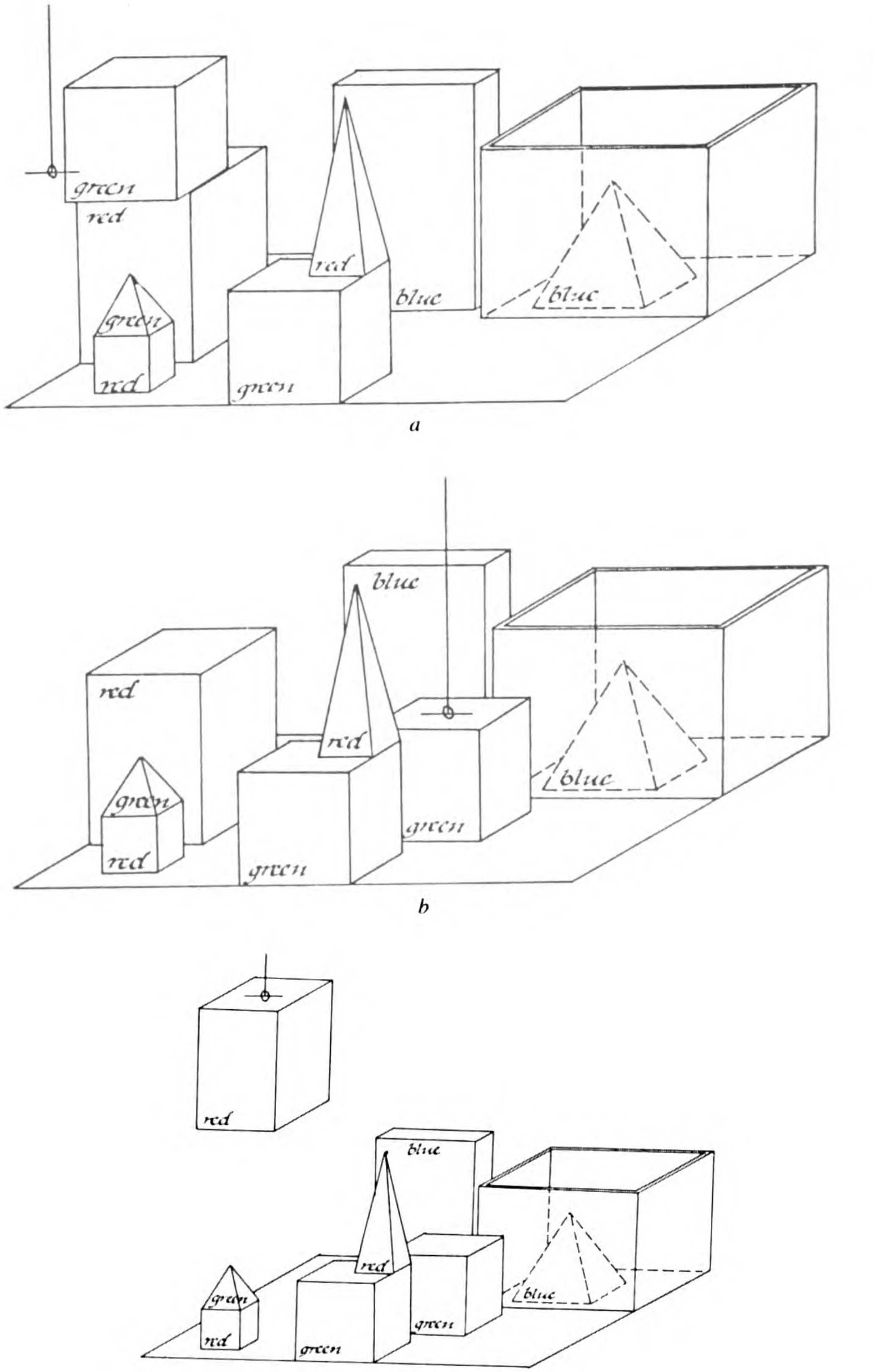

Figure 1 – Block world

with its own "hand." In addition to questions SHRDLU can understand declarative sentences (e.g. "I like blue pyramids") and imperative sentences ("Pick up a red cube") as well as procedural statements (e.g. "A *steeple* is stack containing two green blocks and a pyramid.") SHRDLU keeps a record of its goals and subgoals, so that it is able to carry out dialogues like those below, given the sequence of actions from figure 1.

User: Why did you pick up the green block?
SHRDLU: To get rid of it.
User: Why did you do that?
SHRDLU: So I could pick up the red block.
User: Why did you do that?
SHRDLU: Because you asked me to.

Furthermore, it records declarative information in a form that allows it to use the information either to answer questions or to carry out instructions. Thus, after being told what a steeple is (as above) a user may ask "Are there any steeples on the table now?" to which SHRDLU will answer "yes" or "no" appropriately, using the procedural information to check for an instance of a steeple in the data base. Alternatively, the user may say "Build one," in which case SHRDLU will do so, using the same definition to construct a program to carry out the building of the structure.

SHRDLU can carry out a dialogue with a user to disambiguate sentences. For example, if asked "Are there any purple pyramids on the red block?" it may in turn ask the user "Do you mean 1. directly on top of or 2. supported by?" unless the answer in both cases is "no."

Finally, as illustrated throughout this section, SHRDLU can handle pronoun and phrase reference (e.g. "Why did you do *that*?" "Build *one*.") and it can accept arbitrarily complicated sentence structures. (E.g. "Does the shortest thing the tallest pyramid's support supports support anything green?")

SHRDLU does this by interpreting all sentences as procedures (i.e. programs) which are then executed to search its data base, or to run block manipulation programs, or to generate new programs. It uses MICROPLANNER [5], a programming language designed especially to make it easy to find items which satisfy a goal, like (GOAL (?X IN BOX)), either by searching the data base for an item?X which is in the box (pattern directed data base search), or by calling programs which will change the scene and data base so that there is some item ?X, in the box (pattern directed procedure invocation). MICROPLANNER also contains facilities for automatic backup, so that variables can be assigned tentative values which can later be taken back if they do not work out. Thus, the MICROPLANNER program shown below represents the English sentence "Pick up any yellow block in the box which supports a pyramid;" the program will automatically try various values for ?X and ?Y until it either succeeds in satisfying all the goals, or until it has exhausted all possible choices for ?X and ?Y.

```
(GOAL (?X IN BOX))
(GOAL (?X IS-A BLOCK))
(GOAL (COLOR ?X YELLOW))
(GOAL (SUPPORTS ?X ?Y))
(GOAL (?X IS-A PYRAMID))
(GOAL (PICK-UP ?X) (USE FUNCTION-PICK-UP))
```

The PLANES System

Like LUNAR, PLANES [6] is designed to operate on a real data base, but PLANES operates on a much larger data base with a wider universe of discourse. In addition, PLANES will perform much more complex data base operations, and is able to use strategy in searching.

To provide an idea of our long range goals, a sample examplified scenario of what we hope to be the eventual operation of our system is given below:

User: How many Phantoms required unscheduled maintenance in April 1975?

PLANES: 30 Phantoms. Do you want to see them?

User: No. Did any of these require radar maintenance?

PLANES: Yes, three of them. Do you want to see them?

User: Yes.

PLANES: Phantom 159829 required a new radar screen.
Phantom 159772 required a new power supply.
Phantom 158336 crashed as a result of radar failure.

User: Did any other planes crash?

PLANES: I assume you mean during April 1975.
Two other planes crashed: a Phantom and a P3.

User: Is it true that in both cases and April flights occurred while on the fuselage?

PLANES: I cannot understand your question it is non-grammatical and meaningless.

User: Is it true that both Phantoms were fron the same squadron?

PLANES: I assume you mean "from" instead of "fron."
Yes, both planes were from the same squadron.

User: Is there anything else in common between the two planes?

PLANES: Yes, both were serviced on April 24th by maintenance group HEBRON FMFPAC.

The following sections describe the data base and our progress on problems which must be solved in order to realize the scenario; this includes progress on representation of common sense information and procedures on problems of pronoun reference and storage of partial results on the ability to answer vague or poorly defined questions, and on the ability of the system to recognize when requests are meaningless or too poorly formulated to answer.

The PLANES Data Base

We have obtained a data base from the Navy 3-M Data Base for Aircraft, Mechanicsburg, PA., consisting of detailed records of aircraft maintenance and flight information extending over a period of time. Each time a plane is serviced, a record is made including such information as the time and duration of the maintenance, who performed it, what action was taken which parts were used or cannibalized, the manufacturers of these parts, whether or not the service was scheduled or unscheduled, and so on. Records on the number of flights and the number of hours in the air are also kept for each plane. There are roughly thirty different record formats which occur in the data base, each containing between ten and twenty separate *fields*, where each field encodes information like the date of the action, type of aircraft, serial number of the aircraft, type of malfunction, component serviced, the work station performing maintenance and so on. A library of search routines for extracting records and fields has been compiled [7].

Pronoun Reference

Pronouns and referential phrases can be handled by the system in the following way. Whenever the system matches a phrase referring to time (such as "April 1975") or type plane (e.g. "A7"), etc. the system stores this information in *context registers*. When pronouns occur, the system identifies the type of item (or items) to which that pronoun could point, and is the type of item is unique, the system substitutes the value of the appropriate context register for the pronoun. The system can decide what type of items could be referred to by a pronoun by matching the sentence against its prestored request forms. Context registers are also maintained for answers to earlier questions, so the system can answer follow-up questions, as in:

(S1) How many engine maintenances did Phantom number A49283 have during April 1975? or

(S2) *Of these*, how many were unscheduled?

Figure 2 shows a portion of the prestored request network, and Figure 3 shows the prestored request form associated with the network of Figure 2. To show how pronoun reference is handled, suppose that the request:

(S3) Please tell me if phantom number A49283 had any engine maintenance during April 1974.

is given to the program. This request will match the nodes leading to prestored request form 1, will set *context registers* *specific-planes to ((plane-type F4)(tail-number A49283)), *maintenance-actions to ((type-equipment engine)(type-maintenance any)) and *time-period to (time-period April 1 1974 April 30 1974).

The *request meaning skeleton* will then be instantiated, and the message:

(S4) Is it correct to assume that you want to know if the F4 with tail number A49283 had any engine maintenance between April 1 1974 and April 30 1974?

typed out to the user. If the user types "yes" then the program will execute the instantiated *search function skeleton* and fill in the spaces of the answer skeleton to produce something like:

(S5) Yes, 3 engine maintenances were performed on F4 number A49283, one on April 6, 1974, one on April 10, 1974 and one on April 27, 1974.

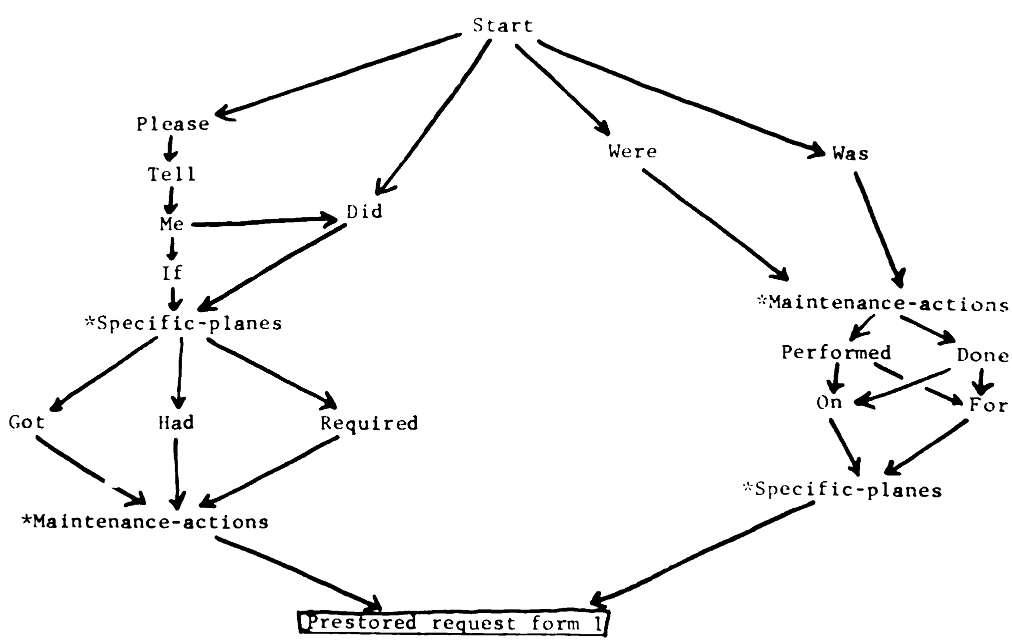

Figure 2 — Portion of prestored request network. Nodes visited in matching (S1) are circled (see text).

1. Request meaning skeleton:

```
(IF *SPECIFIC-PLANES HAD *MAINTENANCE-ACTIONS  *T-P)
```

2. Data base search function:

```
(FOR ALL XI/(*SPECIFIC-PLANES (*P-TYPE  *MAINT  *T-P)):
     (MEMBER (MAINT-FIELD)  *MAINTENANCE-ACTIONS);
     (RETURN (LIST  (TAIL-NUMBER) (MAINT-FIELD) (DATE))))
```

3. Answer skeleton:

```
((NOT (NULL ANSWER))(LIST "YES (LENGTH ANSWER)
       *MAINTENANCE-ACTIONS "WERE "PERFORMED 'ON
       *SPECIFIC-PLANES  (ENUMERATE ANSWER '(ONE ON))))
(T  '(NO))
```

Figure 3 — Prestored request form 1

Suppose that sentence (1) is then followed by:

(S6) Did it have any unscheduled landing gear maintenance?

This will match the same prestored request form as did sentence (1), but in this case "it" will match *specific-planes, and the contents of the current context register for *specific-planes will be assumed to apply for this sentence also.

To complete the example, when the program attempts to fill out the request meaning skeleton (see figure 3), it will note that a value for *time-period is needed, and will obtain this from the *time-period context register also. Of course, as always the program will check with the user to make sure that it has correctly interpreted his meaning before continuing.

"Common Sense"

We would like to trap certain types of "unreasonable" requests without actually performing a data base search for answers. For example the requests:

(S7) Did any Phantom have more than 500 engine maintenances during August 1973? or
(S8) Did any Skyhawk crash more than 3 times last month?

are suspicious. Whenever a request form includes a comparison with a number, a check can be added to the request form, using simple tables giving an order of magnitude estimate for items like the number of man-hours for various types of maintenance, average frequency of failure rates, and information about the fact that certain events, e.g. crashes, typically happen only once to a particular airplane.

It is a long range goal of this research to have the system answer vaguely formulated questions like:

(S9) Are there any common factors in the maintenance histories of the two Phantoms which crashed last month?

In order to answer such questions, the system must have an understanding of what "common factors" are: similar events or event sequences, servicing by the same shops, the missing of periodic services, failures of the same subsystems, etc. Clearly, we do not want the system to provide an answer like:

(S10) Both aircraft have 7 as the 4th digit in their serial numbers.

Search Strategies

We are in the process of adding the ability of using simple strategies to make searches for data more efficient. Using the same facts which allow the system to abort searches in the event of "unreasonable" requests (see the preceding section) the system can order its search procedures for fastest operation. For example, suppose PLANES is asked:

(S11) Which of the Phantoms which crashed in May had engine maintenance in April?

There are three possible strategies:

STRATEGY 1: Find the set of all Phantoms which had engine maintenance in April, then find the set of all Phantoms which crashed in May, and intersect the two sets.

STRATEGY 2: Find the set of Phantoms which had engine maintenance in April, then look through May data; for each Phantom which crashed, see if it belongs to the engine maintenance set.

STRATEGY 3: Find the set of Phantoms which crashed in May, then look through April data; for each Phantom which had engine maintenance, see if it belongs to the crashed set.

Clearly strategy 3) is the best; if no planes crashed, then we do not even need to look through April engine maintenance data at all.

We are also examining methods for allowing a user to interactively specify complex strategies to the program, and ways of having the program use knowledge about a user (e.g. whether he is a manager or an engineer) to help interpret user input and questions.

Alerters and Pattern Recognition

One special type of search strategy we are investigating involves identifying "interesting" patterns of data, and setting up programs which watch for such patterns to occur. (Programs which watch for patterns are usually referred to as *demons*.)

Our work in this area has so far been concentrated on data analysis; we would first like to have a good idea of the types of patterns and relations which exist and which are of interest. To this end we ordered and received detailed descriptions of serious aircraft accidents involving mechanical failures from the Naval Safety Center, Norfolk, VA. These descriptions contain a narrative of follow-up accident investigations, and attempt to identify causes of the accidents, based in part on the maintenance records of the aircraft involved. We are using these descriptions as a model of the type of action we would like our system to be able to perform automatically.

Once we are able to identify and characterize patterns which lead to problems, we intend to investigate and program demons which can watch for such patterns to occur, and notify a user when a potentially dangerous situation exists. In the long run, we would like to program systems which will "browse" through the data base, looking for new cause-effect relationships, and automatically setting up their own demons to watch for possible trouble.

Figure 4 shows a block diagram for the overall organization of our system. Both strategies and pattern recognizers/alerters are associated with the box marked "Interpreter (Standard Functions-Different Realizations)." Strategies in PLANES are merely different search realizations of the same logical request.

Relationship to Other Work

I have referred to our work as an *engineering approach* because it falls outside the boundaries of traditional linguistics. There is no dictionary entry for a large fraction of the words "understood" by the system; in general, words are defined implicitly within each pattern in which they occur in the prestored request network. Transformations are not used; for example, both active and passive forms of requests are prestored.

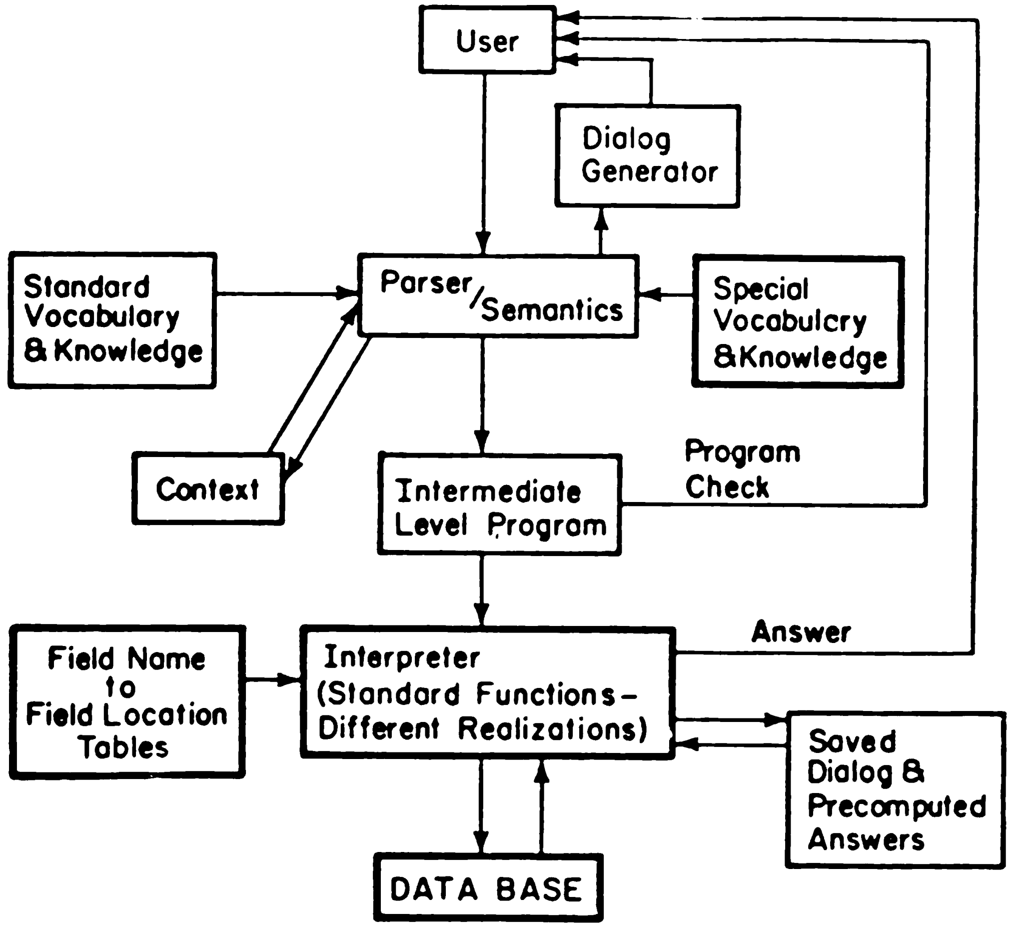

Figure 4 — Block diagram of PLANES

Some parsing ability does exist within the matching programs for phrase types. Phrase types are in general either prepositional phrases or noun phrases, and are analyzed in a manner directly drawn from Winograd's noun phrase analysis [3]. Some other linguistic mechanisms are also based on Winograd's work.

The way in which the meanings of requests (i.e. prestored request forms) are stored is very similar to the way meanings are stored in Woods' LUNAR program [2]. Overall, Woods' program is the most similar precursor in intent and operation, though the data base we are using and the variety of questions which can be asked in our system is much greater.

It should be obvious that this system does not attempt to model the internal mechanisms of human language understanding; it is an attempt to solve the problem of making a large body of data accessible via natural language, using no more mechanisms than are absolutely necessary. The environment of the program is quite remote from that of a general language understanding system. Questions are all either in the past tense or present tense, and present tense is used only to refer either to the dialogue or to things which are always true. The number of objects, events and relations in the program's universe of discourse can be easily enumerated. The role of the program with respect to a user is always that of a data retriever.

Nonetheless, there are certain common issues which a general understanding system must face. One particularly pertinent issue concerns the appropriate unit of knowledge. Should words be defined explicitly, as in dictionary "definitions," or implicitly, as in this system? Should "world knowledge" and linguistic knowledge be stored separately or should they be merged as in this system? I believe that a general language understanding system can benefit from some of the ideas in this paper.

In order to have available the knowledge contained in the prestored request network, something akin to it must be constructed. Certainly, such facts as "Airplanes require maintenance" do not emerge from concatenating isolated word definitions of "airplane," "require" and "maintenance," unless these facts are somehow made part of these or related definitions. (i.e. machines require maintenance, and an airplane is a machine.)

Similarly, one cannot write a program in which data base search functions can be incrementally constructed, (as in SHRDLU [3]) and in which at the same time meaningless requests can be trapped, without writing a program larger and slower than ours.

Whether or not one should transform all input sentences into a canonical form to save on world knowledge storage space, or whether all surface forms should be matched directly is much more debatable, but the storing of surface forms does allow non-grammatical or partial input sentences to be tolerated easily.

Advantages for Data Base Question Answering Systems

There are some distinct advantages to the type of system described in this article.

1. Idioms can be handled very neatly and easily.
2. The system can operate very rapidly and need never do backtracking.
3. The prestored request network allows pronoun reference to be handled in a way that seems intuitively clear and which is simple to implement.
4. Complex search functions can be neatly associated with sentences intended to invoke them.
5. Perhaps most important, the system is simple to write, although the writing may be time consuming, and each application to a new data base would require a substantial amount of rewriting.

Summary

The preceding sections have described a number of parallel, inter-related parts of our work on PLANES, which is aiming toward a much more intelligent, user-oriented system to interface a user with a large data base. While we are working with a specific data base of Naval aircraft data, we feel that the ideas and programs we are generating can be of wide value in both military and non-military applications.

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Magneto Hydrodynamic R&D Program at Arnold Engineering Development Center (AEDC)

Dr. G. R. Garrison of the Arnold Engineering Development Center discussed the facilities, instrumentation, and data processing equipment which have been installed under ERDA funding to facilitate studies relating to the use of MHD devices as topping cycles for central station electric power facilities.

Previous work with MHD facilities in this country and abroad demonstrated that up to 6% of plasma stream energy can be extracted in an MHD device. Dr. Garrison stated that extraction capability must approximate 16% in order to successfully utilize MHD's in a topping cycle configuration - the facility at AEDC will attempt to demonstrate this capability.

Nylon-11 May Be Ideal High Pressure Lube

Dr. L. C. Towle of the Naval Research Laboratory reports that Nylon-11 may be an ideal lubricant for high pressure applications, and it won't break down as easily as other solid films, such as fluoroethylenes, presently in use.

The solid film lubricant promises to have many applications for the Navy and industry. The use of solid film lubricants has become increasingly common in the last decade, particularly in special applications where conventional greases and oils lose their effectiveness due to high stress conditions. The finite shear strength of a solid film retards its expulsion from regions of high stress and helps maintain the integrity of the lubricant film.

In preliminary lab tests, the friction behavior of Nylon-11 at contact pressures up to 120,000 pounds per square inch (8 kilobars) at room temperature was measured. The friction coefficient was unusually small or only about one-half of that of fluoroethylene films measured in the same test apparatus under comparable conditions.

Nylon is a generic term scientists use for polyamides which are long-chain synthetic polymeric amides that have recurring amide groups as an integral part of the main polymer chain. Nylon-11 is distinguished from other commercially available nylons by a relatively low melting point (186 C), broad processing temperature range, low specific gravity (1.04), low moisture absorptivity (1.9%), and high flexibility. It is highly solvent resistant and has found extensive application as a corrosion resistant coating.

Because of the solvent resistant characteristics of Nylon-11 films, they are easily prepared by using a dry powder coating technique.

Research Notes

New System Absorbs Oil Spills

An open sea oil spill recovery system, designed by the Navy to pick up 50,000 gallons of oil an hour, could prevent major spills from reaching coastlines if deployed in time and in sufficient numbers.

The Civil Engineering Laboratory (CEL), Naval Construction Battalion Center, Port Hueneme, Calif., has developed a concept which uses 3.6 million polyurethane foam chips an hour to absorb the spill. The chips are (1) sprayed across a 20-foot path of oil, (2) guided onto a collecting belt, (3) squeezed "dry" of the oil, and (4) returned to the system for reuse. It takes a single chip about 60 seconds to complete the cycle and is good for at least 50 clean-up runs.

Successful open sea tests have been conducted in rough waters with four-foot waves with the Oil Spill Recovery System. Modifications are underway before the prototype is subjected to additional tests.

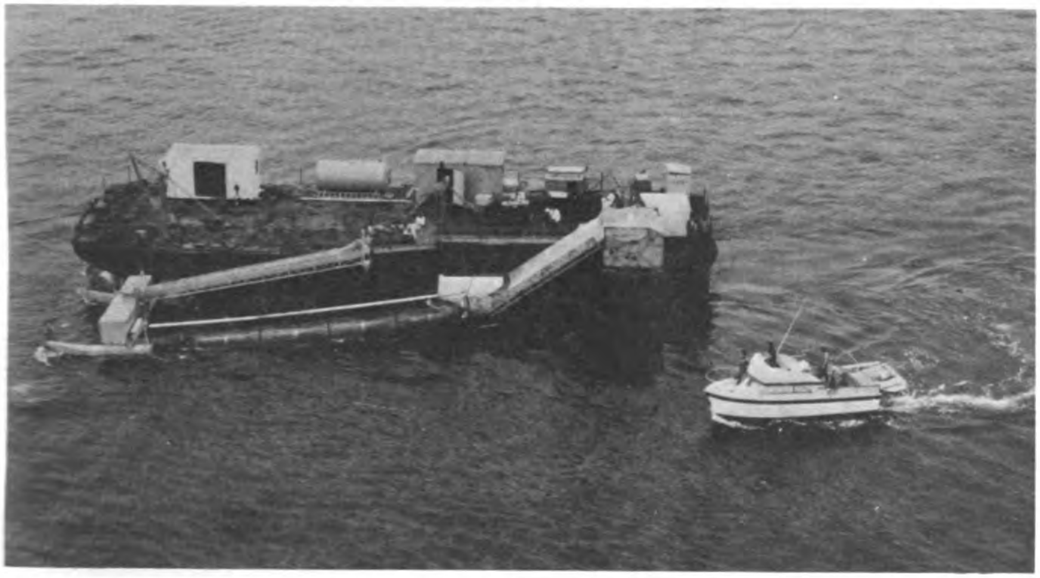
Long-range plans call for a fleet of recovery systems to be located strategically along both coasts and other areas facing possible ship oil spill disasters. The Navy's Supervisor of Salvage, sponsor of the project, had requested development of a recovery system that could be deployed by aircraft and be operable in the water within 24 hours. The System can be operating in the waters within 12 hours.

The working model recently tested four miles at sea is 75 feet long and 20 feet wide. The system can be attached to the side of a seagoing tug, work barge, or an ARS class of ship. The system consists of (1) the broadcaster which distributes the sorbent chips into the water; (2) the herding barrier which confines the oil as it enters a channel formed by a barrier (modified oil boom) on one side and the vessel on the other. It is between these boundaries that the oil is adsorbed by the urethane foam sorbent chips; (3) the harvester which picks up the oily chips as they flow to the end of the herding channel; and (4) the regenerator which de-oils the chips by mechanical squeezing. The "dried out" chips are recycled to the broadcaster by a series of conveyor belts.

With the ship advancing at two knots, the recovery system can operate satisfactorily in five-foot waves and still soak up 90% of the oil spill it traverses. Unlike many other oil skimmers that function better in calmer waters, the system performs more efficiently in choppy seas. The rougher the sea state, the more oil comes in contact with the chips, enabling the chips to adsorb the spill more effectively, even in winds up to 25 miles an hour.

With results of the sea test proving that the concept of mechanized handling of sorbent materials is workable in open water, CEL is now modifying the system to make it smaller and to reduce its overall weight from 20 tons to 10 tons.

The importance of using foam chips with proper buoyancy was revealed in early sea trials. To maintain operational efficiency, it is imperative that the system contain the sorbent chips within the herding barrier. During initial tests, a significant number of chips had surfaced behind the harvester and escaped astern. The loss rate was about 20 chips per minute. Although the percentage was small (0.03%), compared to the broadcasting rate of 1,000 chips per second,



Mechanized Sorbent Oil Spill Recovery System is shown during successful open sea trials. It may be attached to any ship of opportunity, in this case a working barge. At the far left is the broadcaster which sprays the chips across a 20-foot path of the spill.

the loss would have posed a problem in actual operations if not corrected. Recovering an oil spill at sea, the system would have to be replenished within hours (maximum broadcaster capacity being 30,000 chips). And a large number of oil-soaked chips would have escaped to the environment.

Accordingly, a new type of chip (20% closed cell) was introduced into the system. Since they were pink in color, the chips were easily identifiable from the original buff colored (100% open cell) chips. Except at the initial stage when a number of chips were thrown from the regenerator accidentally, not a single pink chip was seen to escape the system during normal operation. Engineers conclude that when sorbent chips with proper buoyancy are used, the system retains them throughout the cycle.

After testing various materials, the Laboratory decided upon a polyurethane foam chip (3″ × 3″ and 1/4″ thick) which becomes 90% saturated within six seconds. This enables the system to recover the maximum amount of oil without the chip getting water soaked and sinking below the surface and escaping. Thus the chip, with the right buoyancy and soaking oil at a desirable sorption rate, floats through the herding channel in a designed manner toward the regenerator.

According to Navy definition, a "large" oil spill involves more than 100,000 gallons. A "moderate" spill entails 10,000 gallons and a "small" spill is less than 10,000 gallons. Approximately 90% of open sea spills invovling Navy ships fall within the "small" category. But the occeasional large spill is the one that threatens to be catastrophic in terms of environmental damage to beaches and coastal properties.

Operators of the recovery system have several options in storing the oil, depending on the size of the spill. The oil could be stored aboard service barge if the spill were small, or it could be pumped by hose connected to a support service vessel, or discharged into floating rubber tanks which can be towed to the scene.

Mobile Mini-Computer System for Ocean Research

Naval Research Laboratory scientists have designed and developed a portable shipboard computer system to help experimenters acquire, process and analyze data while at sea.

The system, similar to stationary facilities at other laboratories, is being used to support oceanographic research aboard ships and in aircraft in the areas of navigation, underwater photography, and acoustical, climatical, geophysical, biological and chemical oceanography.

The system consists of two identical mini-computers; one is used for the real-time acquisition of oceanographic data and navigation, and the second for data processing, general purpose computing, and spectrum analysis using a fast Fourier analyzer. The computers are operated in a multiprogrammed, multi-user environment under a real-time disc-based software system.

A random access disc and dual magnetic tape units provide for program and data storage on each computer. A data acquisition system connected to the real-time computer acquires, conditions and converts analog signals from the oceanographic sensors to digital format. A digitizing table interfaced with the computer provides direct data digitizing of all analog charts and graphs. For hard copy output, a large flatbed plotter and smaller drum plotters are used along with high-speed line printers.

Recently, an Arctic magnetic study was conducted aboard an aircraft out of Thule, Greenland. One of the shipboard computers with disc, magnetic tape, line printer, CRT and 30-inch drum plotter was placed aboard the aircraft. The magnetometer, inertial navigation system, and altimeter were interfaced to the computer for real-time data acquisition and processing. Approximately 21 days of data were acquired and processed in the aircraft.

A Radar System for Battlefield Surveillance

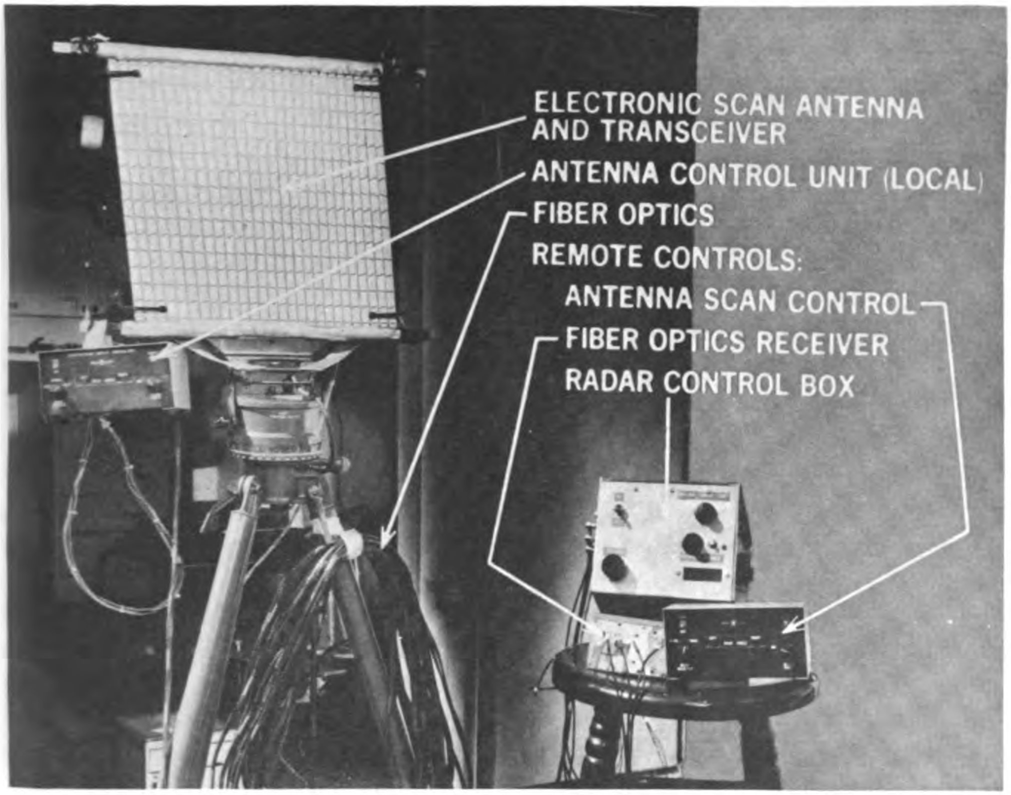
A radar system, designed for moving target and battlefield surveillance, is being developed for the Marine Corps under the direction of the Naval Electronics Laboratory Center (NELC), San Diego, California.

This man-pack system is lightweight, small and inexpensive. It is to serve as a front line, highly mobile, tactical sensor for detection of enemy personnel and vehicles.

The radar includes an electronic scan antenna and a solid-state superheterodyne transceiver with biphase coding capability and a remote control link utilizing fiber optics techniques.

The experimental battlefield surveillance radar employs an electronic scan antenna which has 26 elements and uses two ferrite waveguides (top and bottom) to provide ± 45 degree scan coverage. The beam scan control has both manual and automatic scan modes selectable by a switch. The antenna provides a six by six by six degree beamwidth at 9 GHz with sidelobes down 18 to 20 dB.

The beam scan radar system offers significant reduction in weight (design goal is 10 pounds) and offers a potential 10:1 cost reduction over conventional phased array scanning techniques which usually require a diode or ferrite phase



Lightweight, battlefield surveillance radar system

shifter for each array element. Because of these capabilities, it is being considered for many other military and civilian applications including small boat applications.

The NELC radar system, under development for about four years, is sponsored by the Naval Electronic Systems Command (NAVELEX 3302), Washington, D.C. The X-band solid state transceiver and the antenna were designed and developed by Rockwell International.

The electronic scan antenna design, which is based on a "Regia-Spencer" type antenna, employs ferrite analog circuits to control the beam position. The final antenna is expected to weigh about two pounds and will have a beam control power of about 0.5 watts.

The transmitter portion of the transceiver consists of an x-band signal that is derived from an s-band source, quadrupled, and biphase coded. The resultant signal is applied to the impact plasma avalanche transit time (IMPATT) diode.

The primary purpose of the transceiver development is to achieve a more efficient power source and significantly increase the power output. The predicted transmitter efficiency is about eight percent, and the average power will be about 2.5 watts. This is an order of magnitude increase in efficiency and a 20 dB gain in transmitter power, as compared to the present generation battlefield surveillance radar.

The primary advantages of using fiber optics for remote control capability are low weight, rfi/emi immunity, and wide bandwidth capability. The predicted weight for 50 meters of a four-channel fiber optics cable is about one pound, (this cable weight is included in the 10 pound goal).

Further information may be obtained from Carl Erickson, Head, Surveillance Countermeasures Division (Code 2300), telephone area code 714, 225-6649, Naval Electronics Laboratory Center, 271 Catalina Blvd., San Diego, CA 92152.

New Test Sets for Radio Equipment

In response to fleet need, the Naval Electronics Laboratory Center (NELC) in San Diego has developed a test set for use with the AN/SRC-20 series of radio equipments.

This UHF Communication Test Set (CTS) is designed to provide a quick and simple means of determining key system parameters, such as transmit power, voltage standing wave ratio (VSR), modulation percentage, and receiver sensitivity.

The CTS is a small (5″ × 7″ × 9″), lightweight (10 pounds), portable test unit which is used to evaluate the operational readiness of the AN/SRC-20 series radio sets. The readiness evaluation is based on measurement of the above mentioned four key system parameters. Readout of the information is provided by means of colored lights for go-pass-fail determination, and a panel meter for more quantitative measurements.

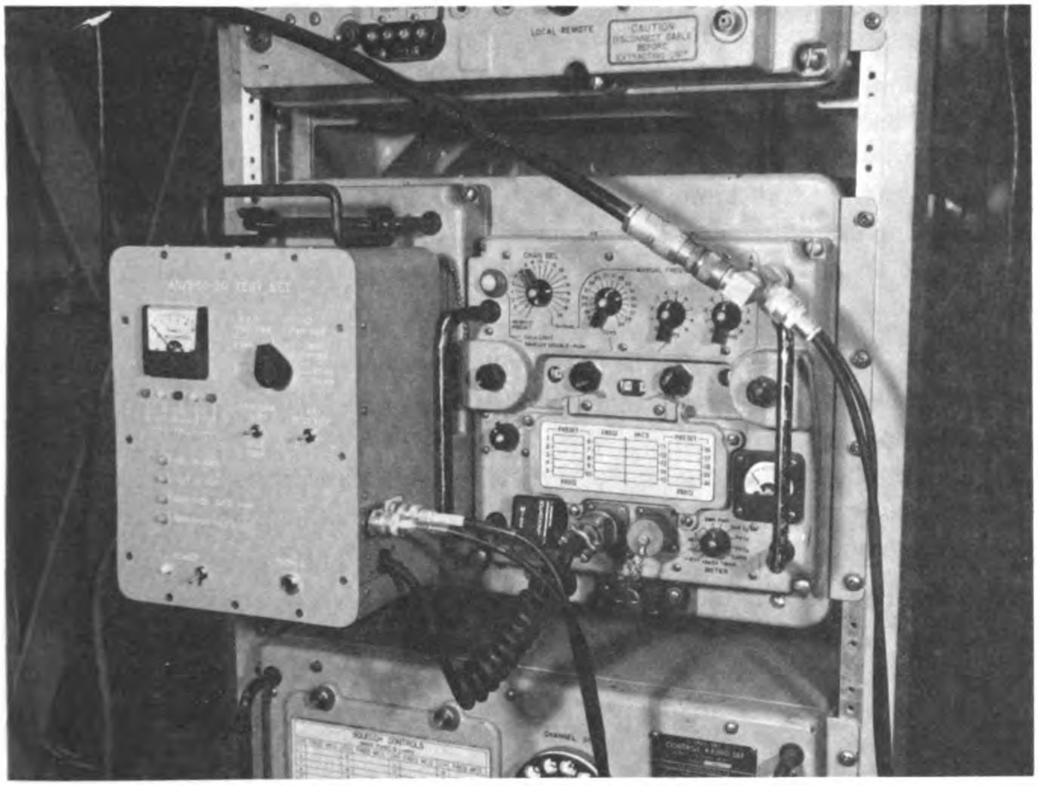
The four measurements can be performed by the CTS in about 10 seconds. The test unit also features quick and simple connection to only two front panel connections on the AN/ARC-20.

To measure receiver sensitivity, a stimulus generator supplies amplitude modulated RF signals simultaneously at all frequencies to which the radio set may tune. This known constant level stimulus is injected into the antenna input of the receiver under test. The audio output from the receiver is fed to circuitry which measures the signal to noise ratio. This signal to noise ratio is directly related to receiver sensitivity. A look up table is provided to allow direct conversion from the meter readout to receiver sensitivity.

Transmitter power output is determined from the average dc value of the forward power sample obtained from the CTS internal directional coupler. A low pass filter is used to isolate the dc component of the directional coupler output. The resulting signal is then amplified and routed to the readout section of the CTS.

VSWR is a measure of how well the RF energy generated by the transmitter is coupled into the antenna/multicoupler. Techniques employed in the CTS provide this measurement in terms of reflection coefficient which is the ratio of incident and reflected power samples from the directional coupler.

In the modulation percentage test, a standard modulating stimulus signal is provided to the transmitter by the transmitter stimulus generator through the front panel microphone input. The degree to which this standard signal modulates the transmitted RF is an indication of the operational condition of the modulator. The Test Set is calibrated to provide a 60 percent modulating signal to a properly operating transmitter.



The test set quickly evaluates the operational readiness of the AN/SRC-20 radio set.

Further information may be obtained from Frank Zupan, project manager, telephone area code 714, 225-6823, or Ken Campbell, project engineer, telephone 225-7494, Naval Electronics Laboratory Center, Code 3500, 271 Catalina Blvd., San Diego, CA 92152.

Airbrone Light Optical Fiber Technology

Naval Electronics Laboratory Center (NELC), San Diego, recently received delivery of the A-7 ALOFT (airborne light optical fiber technology) avionics interface system from IBM Federal Systems Division.

The A-7 ALOFT demonstration was conducted under the sponsorship of the Naval Air Systems Command to confirm that fiber optics is a practical, mature technology for use in internal aircraft data signal transmission. The flight test and the evaluation of the ALOFT system was the first demonstration of the feasibility of utilizing fiber optics in a full system application in an operational environment. Previous demonstrations of this technology in the U.S. have been limited to laboratory level demonstrations or small scale flight evaluations at the subsystem level.

Further testing of the ALOFT system will be conducted at LTV, Vought Systems Division, Dallas, in December to determine total software/hardware compatibility and to evaluate the performance of ALOFT hardware during environmental tests.

Environmental tests at LTV will attempt to duplicate the temperature, altitude, vibration and electromagnetic interference conditions found in the A-7 aircraft. The fiber optic cabling interface system and the ALOFT hardware will be tested and evaluated to the limits of the A-7 environmental conditions while under operation. During the design development of the ALOFT system by IBM, LTV developed an installation plan which will be used by the Navy to integrate the ALOFT hardware into an A-7 test bed aircraft at China Lake. The flight test phase will be conducted by NWC upon completion of the ground tests at LTV beginning on January 6, 1976. Approximately 50 to 100 flight hours of in-flight testing are planned, including navigation and weapon delivery accuracy tests.

The ALOFT system includes a Navy A-7 tactical computer which has been modified by IBM so that external signal transmissions to the peripheral avionics take place over the fiber optic cables instead of the original copper wiring. The original 115 individual signals that were transmitted in the original system over approximately 300 copper wires have been time division multiplexed into 13 serial data channels between the ALOFT computer and the peripheral avionics adaptors. A major portion of the weight reduction is due to the multiplexing. However, since the multiplexing is achieved through bi-phase Manchester coding with a maximum data rate of 10 mega bits, twisted pair wire could not have been utilized as the interface medium in the ALOFT system. Coaxial cable could have been used after the electronic multiplexing which would have achieved a cable weight reduction ratio of 8 to 1; but coaxial cable would increase susceptibility to electromagnetic capability (EMC) problems such as RFI/EMI. The configuration utilized for fiber optics signal transmission achieved a 21

Side-by-side comparison showing the weight and volume reduction by using fiber optic cables to 1 reduction in cable weight without the increased susceptibility to EMC problems that could be expected at the higher increased data rates. Another aspect of considerable importance is the increased immunity to electromagnetic pulse interference (EMP) offered by the fiber optic interface system.

Parallel to the test and evaluation of the ALOFT system, an economic analysis is being conducted by the Navy to establish the cost potentials of utilizing fiber optics interfaces in future avionics systems. The forecasting techniques being utilized in this analysis have arrived at a preliminary conclusion that the production base/components cost profiles are anticipated to follow a 70 to 80 percent slope on an experience curve. This means the present costs of components from industry can be expected to be reduced to 70 to 80 percent of previous costs with each doubling of production volume. This also means that future costs of the required components should be completely determined by the demand placed on industry to deliver the needed quantities of components. A hypothetical scenario of possible military and commercial applications of fiber optics in planned and future systems has been developed for NELC by the Naval Postgraduate School, Monterey. The economic analysis will also evaluate the cost/effectiveness trade-offs between fiber optics and coaxial cable as alternative interface systems where costs are determined at various levels of effectiveness that will be required in current and future avionics systems.

The results and conclusions of the ALOFT flight test demonstration and the economic analysis may do much to answer in quantitative terms the questions presently being posed by avionics systems designers in Department of Defense and industry as to the capability and operational potential of fiber optics data communications.

If results are favorable, the ALOFT demonstration should pave the way for a multitude of advance development avionics systems such as point-to-point communication interfaces, avionics data bus systems and fly-by-fiber optic control systems.

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Cover Caption

Minature swine in the hyperbaric chamber facility at Virginia Mason Research Center. Minature swine are useful models in hyperbaric research on aseptic necrosis. See page 7.

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