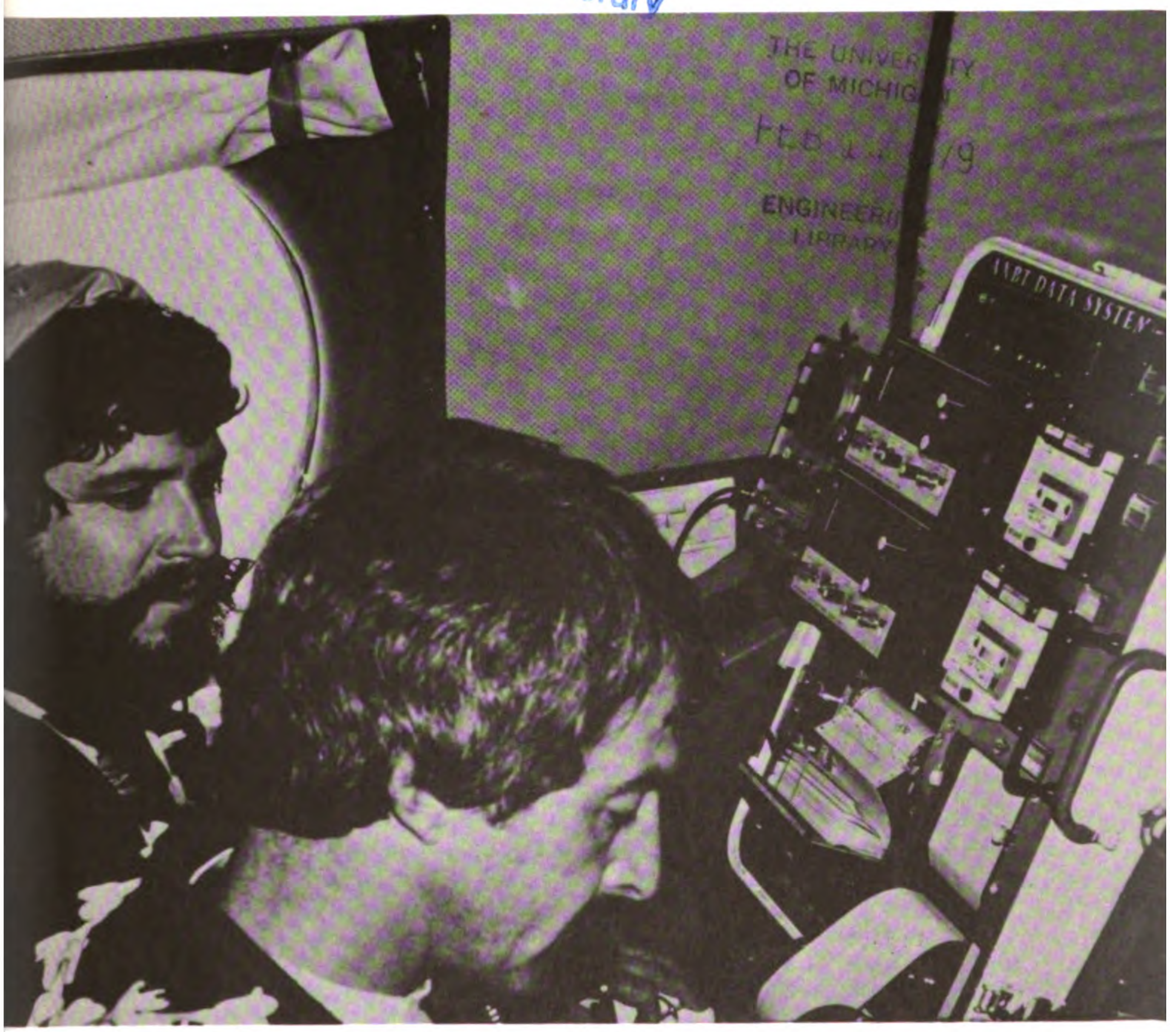
U.S. OFFICE OF NAVAL RESEARCH 407-C

NAVAL RESEARCH

REVIEWS

SEPTEMBER 1978



PROFILES IN SCIENCE

Dr. Samuel C. Collins

Samuel C. Collins, Professor Emeritus of Mechanical Engineering at the Massachusetts Institute of Technology, is currently a consultant on the staff of the Naval Research Laboratory where he is developing a closed-cycle helium liquefier — refrigerator suitable for shipboard superconducting propulsion systems.

For thirty four years Dr. Collins was a professor at MIT, and from his classroom have come many of the outstanding scientists of today. The Office of Naval Research has supported some of his important projects dating back 30 years.

During World War II, Dr. Collins developed the airborne oxygen liquefier for aircraft. In 1947 he invented the Collins cryostat, the first commercially feasible helium liquefier, which marked the beginning of a new era for low temperature research.

He holds 45 patents in the diverse areas of cryogenic devices, ship design, and medical apparatuses. He is a member of the National Academy of Sciences and a holder of the Kummerling-Onnes Gold Medal as well as the Rumford Medal of The American Academy of Arts and Sciences.

Aircraft Monitoring of Ocean Thermal Structure and Currents

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NORPAX (North Pacific Experiment) is a multiinstitutional program sponsored by the National Science Foundation and the Office of Naval Research to study the large-scale fluctuations in the thermal structure of the Pacific Ocean from 20°S to 60°N and their relations to the overlying atmosphere. Achievement of this goal should eventually lead to the ability to predict the thermal structure of the upper layer of the Pacific Ocean and to improved weather/climate prediction for both the northeast Pacific Ocean and North America.

Scripps Institution of Oceanography is one of the major institutions participating in the program and also serves as the center for administration of the NORPAX project, which includes 34 scientists from 14 universities. Three major activities are being pursued at Scripps: (1) statistical/analytical studies of the ocean and the atmosphere and their interaction, (2) field studies on the variability in heat content and surface currents in the upper waters of the mid-latitude North Pacific, and (3) a field study designed to test the feasibility of making long-term measurements of the thermal structure in the equatorial Pacific. This study of the equatorial Pacific is the NORPAX Shuttle Experiment which is described in this article.

The basic goal of the NORPAX equatorial program is to provide an understanding of the mechanics of the ocean-atmosphere system in the tropical Pacific. Various NORPAX investigators have been involved in a variety of tropical studies. These include analyses of sea surface temperature, sea level, pressure, rainfall, cloud cover, wind, and oceanic thermal field data sets. These studies have led to new ideas about the response of the tropical ocean to changes in the wind field and about oceanic influences on the atmosphere. An example is the NORPAX hypothesis that variations of large scale zonal currents in the central tropical Pacific Ocean, induced by low frequency fluctuations in the trade winds, cause large scale changes in the heat content of the upper layers of the eastern tropical Pacific Ocean.

To test such ideas, NORPAX investigators have recently begun an ambitious field program to provide observations of oceanic variability. These data will allow us to infer and perhaps quantify the dominant physical processes operating in the tropical Pacific. They should also lead to the development of advanced theoretical concepts and numerical models. From November 1977 to February 1978, an intensive field program was conducted by NORPAX investigators in the tropical Pacific. Measurements were made from ships, aircraft, moored instrumentation, satellite-tracked drifting buoys, and island stations. Although each of these data sets will provide crucial information that describes ocean variability, the core data set is that collected from the P-13 aircraft. This core data set will be used to provide the large scale background from which the other data sets can be objectively interpreted. This phase of the NORPAX program is called the Shuttle Experiment. (Figure 1).

The aircraft field program was an unqualified success. This was no small accomplishment considering the complexity of the logistics and the many agencies that were involved (see acknowledgements). From 5 November 1977 (Flight #1) through 1 February 1978 (Flight #26), there were thirteen round trips flown between Honolulu and Tahiti (Figures 2 and 3). The primary measurement program aboard these flights was the collection of AXBT (air expendable bathythermograph) data along N-S flight tracks. The standard station spacing between 20°N and 14°N was 1° of latitude. Similar spacing applied south of 8°S to Tahiti (17°S). In the low latitude region between 14°N and 8°S, the standard station spacing was 0.5° of latitude (~55km). During November 1977, sampling was concentrated along the 150°W meridian with four "burst" samples (flights separated by only two days) between 16-22 November 1977. During December 1977 and January 1978, the flights were approximately weekly with southbound flights along 150°W and northbound flights along 158°W (see Figure 4). Thus, a three-month time series of sixteen temperature sections was obtained along 150°W and a two-month series of ten sections from 158°W.

Before discussing the preliminary scientific results, we will note some of the technical aspects of the experiment. The data recovery was extremely high (~96% good AXBT drops) thanks to the performance of the Hermies AXBTs and the digital data recorder developed at Scripps (cover picture). Navigation on all Navy P-3 flights was provided by a rented LTN-72 inertial navigational system. Typical error in navigation after flying over 10 hours and 2700 miles was ± 2 nautical miles. Without the LTN-72, the uncertainty would have been as large as ± 60 nautical miles, seriously compromising the scientific results. After each round trip, the data gathered were run through editing programs at the University of Hawaii to remove spikes and false values and the data were then accumulated immediately; consequently, we were able to modify our sampling grid based on early results.

The immediate results indicate that the large scale current systems, North Equatorial Current (NEC), North Equatorial Counter Current (NECC), and South Equatorial Current (SEC), varied slowly during the

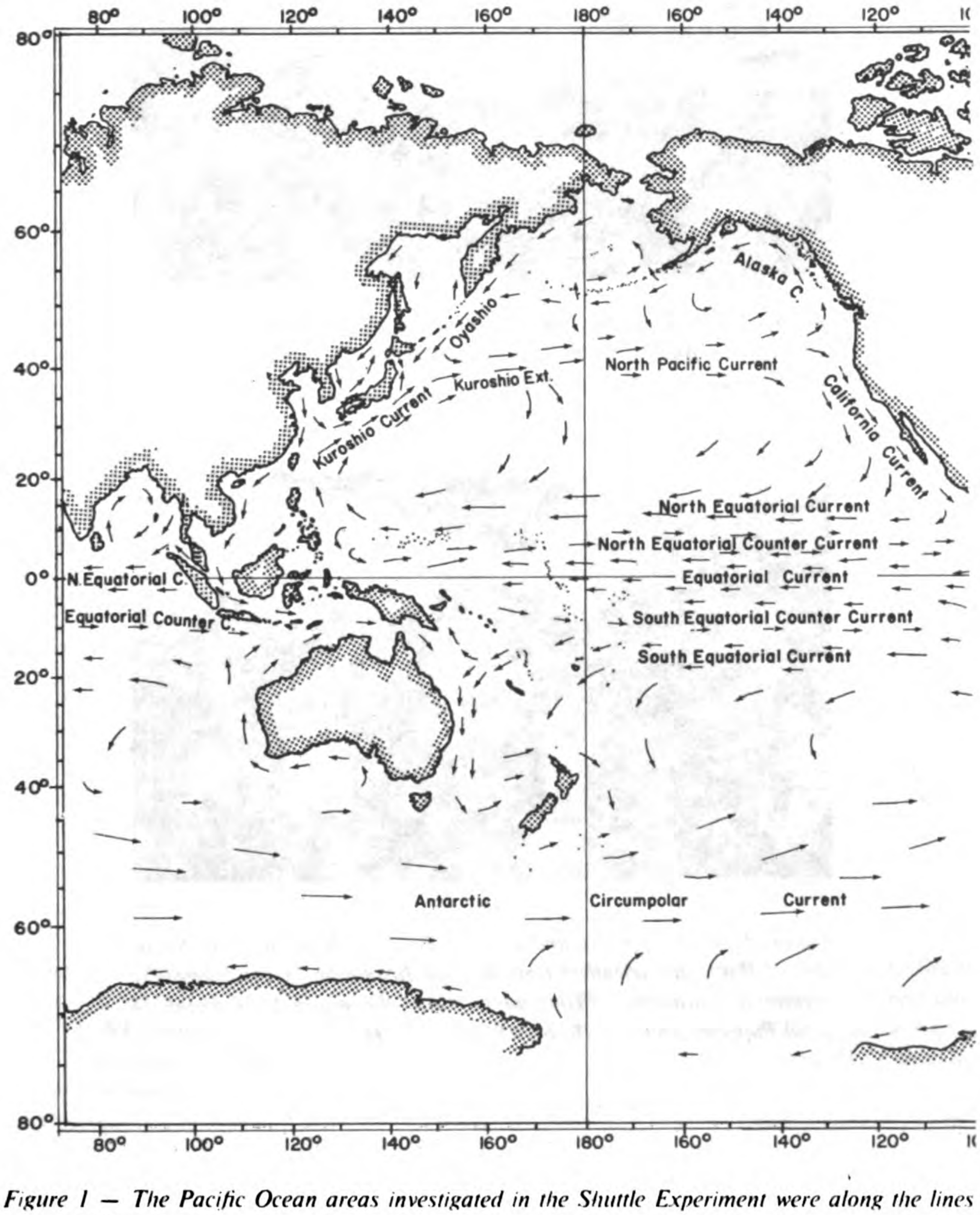


Figure 1 — The Pacific Ocean areas investigated in the Shuttle Experiment were along the lines of the 150°W and 158°W meridians between Hawaii in the North Equatorial Current and Tahiti in the South Equatorial Current.

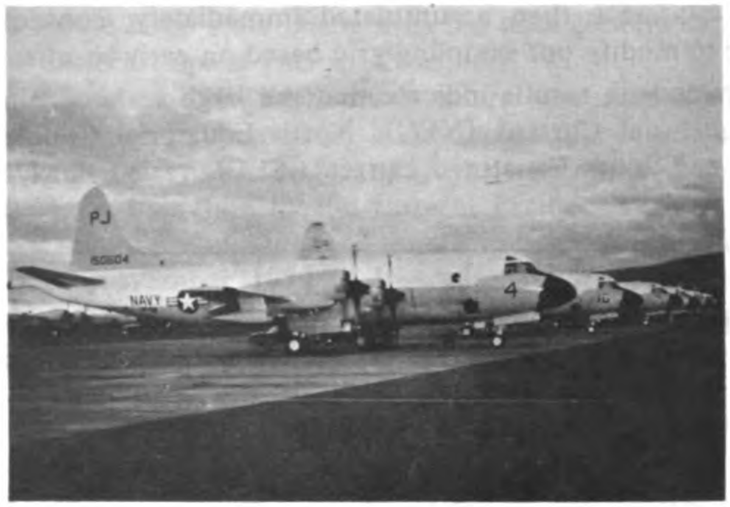
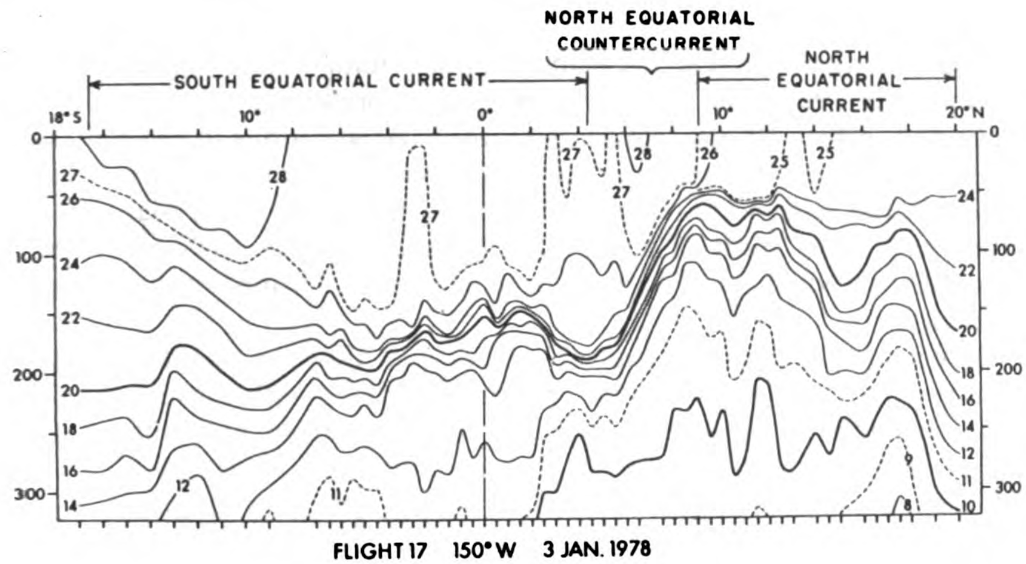
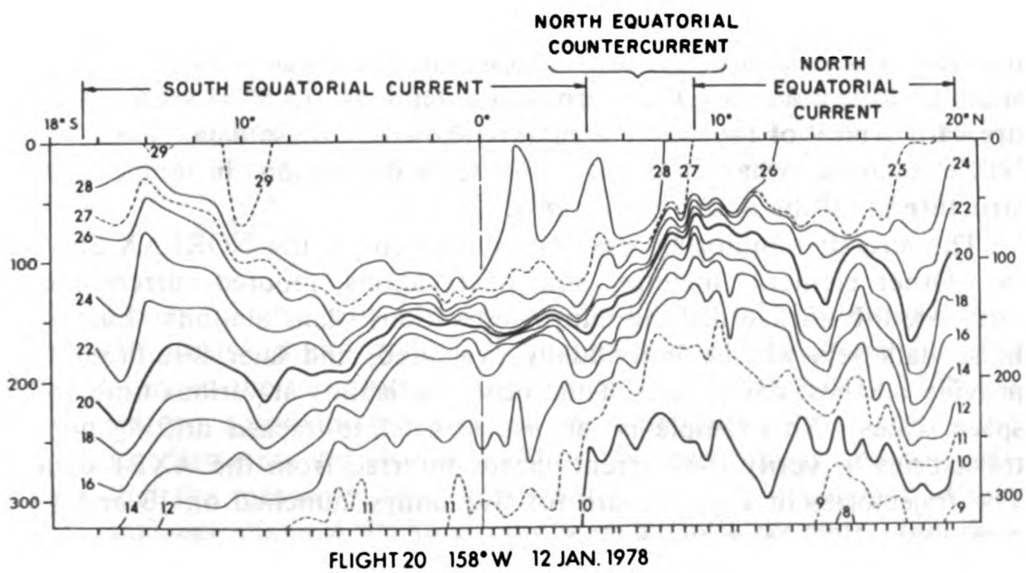


Figure 2 — A U.S. Navy Reserve P-3 aircraft from VP-69 Squadron stationed at Whidbey Island, Washington being prepared for the early moring takeoff to Papeete, Tahiti.

Figure 3 — The officers and crew of the U.S. Navy Reserve Squadron VP-69 and scientists from Scripps Institution of Oceanography receive a "parahi oe" (Tahitian farewell) the morning of Flight 24 from Papeete, Tahiti to Barbers Point NAS, Hawaii.



(a)



(b)

Figure 4 — Isothermal lines indicating temperature in degree centigrade in the Pacific Ocean along 150°W (a) and 158°W (b) Data were collected on 3 and 12 January 1978 respectively, using AXBTs dropped from the NOAA P-3 research aircraft during the NORPAX Shuttle Experiment. Boundaries of the major tropical currents are shown across the top, and SXBT drop locations are indicated at the bottom of each figure.

three months. This conclusion is based on preliminary computation of the mass transports calculated using historical temperature/salinity relationships to calculate density. If these preliminary results are confirmed, it may be possible to measure major variations in the central tropical ocean with temperature sections taken once or twice per month. Although the large scale temporal variability is "slow", the spatial variations occur over short distances; for instance, in the transition zone from NEC to NECC, a 1° latitude or smaller spatial sampling interval is necessary.

Inspection of Figure 4a and 4b reveals that there is resonably large variability in the NEC and SEC systems associated with mesoscale eddies. Evidence of an intense cyclonic eddy is seen in both Figure 4a and 4b between 14°N and 18°N. These eddies have diameters of 300-400 km and take about one month to appear and then disappear at a meridian. Both eddy cores are found between 16° and 18°N. In Figure 4a, the ridge between the NEC and NECC (8° to 13°N) is broad and apparently double peaked. This was observed in most of the sections. Whether this is a zonal feature or a local eddy cannot be resolved using the AXBTs alone.

Analysis shows that the space and time variabilities in the thermal structure near the equator can be large and rapid, while the NECC is marked by a structure that varies slowly in both space and time. The smooth slope indicating the thermocline depth (4° to 8°N) seen in Figure 4a is typical of the NECC structure shown by these data. Thus, the NECC seemed to have the least short term fluctuations in temperature structure of all the observed currents.

The aircraft monitoring was one component of the NORPAX Shuttle. Other elements included ship observations, moored current meters, satellite-tracked drifting buoys and various island stations. Each of these data sets will be individually evaluated, and later interfaced to provide our best description of the ocean variability at various time and space scales. An example is the use of satellite-tracked drifting buoy trajectories to verify the current speeds inferred from the AXBT data. The trajectories in Figure 5 are for five buoys launched on 13 and 14 November 1977 from the R/V KANA KEOKI. Initially, they were located along 150°W between 12° and 15°N in the NEC. By mid-February, all buoys had moved to the vicinity of 160°W indicating a mean westward flow of 13 cm/sec. Closer inspection of the trajectories reveals details of the flow also indicated by AXBT sections. The cyclonic mesoscale (300km diameter) eddies seen between 14° and 18°N are also clearly seen in the buoy trajectories. These eddies have rotational velocities of 20-25 cm/sec and the one-month residence time at a meridian discussed previously is confirmed by the 13 cm/sec westward movement indicated by the buoys.

The apparent northern peak in the ridge between the NEC and NECC (at 12°N in Figure 4a) would not seem to have east/west continuity, but rather to be the southern edge of the NEC with a 100-

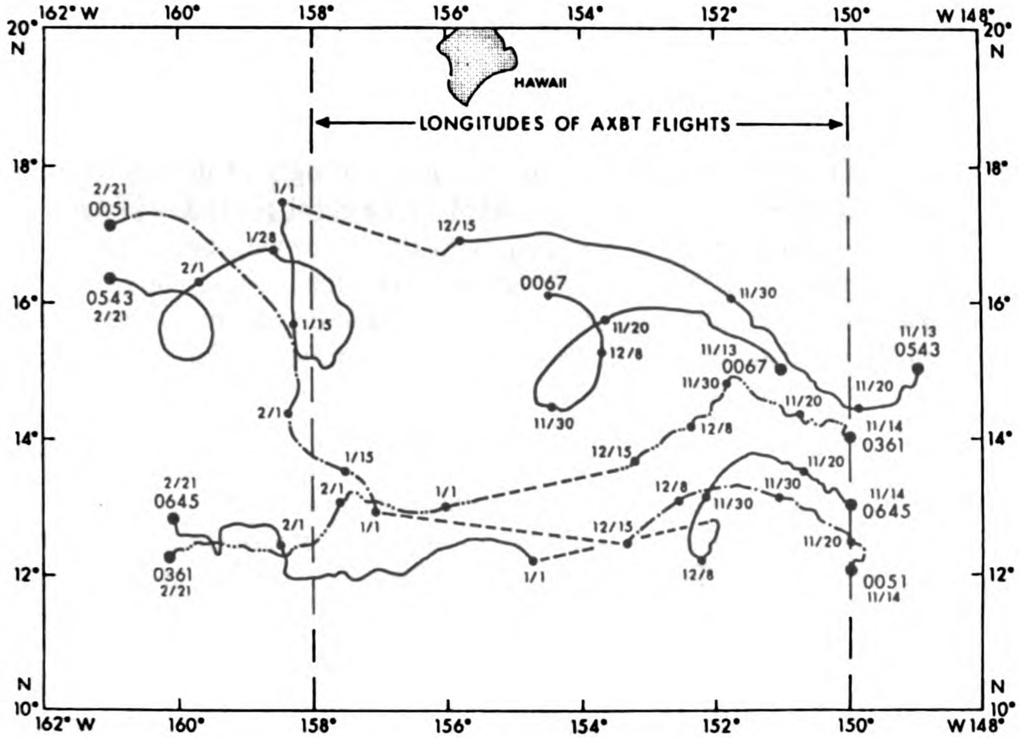


Figure 5 — Satellite-tracked drifting buoy trajectories in the North Equatorial Current; buoys are parachute-drogued to 35 m depth. These buoys wre launched from the R/V KANA KEOKI one week after the first AXBT flight along 150°W and arrived in the neighborhood of 158°W at the same time as the final AXBT flight up 158°W. The dashed lines interrupting the trajectories during the last two weeks of December indicate data losses due to a temporary cessation of the buoy monitoring at NASA.

200km eddy feature. This is suggested by the fact that the mean flow is definitely westward and cyclonic (counterclockwise) rotational features are present in the trajectories. The rotational velocities at 12-13°N are ~10 cm/sec, approximately one-half the amplitude further north, and the eddy diameters are also less. Thus, our preliminary analysis indicates that the mesoscale structure might be latitude-dependent. Complete analyses of the AXBT and other data sets are presently underway and we expect to have more exciting results in the near future.

The overall objective of the Shuttle Experiment was to obtain descriptions of the time and space scales of ocean variability with the ultimate objective of applying this information to the design of a large scale monitoring network. Our early results are very encouraging because they suggest that a well designed aircraft (AXBT) and ship-of-opportunity (XBT) program used in concert with other measurements, can provide the data required for long term monitoring of the tropical oceans.

It is expected that these studies will lead to a more ambitious measurement program that will coordinate with the First Global Experiment in an intensified, atmospheric, ocean, global measurement program.

Again, we plan to collect north/south temperature sections beginning in January 1979 and ending April 1980. We will also expand our sampling objectives to east/west temperature sections. There is little or no information on the east/west scales of ocean variability in the tropical Pacific. Such information is crucial for monitoring and design of field experiments as well as being suggestive of physical mechanisms acting in the equatorial Pacific. Proceeding with this stepwise, logical plan, we are optimistic that understanding of low frequency, large scale ocean/atmosphere interaction will be achieved and that this understanding will be a substantial aid in short term environmental forecasting.

Acknowledgements

The National Science Foundation (NSF) supported the core proposal for the project organization, scientific/technical support and data collection and processing. The Office of Naval Research (ONR) provided the 1700 Hermies AXBT probes used (we understand that this is the largest deployment of AXBTs ever used in a single experiment), arranged by the twelve U.S. Navy Reserve P-3 aircraft flights (Figures 2 and 3), and funded support for these flights and the rental of a LTN-72 inertial navigation system used aboard the Reserve P-3s. The National Oceanic and Atmospheric Administration (NOAA) dedicated their new P-3D aircraft to fly six weekly round trips during the middle of the experiment (split funded by NSF). Finally, the U.S. Naval Oceanographic Office (NOO) VXN-8 aircraft flew the final two flights to complete the observational program.

Human Learning and Performance

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It may be somewhat of a surprise to learn how little is known about learning. People have learned and taught for thousands of years. The art of instruction is well developed; but the psychology of the human mind is enormously complex, and the scientific study of mental processes is still in its infancy. It is only in the past decade that new developments in our understanding of human memory, attention, and language and the information processing principles of intelligent behavior and control structures have provided the first tentative steps toward true scientific understanding.

The study of learning is of great importance to the Navy. This is true not only in such obvious situations as a person's initial basic and specialty training, but for almost all of a person's stay in the Navy. People are continually learning about their jobs and their environment. Sometimes the learning is of a formal nature, as when one takes a course or attends a series of lectures or reads a new set of manuals. More often, the learning is informal and unacknowledged except in such phrases as "on the job training" or, more simply, as "experience." In some ways, the informal training is the more important for it provides the additional "tuning" to one's knowledge that makes its application flow smoothly, effortlessly, and almost without conscious thought. In many situations, the relative novice and the experienced veteran may perform identically. Indeed, the novice fresh out of training may actually have more knowledge. But the differences show up dramatically in times of emergency. Here is where the smooth, relatively effortless and automatic performance of the veteran can make a major difference.

The need for training never ceases. Even the people who are most expert and experienced get rusty when they do not use their skills for even a few weeks or months (as in shore leave). The expert performer may be so good that others do not notice any deterioration, but he knows; and in periods of stress, the distinction can make the difference between life and death.

Modes of Learning

There are many varieties of learning. Some topics such as history or strategy have a large intellectual component. Others such as piloting a small boat or aircraft are more performance-oriented, requiring motor skills. Most tasks require mixtures of skills and mixtures of components. An understanding of the history of a naval campaign is helped by knowledge of the nature of the ships, geographical considerations, and the personalities of the participants. To understand the importance of the Navy during the American Civil War, one must know about the importance of steam and sail, of the currents off Cape Hatteras (where rebel runners passed around the naval blockage), and the meandering nature of the Mississippi River (where the river boats were so successful in controlling the transportation routes). To understand small boat handling, one should also understand mass and momentum and tides and currents, not to mention rules of navigation and right of way.

Human Information Processing

There is no simple way to study learning without also studying the functions and capabilities of human attention, memory, perception, language, and thought. Perception requires memory, plus considerable processing capability. Language mechanisms seem to require many of the same functional capabilities as do perceptual processing, including memory processes, inferential computational processes, and multiple representations of the information being used. To learn something requires active operation of the mechanisms of perception, memory and probably output motor control as well as the computational systems that are responsible for elaboration, inferencing, and determining the representation of the information. All of these processes require elaborate control mechanisms to allocate mental processing resources and to monitor progress. Thus, we cannot study one area of performance in isolation but must know something of all. Obviously, we cannot study everything at once; so, as we focus on the study of one component, we use simplified models of the others. The study of learning, however, does not allow us as much freedom to isolate mechanisms as would the study of visual perception or of short-term memory capacity.

The amount of information received through the senses is enormous. There are approximately 800,000 receptors in each eye and 30,000 in each ear. In addition, we have sensory information about muscle, limb and body positions, temperature, head orientation, odor, smell, taste, and touch. The total data rate of information sent is within the megabit range. Because it is impossible for the human to attend to such large data rates, some intelligent selection must be made.

The selection process is a result of the mechanisms of human selective attention. This selection process has the virtue of concentrating mental processing effort upon meaningful and important aspects of the data. It has obvious deficits in that critical events occurring within the discarded data stream might be missed. To overcome this problem, it appears that the human information system allows itself to be interrupted, to be driven by the occurrences of important data, even when its primary attention is directed elsewhere. This is called *data-driven* processing. Processing that is guided by prior knowledge is called *conceptually guided* processing.

Data-driven processing. This mode of processing requires that all signals be monitored to some extent for potentially important patterns. Some of the monitoring can be done by peripheral processing, and within the first stages of sensory analysis. This monitoring cannot be very sophisticated because there simply is not enough processing power. One result is that the system must choose between constant interruption for unnecessary events and missing some percentage of relevant events. In terms of detection theory, the monitoring of external signals has a low detectability value, and the system must trade off a high hit rate for a high false alarm rate. The data-driven capability allows a person to respond to newly occurring situations and to keep up with changing environments. It also makes the person distractible, making it difficult to focus attention on a single task for very long. If the environment is rich, then one is continually being distracted by new events. If the environment is unchanging, the distracting events are likely to be internal ones, perhaps novel thought patterns triggered by reflection upon the existing task demands. But one thought triggers another, and the automatic data-driven control of thought patterns can take one's attention far from the current task. If one tries to cut down on the distractability or on the frequency of such daydreaming, then one pays the penalty that occasional relevant data will be ignored.

If daydreaming results from too impoverished an environment, it can be reduced by artifically enriching the external environment. Thus if the task is a radar watch, with infrequent targets, the addition of occasional false targets will not only tend to keep the operators focussed upon the task, but will assess their current states as measured by their responses.

Conceptually guided processing. Processing demands can be much reduced by extensive use of models of the situation. Prior conceptual knowledge appears to be organized within human memory into structures called *schemas.* Any given situation can be analyzed by identifying it with an existing schema which serves as a prototype. Newly arriving information can be used to confirm the expectations generated by the prototype schema, or to perform minor modifications or elaborations. Once a schema is well established, it serves to guide all further processing. Sometimes discrepant information may not always be processed properly. Conceptually guided processing has both virtues and deficits. One virtue is that it allows people to perform smoothly and efficiently whenever they have existing schemas that can guide their analyses. Without pre-existing schemas, the computational load will exceed the capacity of mental processing. Thus, a novice at a task may have been taught all the knowledge of the task, but will not yet have developed appropriate schemas for all situations so that responses must be computed rather than simply retrieved. In times of crisis, when events occur frequently and responses must be made rapidly, it is impossible to keep up. A deficit associated with schema-guided processing is that the pre-existing schemas lead one to interpret new experiences in terms of old patterns, and this can lead to a rigidity of thought and performance. These aspects of performance are summarized in Table 1.

Table 1

Performance Patterns

	DEFINITION	VIRTUES	DEFICITS
Conceptually Guided Processing	*Guidance from prior knowledge:* Processing is guided by schemas, by prototypical knowledge and past experience, setting up expectations, guiding the interpretation of current events and the responses to them	*Efficiency:* Large reduction in processing required to analyze the situation. Large repertoire of possible evalutions and responses. Efficient, fast performance	*Rigidity:* May lead to stereotyped responses, rigidity in dealing with new situations Ability to deal with complex situations with limited processing (with attention one partial attenuation on the task) may lead to poor behavior patterns and occasional difficulties in unusual situations.
Data-driven processing	*Current processing interrupted to deal with new data:* Processing is directed towards dealing with new sensory inputs, or internally generated data from on-going processing. Current flow of processing is interrupted.	*Responsiveness:* Provides for a responsive and flexible system. Minimizes possibility of missing important events due to attenuation elsewhere.	*Distractability:* The system is distractable, continually being interrupted from its primary task to deal with new events. Even in the absence of sensory events, processing wanders off its main course to deal with unexpected.

Automated Tutorial Instruction

At the Center for Human Information Processing at the University of California, San Diego, we have been investigating a number of aspects of human information processing with the support of the Office of Naval Research. Our studies are primarily theoretical and are aimed at understanding the basic principles. Even a slight improvement in understanding can potentially be translated into benefits: a reduction in instructional time, or an increase in quality, and decrease in the drop-out rate of students. Some of our results have potential implications for long-term on the job training, and for the continual practice that seems to be necessary to sustain high levels of performance. A good deal of our effort has gone into the study of new ways of automating the instruction process because automation has the potential of improving the quality of initial instruction in a topic and of providing personalized instruction with fewer human instructors (or none at all) at remote locations. Practical application of the results of these studies requires two things: a deeper understanding of learning, and the development of small, inexpensive computers with powerful processing units, large amounts of memory, and high quality displays. At the current rate of progress, one can expect to see self-contained learning systems of reasonable flexibility and power within the next decade.

One of our goals is the development of an automated tutorial environment. We hope to construct systems that will guide the training of students with minimum intervention by human tutors. Substantial problems must be overcome before we can have intelligent, automated tutorial systems that understand both the topic being studied and the nature of the instruction. We focus our attention on the important theoretical issues that lie in the path towards this goal.

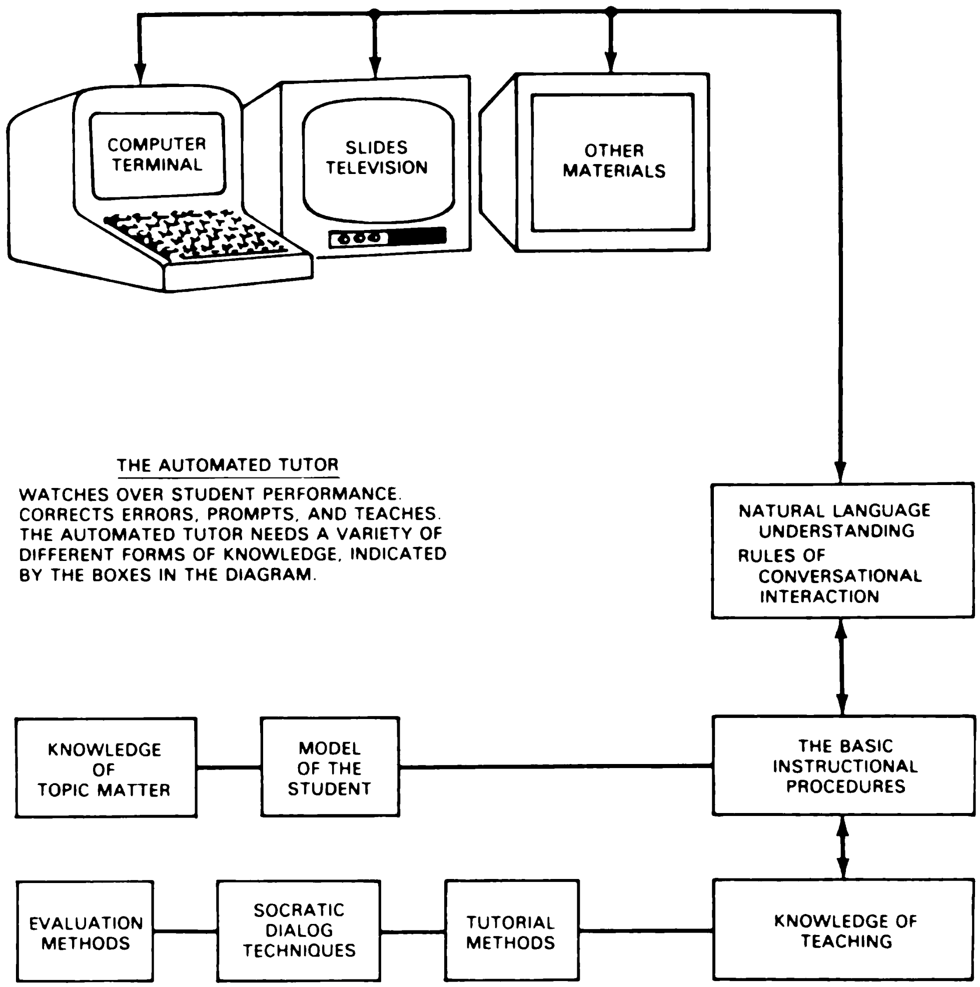
Eventually, we hope that everyone will benefit from automated tutorial systems. Essentially, these systems would "watch over the students' shoulders" as they studied a course topic or as they practiced already learned skills. The automatic tutor would construct an internal model of the students' knowledge states and of the teaching strategies most beneficial for them. Periodically, it might interrupt with some comments. Occasionally it would give examinations or direct the student to watch a television tape or read a particular section of a text (see Figure 1).

Our goal requires that we understand the process of learning and of teaching in order to give better guidance at the tutorial session, assessment of the student's state of knowledge at any time, and direction to both student and human tutor. This means that we must learn how to represent the knowledge about the topic matter in a form that an automated system can use and understand. We must understand tutorial strategies and devise methods of determining when any particular strategy is effective. We must understand the student so that we can develop an appropriate description of him or her. When a student has difficulty with some task, the cause could be a lack of knowledge of some prerequisite. A good teacher is able to work with the student to discover where the real problem lies.

Central to all these issues is the ability to represent knowledge of a topic in such a way that automated programs can reason from it. Considerable progress has been made by research workers in this area, now called *Cognitive Science* — a combination of cognitive psychology,

THE STUDENT

PERFORMS THE TASK BEING LEARNED ON A COMPUTER TERMINAL. HE ALSO HAS OTHER LEARNING AIDS, SUCH AS MANUALS, BOOKS, SLIDES, AND TELEVISION – SOME OF WHICH ARE COMPUTER CONTROLLED.



THE AUTOMATED TUTOR

WATCHES OVER STUDENT PERFORMANCE. CORRECTS ERRORS, PROMPTS, AND TEACHES. THE AUTOMATED TUTOR NEEDS A VARIETY OF DIFFERENT FORMS OF KNOWLEDGE, INDICATED BY THE BOXES IN THE DIAGRAM.

Figure 1 — The interaction of the student and the automated tutor

artificial intelligence, and linguistics. One technique of representation uses semantic networks — the representation of the interconnections between different concepts (see Figure 2).

This representation can be understood by the appropriate computer programs, and it allows several things. The program can reason directly from the representation to answer novel questions (Why was the Cumberland River important to the South?) Note that the answers to the questions need not be stored. If the computer can understand the question and represent it in a semantic network and if the appropriate information is present, the program can solve for the answer, put it into the appropriate semantic structures, and then translate it into English.

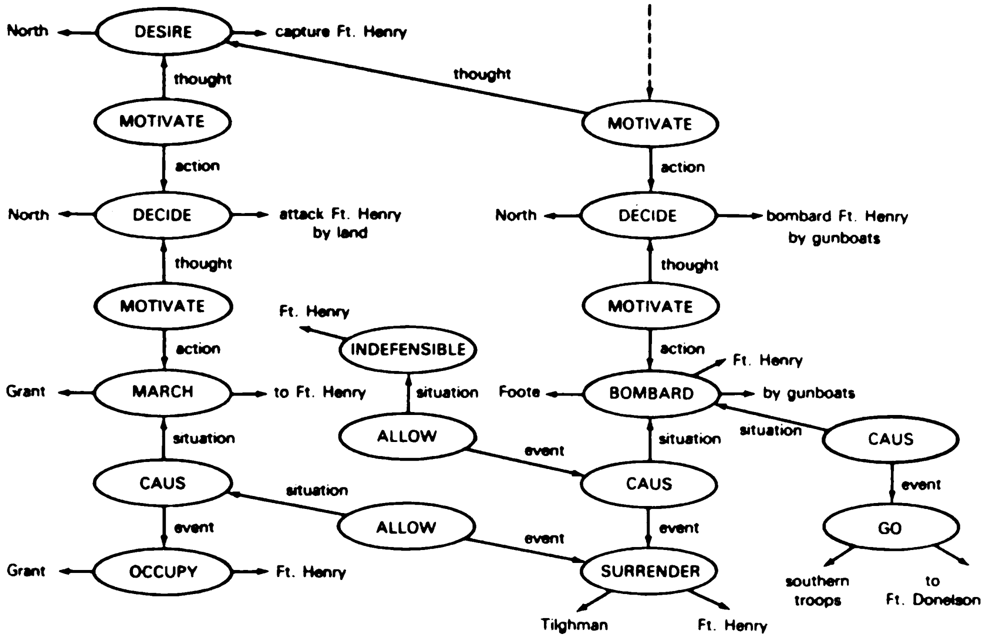


Figure 2 — An example of a semantic network. In this case, the network represents a highly abbreviated version of the American Civil War battles around Forts Henry and Donelson on the Tennessee and Cumberland Rivers, very early in the war. In words, this portion of the data base represents the following: The North's desire to capture Ft. Henry motivated them to attack the Fort by land, believing that if Grant would march upon the Fort, he could occupy it. Simultaneously, the desire to capture the Fort motivated them to decide to bombard it with gunboats. This decision resulted in the bombardment of Flag Officer Foote, causing most of the southern troops in the Fort to flee to Fort Donelson. This made the Fort indefensible, so the remaining Confederates, under Tilghman, surrendered. This finnally allowed Grant to occupy the Fort. Note how the data base incorporates beliefs and plans, as well as the actual actions. Thus, the plan was for Grant to march upon the Fort and capture it. In fact, the Navy captured the Fort before he could get there.

Programs exist today that do all these things. Although they are huge and require large scale computers, this situation is changing. Intelligent instructional systems now exist at several research laboratories. They are experimental research systems and are limited in their ability, being unable to handle the complex topics of real instruction. Workers at MIT have devised systems that guide in the playing of a game called "Wumpus." The system watches over the game player; and if the player seems not to take advantage of all the knowledge that is available, it can suggest strategies. "Did you realize," the system might suggest, "that you aren't making full use of the information available to you? You could determine that the move you intend to take is a bad one... " — and the system then introduces a new principle to the player. Workers at Bolt, Beranek, and Newman, Cambridge, MA, have devised programs that can watch over a person trying to find the circuit malfunction in a highly regulated electronic power supply. As the person suggests measurements to take in searching for possible explanations for the malfunction, the system evaluates the behavior and can suggest alternative strategies. In our laboratory, we have devised the FLOW tutor program that watches students learning a simple computer programming language (FLOW), infers the student's knowledge from the way each new problem is tackled, and offers tutorial advice at appropriate times.

A simplified illustration of the operation of the FLOW tutor is shown in Figure 3. The student reads the instruction manual for FLOW that is presented on one computer terminal and performs the problem exercises on another, adjacent terminal. The FLOW tutor is a computer program based upon a semantic network representation of knowledge about the FLOW programming language and about the state of the student's knowledge. The tutor "watches" the student by observing which section of the manual is being read and by monitoring the student responses.

Figure 3 shows how the FLOW tutor generates its expectations of student responses, based upon its knowledge of the current state of the student and the problem being performed. In Figure 3, the student has just finished writing his first program (shown in the box labelled "Simulation of student task"). This program printed the student's first name followed by his last name. Both names appeared on the same line, with no space between them — as PETERSOLSOL. The student is now instructed to modify the program to insert a space between his first and last name. The TUTOR sets up a series of schemas that reflect its expectations and predictions. Basically, the expectations are that the student will follow the sequence of actions shown in the first row of the box labelled "Expectation of student actions" (change the FLOW state to LIST, insert the statement "DISPLAY", list the program, then run the program). The first of these expectations, in turn, sets up the specific prediction that the student will type the letter "L" (as shown by the shaded box numbered "1"). The second of the expectations sets up the specific predictions that the student will type "RUBOUT RUBOUT 1 d" (where d is any digit between 1 and 9), followed by typing the sequence: D "space". Finally, the last two of the general expectations predict the 10th and 11th keypresses will be an L and then a R. If the student were to follow this sequence, then the TUTOR would conclude that he understood the material and would ask him to advance to the next problem.

The power of the TUTOR is displayed when the student fails to meet with the predictions. One student we studied, at this point in the instructional sequence, responded by typing first a D rather than the expected L. This is an illegal key in the current state of the system, and the letter has no effect except to appear briefly on the screen, to signal the student by sounding a "beep," and then to disappear. Why did the student type a D? Note that it matches a future prediction (the prediction numbered "6") which perhaps the student is anticipating.

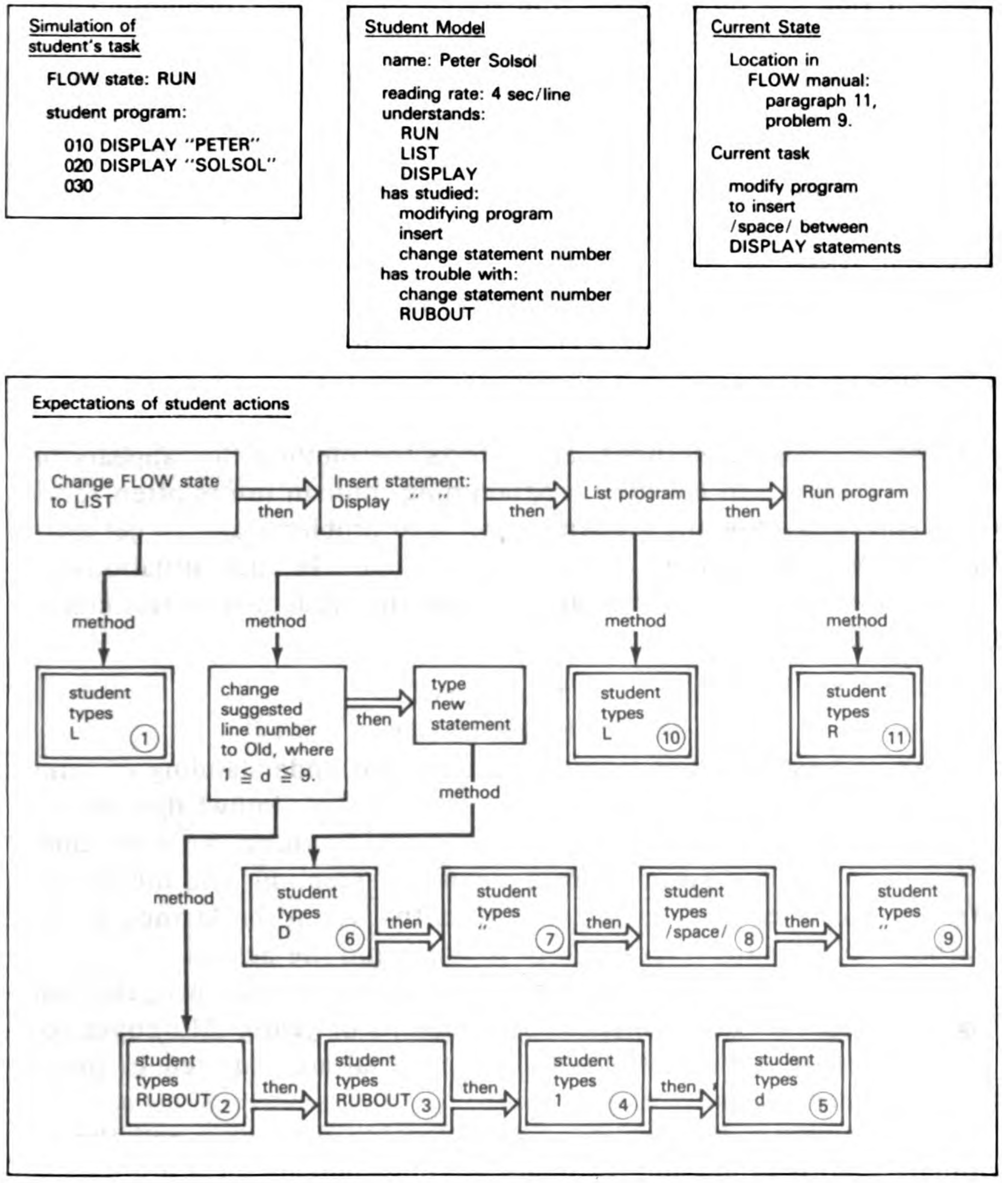


Figure 3 — Some of the operational states of the FLOW Tutor. The FLOW tutor has a model of the student, knowledge of the current state of the system, knowledge of the FLOW programming language and system, and knowledge of the contents of the student instruction manual. In this example, the system expands its expectations, starting with the fact that the student is attempting Problem 9. This leads to a specific prediction of the 11 characters to be typed by the student (shown in the shaded squares: the numbers in circles indicate the order of the predicted output.)

This would be data-driven processing; the arrival of a specific datum drives the system to find some explanation for its occurrennce. Of course, the D could also represent a simple typing error or one of several other possibilities. The TUTOR program hypothesizes a reason for the error but does not prompt the student at this time. Rather, it waits; if this is a typing error, the student will correct it without assistance. In this particular sequence, the student typed D again and eventually had to be told to LIST the program, and then had to be told how to list it by typing L.

Notice that there is a fair amount of apparatus set up just to analyze the single keypress of the student. We believe this to be an essential aspect of tutoring. The good tutor thinks ahead of the student, predicting the student's behavior and giving reasons for student errors and difficulties. Moreover, the good tutor is aware that the reasons may be erroneous, and so will often wait for more evidence before interrupting the student. The good tutor also has a reasonably large repertoire of tutoring methods, and selects the method that appears best for the occasion. In teaching programming, human tutors often remain quiet and thus allow the student to get into problems and to get out of them without tutorial aid as much as possible. In such situations, the tutor intervenes only when it appears that the student is in real conceptual difficulty.

Summary

The understanding of learning requires the understanding of human cognitive processes. Many different forms of knowledge interact. Many different skills interact. To understand learning, we must understand memory, language, problem solving, perception, and motor skills. We must also learn to analyze the tasks that are to be learned because learning requires the interaction of the task and the person.

Real learning takes time. For most topics of importance, the learning times are measured in periods of months or years. Moreover, continued exercise and practice with the material are required to prevent the knowledge from deteriorating.

Considerable enhancement of both the initial training and the continued practice is possible through the development of automated tutorial systems. These systems must have intelligent knowledge of the topics being tutored, of the knowledge and performance state of the student, and of the appropriate tutorial techniques. To do these things properly requires considerable advances in our understanding of intelligent computer systems, in the means of representing knowledge, in the strategies for teaching, and in the process of learning.

Within the past decade there have been dramatic gains in our understanding of the human information processing system and in our ability to construct intelligent computer systems. Intelligent tutorial systems are now operating for limited topic domains. Even though such systems are small in coverage and in the size of the computer system needed to support them and large in terms of the effort needed to construct them, it is a successful beginning for future computer development.

The armed forces in general, and the Navy in particular, are massive consumers of training programs. An enormous amount of information must be acquired before using technological systems. Moreover, once acquired, the knowledge must be reinforced by continual practice with the material, and advances in technology require "refresher" or "updating" courses. Learning is a large, expensive enterprise, and anything that can increase the efficiency or effectiveness of the process will reap substantial cost and time benefits.

Learning should be enjoyable and should continue throughout life. A sympathetic, intelligent tutor can help to realize these ideals, but providing lifetime human tutors for everyone is clearly impossible. What is possible is the development of intelligent tutorial systems which eventually will be on small, individually owned computers. A new dimension in learning and teaching is before us.

New Information on Opioids

A new class of small peptides called opiods was discovered a few years ago in mamalian brain tissue. These naturally occurring compounds received their name because of their resemblence physiologically to the opiates, morphine and heroin. All of these compounds suppress pain, cause certain motor abnormalities and lead to dependence. Furthermore, their physiological effects are all blocked by the same substance, nalaxone.

The opiods are a family of compounds having similar chemical properties but vary in length due to the number of amino acids in their make-up. The larger molecules, α-endorphin (16 amino acids) and β-endorphins (31 amino acids) include the smaller molecules, enkephalins, (5 amino acids). That being the case it was not certain whether the enkephalins were independent of the endorphins or had a common biochemical pathway. For example, it was not known if the enkephalins were metabolites of the larger endorphins or whether the endorphins were precursors of the enkephalins.

ONR contractor, Dr. Jack D. Barchas at Stanford University Medical School has been working on this particular problem for the past two years. He and his group have recently shown that the enkephalins are found to predominate the brain while the β-endorphins are more abundant in the pituitary gland. They are evidently synthesized independently of each other. In addition to this, his group has been able to trace some of the β-endorphin pathways from a single neuron in the hypothalamus to the midbrain and limbic structures. The enkaphalins are found in areas of the brain and spinal cord that are involved in pain transmission, respiration, motor activity, endocrine control and mood.

The discovery of these substances and the exploration of their function has offered new opportunities in the study of pain suppression, drug addiction and psychiatric disorders.

Research Notes

Structural Optimization of Pressure Hulls

Professor M. Pappas at the New Jersey Institute of Technology with the support of The Office of Naval Research has been involved in optimization studies of pressure hulls for submersibles. He explored the idea of reducing the weight by using non-identical, not equally spaced stiffening rings of uniform cross section. He obtained optimal hull configurations using 3, 11, and 19 stiffening rings and he found that 0.5, 1.6, and 5.5% weight reduction associated with multiple size frame configurations. The pay-offs were obtained when compared to the weight of stiffened shells having stiffeners of uniform cross-section and equal spacing, and when buckling controlled the design. Greater advantages are expected for hulls that are optimal with respect to the number of stiffeners employed since earlier studies have shown that the optimal number of frames is usually greater than 19.

In the future, stronger materials, most likely, will be used and the controlling mode of failure might be buckling. Under the above circumstances the reported savings in weight could be realized.

Unique Fire Detection System

A team of scientists at the Naval Research Laboratory has developed a prototype of a fire detection system for possible use in reducing false alarms on ships. Detectors aboard ships encounter temperature, humidity, airflow extremes and other problems that increase the incidence of false alarms.

There are other unique shipboard problems associated with machinery spaces, fuel and material storage areas which produce aerosols similar to those produced during a fire. A fire detector system must be able to differentiate these aerosols from those that result from products of combustion.

The fire detection system is presently being evaluated in comparison tests with a wide variety of commercial detectors at the Philadelphia Navy Yard as a candidate for shipboard use.

the NRL prototype combines two distinct ionization-type detectors, giving it greater detection reliability and a means of spanning a wider particle size range than detectors presently in use, thus, potentially providing the solution to many of the unique shipboard problems.

In addition, the system has the capability to sample the atmosphere surrounding the detectors and thus to monitor the progress or regress condition of fires on a real-time basis.

Although the early stages of the detector system and the prototype looks very promising, it will be some time before such a system can be manufactured and put to widespread use.

Laser Annealing of Ion Implanted Silicon

About two years ago, Soviet investigators reported at meetings in the U.S on the results of laser irradiation of ion implanted silicon. Samples are severely damaged by the process of ion implantation, and the crystalline disorder must be restored by annealing. Thermal treatments are used which result in varying degrees of successful restoration of crystallinity. Many factors are involved. The laser irradiation represents a new method for introducing heat into the solid to bring about annealing as reported by the Soviets. Subsequently, many groups throughout the world began irradiating ion implanted samples with lasers. In July 1977 an Italian group reported on the laser annealing of amorphous silicon produced by ion bombardment. Their results greatly stimulated efforts to study the processes involved. The Italians began a collaboration with scientists at California Institute of Technology under Professor James Mayer who were to analyze some of the properties of the irradiated samples. The results are indicative of the power of the laser annealing technique which is undergoing enormous development all over the world. Electron device manufacturers, and solar cell materials developers are extremely interested since the technique allows for simpler and cheaper processing capability. Some recent results from the Italy-Cal Tech collaboration are of great interest. A crystalline Si sample is made amorphous to a depth of about 4000 Å by bombardment with Si ions. Q-switched ruby laser beams of varying energy density illuminate these layers. The resultant samples are then investigated for the degree of crystallinity restored by the annealing. Ion backscatterng and transmission electron microscopy are used. For crystals oriented with (100) and (111) surfaces, *complete* recrystallization can be restored if certain laser energy thresholds are exceeded. For the (111) orientation the energy threshold is about 20-30% higher than for the (100) oriented samples. For lower energies, varying conditions of polycrystallinity appear and production of stacking faults is common. Thermal annealing (heating the entire sample in a furnace) results are not as good, and for (111) samples much of the sample is twinned after the anneal cycle. Thus, thermal annealing is a different process than laser annealing. For laser anneals, local temperatures can exceed the melting point of the silicon. This melt is in contact with a solid (crystalline) substrate. After the laser is turned off (a 50 nanosecond pulse is used) the melt cools and silicon recrystallizes. Important results are emerging from this technology area almost daily. The Office of Naval Research is supporting this program at Cal. Tech.

Black Holes in the Nuclei of Galaxies*

The concept of a black hole is almost too fantastic, even for science fiction. Yet, it is an inevitable consequence of Einstein's theory of relatively. A black hole has a surface through which anything can fall, but nothing can emerge—a cosmic "disposall."

Matter within a black hole is crushed to infinite density and infinitesimal volume. The gravitational pull is so strong that even light is trapped in its grip. It curves space and warps time.

Our galaxy must be filled with millions of black holes that result from the collapse of massive stars. When these stars have burned out all their nuclear fuel, they cannot generate enough pressure to resist the overwhelming pull of gravity.

This note by Herbert Friedman, Superintendent of NRL's Space Science Division and Chief Scientist of the E.O. Hulburt Center for Space Research, outlines the current state of the search for black holes in the galaxies.

After millions of years of stable nuclear burning, all of the mass overlying the burned out neclear furnace suddenly comes crashing down in less than a second. If the collapsing star is ten times heavier than our sun, it will disappear inside a black hole only 30 miles in radius.

The universe is filled with, perhaps, a hundred billion galaxies. Most seem to spin serenely, but every now and then an explosion of incredible force takes place at the center of a galaxy. The most brilliant example is the quasar.

Quasars appear to be active galactic nuclei that normally radiate a hundred times the visible power of the Milky Way from a volume less than one millionth its size. They vary in brilliance over a matter of days, even flaring to 10,000 times the brightness of a normal galaxy. Thermonuclear power falls far short of meeting the energy requirements of quasars. Only gravitation, acting on a cosmic scale, can concentrate the required energy.

Scientists have, therefore, come to speak of massive black holes, created by the capture of a million to a hundred million suns, lurking in the nuclei of explosive galaxies. As stars orbit near such a black hole, tidal forces rip them apart and the debris is gobbled up by the gravitational trap. A great cloud of gas envelops the black hole and is heated to enormous temperatures by friction. Some theorists postulate temperatures of billions of degrees, which create an intense flood of X-rays.

Recently, this picture seems to have been supported by observations of the giant elliptical galaxy M-87 in Virgo. About a dozen years ago the Naval Research Laboratory discovered that M-87 was a powerful X-ray source. Now, optical astronomers at Palomar and Kitt Peak have found evidence for a great concentration of mass in the very heart of the galaxy. Per unit of luminosity, the mass is 60 times as great as the sun's. They suggest that the nucleus of M-87 contains a black hole of perhaps 5 billion solar masses.

The nucleus of our own galaxy, now seemingly calm, shows evidence of a past convulsion of catastrophic proportions. A doughnut shaped molecular cloud, containing the mass of a hundred million suns, surrounds the nucleus and is blowing outward like a gigantic smoke ring. Its diameter is about 1600 light years and it is expanding at a speed of about 260,000 miles per hour, implying a great explosion only a million years ago.

Still farther out is a rapidly rotating disk of hydrogen gas, expanding at a rate of a million miles perhour, signifying an even eariler explosion.

At the very center of the galaxy is an intensely bright radio source, Sgr A West, which has a compact core smaller in diameter than our solar system. Radio astronomers have speculated that this is a black hole of some 10 million solar masses, which would measure less than four astronomical units in diameter (1 A.U. equals the distance from earth to sun). The black hole may have powered past explosions and now be storing energy for another cosmic outburst.

To test this speculation, the Naval Research Laboratory astronomers flew a rocket to study X-ray emission from the galactic center. No X-rays could be detected from Sgr A West, although several individual X-ray sources were scattered through the general vicinity of the galactic nucleus.

Perhaps these are black holes enclosing long dead stars that have been wandering for eons through the galaxy and now happen to be passing through the dense bulge at the center of the galaxy, swallowing gas and radiating X-rays.

The NRL study of the galactic center offers no support for the idea of a massive black hole. Perhaps the black hole blew away most of the surrounding mass in an explosion a million years ago and is sucking back new material to be stored up for a new explosion in the future. In the interim, its X-ray luminosity may be too faint to detect.

Some theorists suggest that a massive black hole at the center of the Milky Way may be enveloped by a cloud so thick that the outer fringes of the cloud are no hotter than perhaps 10,000 degrees and radiate mostly ultraviolet light.

Unfortunately, we cannot observe visible or ultraviolet light from the center of the Milky Way, because the disk of the galaxy is filled with dust that blocks our vision. Only X-rays, infrared and radio waves penetrate the murk.

But we can infer what exists at the center of the Milky Way if we examine its twin, the Andromeda galaxy, 2-million light-years distant. Andromeda is a giant spiral galaxy whose disk is tilted towards us at about 30 degrees, so that we can see directly into its nucleus.

George Carruthers of NRL has flown a powerful electronic ultraviolet camera to photograph Andromeda. His picture of the nucleus does not show a brilliant ultraviolet core that could be attributed to a massive black hole.

The black hole score card therefore reads as follows: a bright core in M-87 suggests a billion solar mass black hole and appears to be a powerful X-ray source; the nucleus of the Milky Way reveals a brilliant radio source but shows no similar X-ray source; and Andromeda reveals no ultraviolet source consistent with black hole models.

Perhaps quasars and other explosive galaxies do contain massive black holes which set off violent outbursts lasting about a million years. Our Milky Way may alternately suck and blow matter around a massive black hole in its nucleus. The last blow-off occurred millions of years ago. It may now be gathering energy for another blow.

The search for conclusive proof of the existence of black holes has become a major endeavor of the entire astronomical community. NASA's HEAO (High Energy Astronomical Observatory) series of satellites play a key role.

Oxidation and Heat Liquefy Coal

Dr. Robert Hazlett, a chemist at the Naval Research Laboratory, has successfully converted coal to liquid hydrocarbons by oxidation and heating.

The technique uses air as the reactant and produces small hydrocarbons in yields up to 35 percent. The hydrocarbons obtained have molecular weights between 90 and 210, a range typical of liquid fuels.

The NRL process which uses two steps is carried out at mild reaction conditions. The first step, oxidation, converts vulnerable sites in the coal to oxygenated species. This reaction with air occurs readily at one atmosphere pressure and temperatures below 175°C.

The second step, thermolysis, ruptures the coal molecule at the oxidized site. Thermolysis to small hydrocarbons occurs at 100-300 pounds pressure and 400°C.

This technique uses much less severe reaction conditions than other techniques being developed for coal liquefaction. The yields resulting from this oxidation/thermolysis process equal or exceed yields by other techniques, such as pyrolysis or hydorgenation.

Antenna Motion Compensator for Airborne Radar

Dr. Tomos L. ap Rhys of the Naval Research Laboratory has applied for a patent on an improved displaced-phase-center-antenna technique he developed which compensates for the motion in an airborne radar system more accurately than techniques currently in use, thereby permitting the detection of smaller targets at greater ranges. This invention could prove to be of great operational value to airborne early warning, antisubmarine warfare and other military aircraft with radar systems.

The invention relates to radars of the airborne moving-target indication type, which compensates for the relative motion between fixed objects and the radar system itself and provides a means of cancelling the signals reflected back from fixed objects.

Dr. ap Rhys says his device allows for the change in phase of signals scattered from fixed objects due to motion of the aircraft by effectively moving the antenna (by electronic means) the proper distance, both parallel and normal to the antenna's boresight direction so that the antenna appears stationary in space, over the short time-interval required.

Medical Emergency Computer Model for Military/Civilian Uses

Dr. Paul B. Richards of the Naval Research Laboratory reports the development of a computer model that can simulate the many complexities of an emergency medical system in a matter of 10 minutes or less, at a cost of under $100.

A single mock drill conducted to simulate the medical response to an aviation disaster at an airport, on the other hand, requires many months of preparation, a lot of manpower, and costs approaching $100,000. Even greater expenditures of time, money, and manpower would go into an exercise designed to test a military combat zone medical care system.

The new computer model, dubbed NAMES II (for Navy Amphibious Medical Evacuation Simulation), simulates the medical treatment and evacuation of casualties within a combat zone, but it is also applicable to civilian medical emergency systems. The model provides for various levels of casualty treatment facilities and a full range of evacuation options.

The simulation model can be manipulated to test a wide range of emergency conditions and the effect response of alternate medical systems which might be designed to cope with these conditions.

NAMES II is currently being used to assist medical planners in the Military Departments, and is expected to be of considerable interest to civilian organizations concerned with medical emergencies ranging from every-day automobile accidents to mass casualty situations, such as earthquakes and aircraft accidents.

U. S. GOVERNMENT PRINTING OFFICE : 1978 O - 278-655

Extremely Wide Bandwidth Adaptive Antenna Arrays

Professor Lloyd Griffiths of the University of Colorado has devised a hybrid analog-digital adaptive antenna sidelobe canceller that appears to provide nulling capability over extremely wide bandwidths. This is made by the development of ultra high speed analog to digital converters by TRW under ONR support, that permit direct sampling at radio frequencies. One of the major advantages of the algorithm used is that, unlike conventional adaptive algorithms which require one receiver per element, only one receiver per array is required, thus greatly reducing the cost of adaptive beamforming. Other important advantages include the ability to maintain generally low sidelobe levels and main beam integrity through analog weights and fixed constraints, an important factor for radar applications; and the ability to null narrowband jammers without degrading the antenna patterns in adjacent frequency bands. The algorithm has been tested using both computer simulations, the actual data recorded by the SRI WARF OTH radar. Null depths of 30 to 40 dB were achieved despite the 2 or 3 bit limitation assumed for the A to D converters.

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Editor: WILLIAM J. LESCURE NAVSO P-510

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Cover Caption

Meredith Sessions (left, principal engineer) and William C. Patzert (right, co-principal investigator) of the Scripps Institution of Oceanography operating the portable AXBT digital data recording system developed at Scripps for use aboard P-3 aircraft.

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