NAVAL RESEARCH REVIEWS

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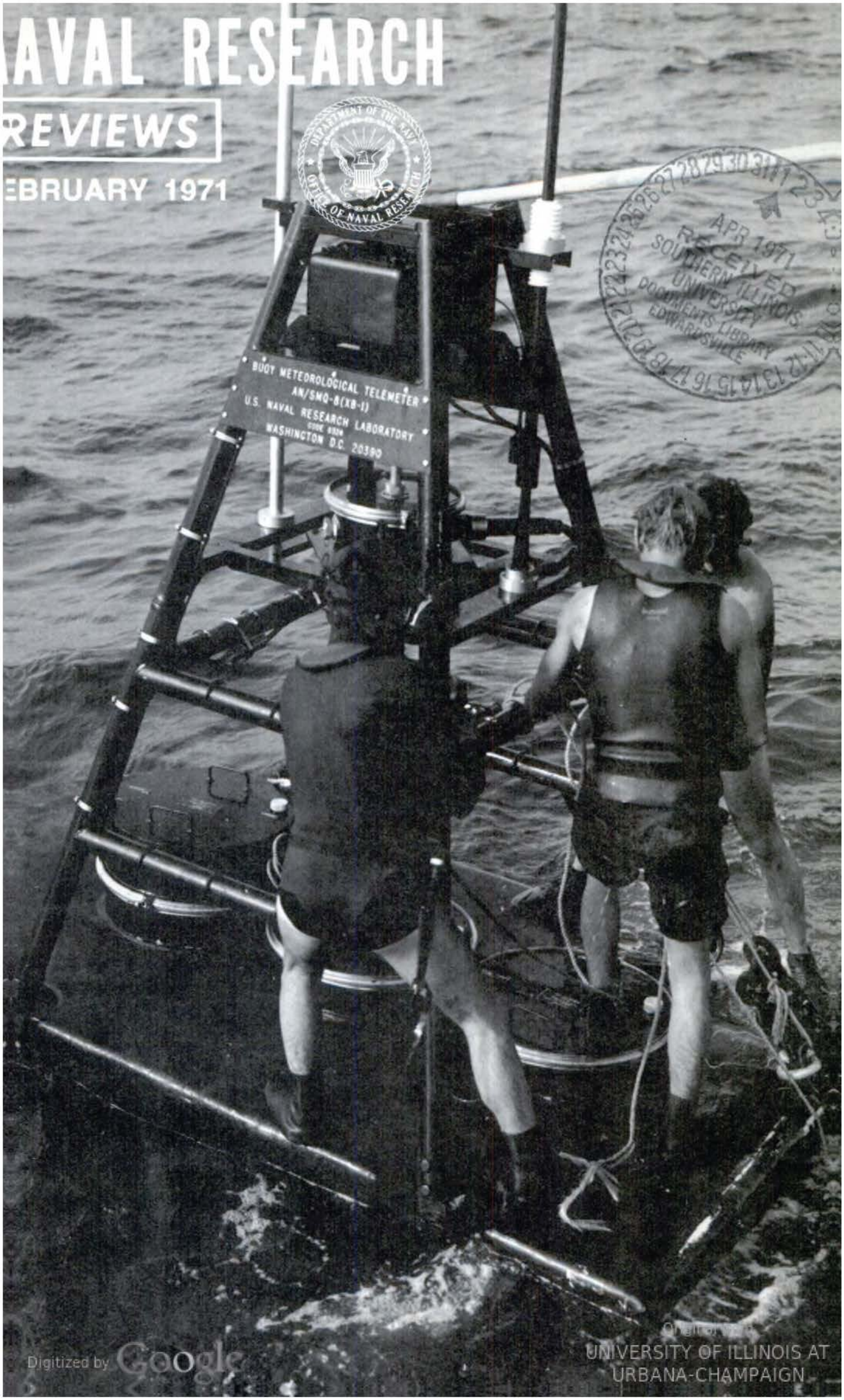

Underwater Holographic Viewing System Successfully Tested by Navy

The Navy has demonstrated that acoustic holography is practical as an underwater viewing and detection system with the successful testing of the first such underwater optical system able to display identifiable images in real time.

The system was developed by Bendix Research Laboratories, Southfield, Michigan, under an Office of Naval Research contract. An experimental operational version of the system to be installed on a Navy deep submersible vehicle is under development by the Navy Underwater Research and Development Center, San Diego, with funds provided by the Naval Ship Systems Command.

The idea of combining holography, the term for lensless photography, with acoustics as a technique for underwater viewing has been under study by the Navy in recent years. Acoustic holography offers certain advantages over conventional search and surveillance techniques, such as direct optical viewing and sonar.

Direct viewing is limited to ranges of several feet under turbid water conditions while acoustic holography is relatively unaffected by water turbulence and turbidity. Conventional sonar cannot provide a recognizable image of the target so that accurate identification and classification of the target becomes a problem. Acoustic holography is capable of producing images of underwater objects including a three-dimensional display, over a comparatively large field of view.

The major disadvantage of underwater acoustic holography as compared to sonar is that its range is limited. The Bendix system is capable of achieving a range of several hundred feet, which makes it impractical for submarine detection, although this is not ruled out as an eventual possibility. The present system, however, will be useful in such applications as search and rescue operations, including search for lost objects, salvage operations, bottom topography mapping, and as a navigation aid for ships and submarines maneuvering in narrow channels.

The major components of the Bendix system are a sound transmitter, the receiving array, electronic signal processing equipment, and a real-time image reconstruction device, with the image displayed on closed circuit television. A key component developed by Bendix is the square planar hydrophone receiver array, which in the initial experimental system consists of 400 individual hydrophones occupying less than two square feet. An operational system may include as many as 10,000 hydrophones mounted on any kind of curved surface.

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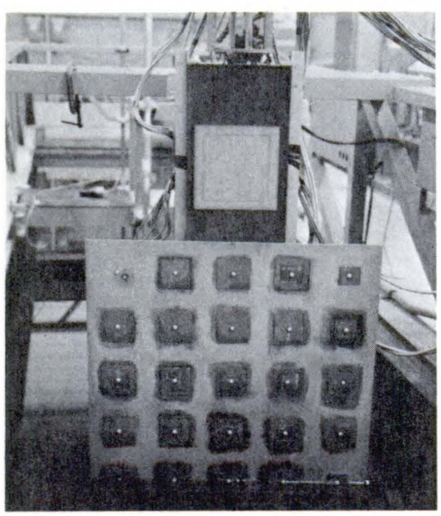

On the top is the receiver array and on the bottom is the transmitter

Symbolic Flight Displays

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The goal of the research described in this article is improved performance of Navy pilots through use of dynamic, symbolic flight displays. A major problem in the design of symbolic displays has been the question of movement relationships between symbols representing the aircraft and those representing the outside world, and the effects of these relationships on control reversals experienced by pilots. The basic questions are: What should move on the display—symbols representing the airplane or those representing the outside world? Also, how should they move? This research involves in-flight comparisons between the conventional flight director display and an experimental display with novel movement relationships.

Introduction

In 1968, a representative year for civil aviation, 89 airplane crashes were classified as weather disorientation accidents by the National Transportation Safety Board. Of the 79 fatalities that resulted, a substantial number occurred when an airplane with a normally operating gyro-horizon display was flown into the ground in a tight spiral. Entry into a highspeed spiral dive is temporally associated with entry into a cloud and the shift in visual frame of reference necessitated by loss of visual contact with the ground. In 1954, Leslie Bryan, Jesse Stonecipher, and Karl Aron, at the University of Illinois, found that planes flown into clouds by licensed pilots without specific training in making 180-degree level turns using cockpit instruments were in well-developed graveyard spirals within an average of 178 seconds.

One of the first systematic investigations that considered pilot errors quantitatively was conducted by Paul Fitts and Richard Jones of the Aeromedical Laboratory at Wright Field in 1947. They analyzed pilots' accounts of 270 errors made while reading and interpreting instruments. The attitude indicator, or artificial horizon, was shown to contribute greatly to a type of error referred to by pilots as reversal errors. Such errors result from misinterpreting an instrument indication and making a control movement that aggravates rather than corrects an undesirable

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condition. There is ample evidence that pilots make occasional errors of this type using the artificial horizon display. Although the number is relatively small, the consequences of these errors are often tragic, and the amount of overlearning associated with the use of this display suggests that the number should be much closer to zero.

Fitts and Jones considered in detail the causes of such errors. They stated, "The proper direction of motion of flight instruments for maximum ease of sensing has been under discussion since instrument flying was inaugurated....However, after twenty years,...the problem has not been solved satisfactorily...." Since the study by Fitts and Jones, more than two decades have passed, and although experimental evidence indicates the inadequacy of the conventional artificial horizon display, it is still in general use. A fundamental problem in basic flight instrumentation remains unsolved.

The Issues

Display Alternatives

Aircraft attitude may be displayed in aircraft coordinates, in which case the parts of the display that represent the outside world move; it may also be presented in earth coordinates, in which case the parts of the display that represent the airplane move. The same alternatives apply to the presentation of position or altitude or any other spatial information. Displays employing one or the other of these alternative coordinate systems have been referred to by many different names, and in some cases the same terms have been used in the opposite sense. The listing that follows relates various commonly used terms to their corresponding coordinate systems.

Display Presented in *Earth Coordinates*		Display Presented in *Aircraft Coordinates*
Outside-in		Inside-out
Fly-from		Fly-to
Moving airplane		Moving horizon
Moving pointer		Moving card or tape
Aircraft referenced or stabilized	(some authors)	Earth referenced or stabilized
Space stabilized	(other authors)	Aircraft stabilized

Earth coordinates refers to three orthogonal axes fixed in position relative to terrestrial space. One axis is vertical and emanates from the center of the earth; the second is orthogonal to the first and is oriented relative to the north pole; the third is orthogonal to the first and second. *Aircraft coordinates* refers to the longitudinal, lateral, and vertical (x, y, and z) axes of the aircraft.

A Question of Point-of-View

In attempting to determine the preferred motion relationships among display symbols and their real-world counterparts, it is necessary to consider the question of whether the pilot thinks that the display represents his vehicle moving against the external world or the external world moving about his vehicle. This question involves what has been termed the pilot's *frame of reference*. With respect to the presentation of aircraft attitude, the issue is illustrated graphically in Figure 1. In whatever manner attitude information is displayed, it is necessary for the pilot to *think* that his aircraft is moving. If he thinks that the outside world is moving, he is disoriented and subject to vertigo.

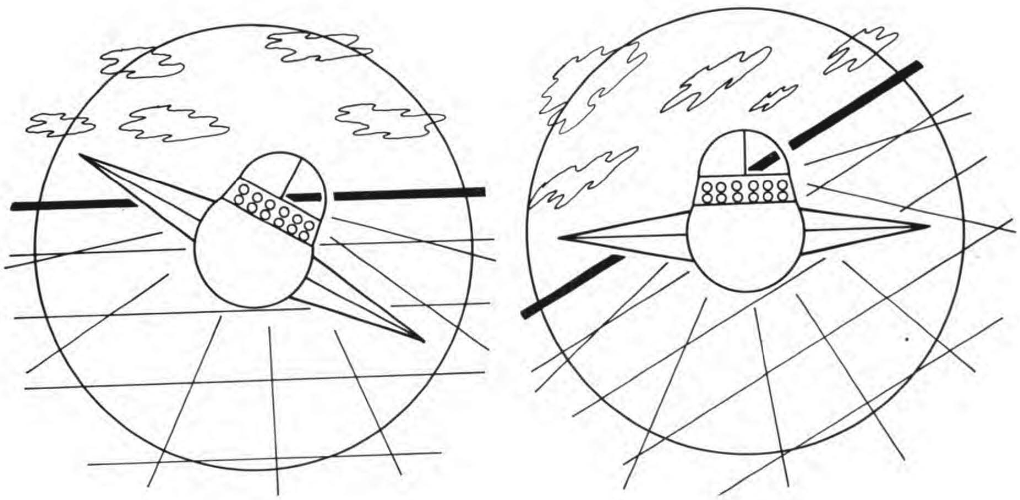

Figure 1 – Illustration of the basic figure-ground controversy in the presentation of aircraft attitude: moving aircraft to the left, moving outside world to the right.

From the date of the invention of gyroscopic flight instruments, including turn indicators, directional gyros, and attitude gyros, the frame of reference for display presentation has been a subject of controversy. The argument found its way into the literature early and was stimulated greatly by the fog flying exploits of Lieutenant James Doolittle under the sponsorship of the Daniel Guggenheim Fund. On September 24, 1929, Doolittle proved conclusively that it was possible to take off and land an airplane by instruments alone. Doolittle took off with the cockpit of the airplane completely covered, flew a distance of 20 miles, and landed at almost exactly the same spot from which he had taken off. The attitude indicator used by Doolittle was the Sperry Horizon which was the prototype for the conventional artificial horizon presentation.

In 1936, Lieutenant Commander John R. Poppen, a naval flight surgeon, presented a rationale for the motion relationship of the Sperry Horizon used by Doolittle. Poppen stated that the correct form of presentation was an exact analog of what would be viewed through the windscreen in contact flight. Essentially he considered the display to be a porthole through which the pilot views a symbolic analog of the real horizon. Poppen carried this line of reasoning to the point of advocating a displacement of the gyroscopic turn needle to the left while in a right turn so as to keep the display index in proper perspective (perpendicular) to the external world. This same rationale has prevailed through the years in support of the moving horizon attitude presentation. Nevertheless, the problem of frequent interpretation and control errors associated with this display remains.

Figure and Ground

The problem of pilot errors on moving horizon attitude displays may be explained in the context of the psychological phenomenon of figure and ground. Psychologically, an object is perceived as moving in relation to other objects in a visual field. The parts of a dynamic scene that appear to be stationary are customarily called the background or simply the ground, and any object that moves is called the figure. When the entire visual field is moving in relation to the observer's eye, as occurs with head movement, the observer usually perceives that he himself is moving and that the background is stationary. The question then becomes, do the figure and ground relationships between the aircraft and the outside world change when the pilot shifts his attention from the outside world to his attitude indicator on the panel inside the cockpit?

In 1947, Walter Grether, also of the Aeromedical Laboratory at Wright Field, postulated a cause of reversals in interpreting flight displays in terms of the concepts of figure and ground. He stated:

> The actual horizon is normally accepted by the pilot as a fixed or stable frame of reference. It becomes a ground (or background) against which his and other aircraft are moving figures. When the horizon disappears, as in instrument flying, the pilot apparently shifts to the cockpit of his own aircraft as the stable reference or ground against which all moving pointers, including the gyro horizon bar, are reacted to as figure. The small, narrow and fallible moving bar apparently cannot substitute for the distant, massive, and infallible true horizon as a stable frame of reference for the pilot. By reaction to the gyro horizon bar as figure instead of ground, he is led to an exactly reversed interpretation.

If the pilot's frame of reference changes when he views a small, abstract instrument representation of the outside world, as opposed to the outside world itself, this change must involve a shift in the figure-ground relationship. Specifically, the aircraft's instrument panel or even the framed aperture of an individual display becomes the background against which the display elements move.

Figure and ground relationships have been found to depend on various display characteristics and may yet be found to depend on others. The highly resolved, dynamic, literal image in full color presented on a display screen by a projection-type flight periscope consistently yields the same stable figure-ground relationships for all pilots regardless of display size. Figure-ground relationships for abstract symbolic representation of the outside world are far less stable. If a highly abstract display subtends an extremely large visual angle, approaching that of a windscreen, the stability of its figure-ground relationships may improve compared with those of a normal three-inch indicator, but this possibility has not been demonstrated in formal experimentation.

Control-Display Relations

Motion compatibility must be considered in conjunction with the pilot's frame of reference. Depending on whether the desired or the actual position of a pilot's aircraft is the frame of reference, the display element may move either in the same direction as the control input or in a direction opposite to the control input. That is, the operator may consider the movement of a display symbol from the fixed reference either as something he must follow to correct his error or as something he has control over and must bring back to the fixed reference. In the first case, a displacement of the symbol to the right of the reference point would dictate a right control movement; in the second case, it would call for the opposite response.

A strange and unfortunate terminology has been applied to simple control and display direction of motion relations. When a moving element of a display represents some aspect of the performance of the vehicle over which the pilot has reasonably direct control, as in the case of a needle on a vertical speed indicator, the display is said to require a *fly-from* response. Thus, when the needle is below its desired position, the proper response is to fly up or "away from" the needle which is "down." Conversely, when the moving element represents an index of desired performance, as in the case of a course deviation needle, the display requires a *fly-to* response. If the needle is to the right of center, indicating that the airplane is to the left of course, the proper response is to fly right, or to the needle. With *fly-to* displays, control and display movements are in opposite directions; with *fly-from* displays, they are in the same direction, at least in simple cases involving reasonably direct control.

Almost without exception, when significant experimental differences have been found between the *fly-to* and *fly-from* alternatives, they have favored the *fly-from* type of presentation.

Moving Airplane Versus Moving Horizon

With respect to attitude presentation specifically, the central question is whether the aircraft symbol or the artificial horizon symbol should move with reference to the fixed display coordinates. Despite the extensive experimental evidence favoring the moving airplane presentation, the issue is not settled after nearly half a century of controversy.

One of the first experiments on aircraft attitude presentation was done by Roger Loucks at the School of Aviation Medicine at Randolph Field in 1945. He simply reversed the direction of rotation of the horizon bar on a conventional attitude indicator in a Link trainer. In his report he concluded:

> ...the superiority of the reversed rotation type of artificial horizon has been exhibited in spite of the fact that when the aircraft assumes a right-roll attitude, the indicator registers this maneuver by showing the miniature airplane with its left wing dipped below the horizon bar. ...it would appear that the direction of rotation of the moving elements in the instrument comprises the factor which the novice reacts to most immediately—a factor which the more experienced pilot has learned to disregard. ...if the correct static pattern were presented along with the appropriate dynamic relationship of the moving elements, *e.g.*, when the horizon remains fixed and the miniature plane rotates, the resulting instrument might be superior to the reversed rotation horizon....

Since the time of the Loucks study, many experiments have been conducted on motion relationships for attitude indicators. The validity of the results is suspect, in some cases due to the experimental procedures and subjects used, but more frequently because the experiments, however well performed, were conducted in fixed-base (non-moving) flight simulators. The validity of results from simulator experiments simply has not been established for questions in which physical acceleration cues are believed to be important, and the results from the few flight experiments that have been done are inconclusive.

A New Application of an Old Idea: Frequency Separation

With few exceptions to date, the alternatives of a moving outside world with a fixed symbol representing the aircraft and an aircraft moving against a stationary outside world have been considered as mutually exclusive arrangements. A third alternative is that of having both the aircraft symbol and the symbol or symbols representing the outside world move. In such a display, some movement relationships may be inside-out while others are outside-in.

When the pilot's task requires sudden control movements, as in recovering from unusual attitudes and flying complex tracking tasks, control-display motion compatibility may be the primary task consideration; when flying straight and level or in gentle flight maneuvers, direction of motion compatibility may be of little concern. There is evidence that the critical consideration is the relative speed of movement of the display indications: when high frequency (suddenly changing or rapidly alternating) information is displayed, the moving element must respond in the expected direction; when low frequency information is displayed, the element's direction of movement apparently is not as crucial.

In 1955, Rube Chernikoff, Henry Birmingham, and Frank Taylor, of the Naval Research Laboratory, found pursuit tracking superior for high frequency control tasks while compensatory tracking was adequate when the pilot's job was leisurely. In a pursuit tracking task, both the target's maneuvers and the controlled vehicle's responses are displayed independently; in a compensatory task, only the difference between the two, or tracking error, is displayed.

These observations led to the notion of using frequency separation as a principle in the design of displays. In a simulator experiment by Donald Bauerschmidt and Stanley Roscoe at Hughes Aircraft Company in 1960, a five-to-one improvement in air-to-air attack steering performance and an 18-to-one reduction in control reversals were found when a pursuit-type frequency-separated display was compared with the conventional attack displays used in all Air Force and Navy interceptors. The Air Force colonels on the North American F-108 Development Engineering Inspection Board, who had served as pre-test subjects in the experiment, voted unanimously to adopt the experimental display. Approximately one week later, in September 1959, the F-108 program was cancelled.

The best known example of a frequency separated display was introduced by Lawrence Fogel of Convair in 1959. Fogel's primary aim in the formulation of what he called a *kinalog* display (a contraction of kinesthetic analog) was to make visually displayed attitude information more nearly compatible with the information a pilot receives through his kinesthetic and vestibular senses. Fogel recognized that the proprioceptors sense only accelerations and convey no direct information concerning rates or positions and, furthermore, that they have relatively high thresholds for sensing accelerations.

Since accelerations in an aircraft, particularly the angular accelerations associated with changes in attitude, are typically transient in nature, Fogel reasoned that visual and vestibular compatibility require only that the initial motion of a display indication from any steady state be in the same direction as the angular acceleration. Thereafter, the direction of display motion may gradually be reversed without conflicting with vestibular and kinesthetic cues. For example, if the pilot moves the control stick to the right to initiate a right turn, the aircraft symbol should immediately rotate clockwise to coincide with the direction of angular acceleration. As the aircraft establishes its right turn and the angular acceleration is replaced by linear acceleration normal to the aircraft's wings, both the horizon line on the display and the aircraft symbol gradually rotate counter-clockwise so that in a steady state turn the aircraft's angle of bank is displayed by the tilt of the horizon bar, as in a conventional presentation.

The principle of frequency separation may be generalized to include all cases in which high frequency (rapidly changing) information, such as roll and pitch rates, angular accelerations, and control inputs are presented in the moving aircraft fashion; and the low frequency (slowly changing) information, such as attitude and heading, continue to be presented in the conventional moving world manner.

If such a display configuration were found to be advantageous in presenting flight information, many possibilities would be open to display designers. One of the more obvious of these is that the pilot's flight tasks could be presented in a hierarchical manner as advocated by Walter Carel in 1965. In a situation in which rapid or sudden control inputs are necessary, such as in air-to-air attacks, the pilot could respond to higher order, or so-called inner-loop dynamic indications with compatible control-display motion relationships. Lower-order or outer-loop dynamic variables, such as aircraft position which is neither immediately nor evidently related to control movements, would be presented in the conventional manner. Although the principle of hierarchical frequency separation intuitively has many possibilities, it has never been systematically investigated in an experimental program.

Despite the fact that the frequency separation principle has not been the subject of systematic experimental study, it has found several applications in aircraft cockpits without explicit recognition. The widely used Air Force ID-249 and display used in the Butler VAC area navigation system, both shown in Figure 2, are frequency separated displays in which the aircraft's slowly changing displacement from selected course

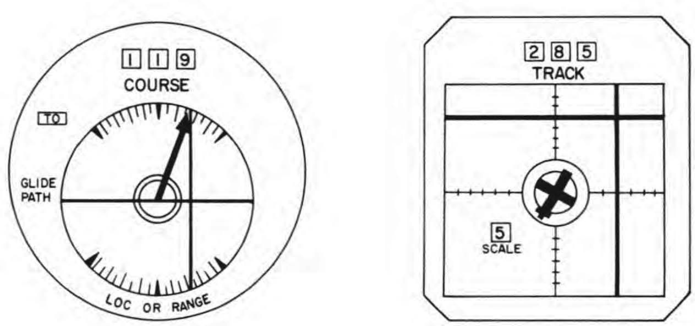

Figure 2 — Air Force ID-249 left, Butler SPI (Symbolic Pictorial Indicator) right

is presented inside-out, while the aircraft's more rapidly changing heading relative to the selected course is presented outside-in. The Lear LIFE display system shown in Figure 3, which accompanied the L-102 autopilot and was adopted by a few local service airlines flying the Fairchild F-27, presented aircraft attitude outside-in and aircraft heading inside-out in a manner such that the display's peripheral bank index could be aligned with the desired heading index in a pursuit tracking fashion.

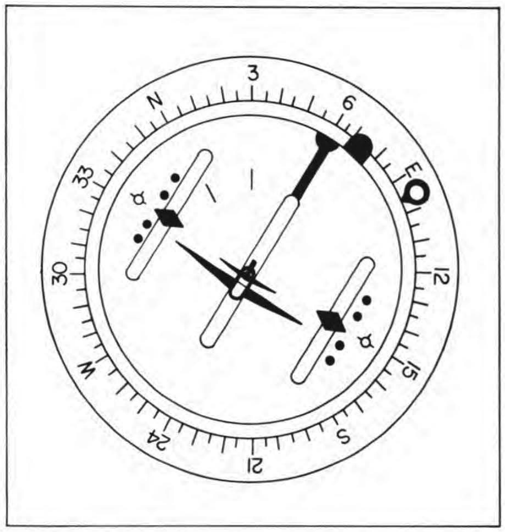

Figure 3 — Lear LIFE (Lear Integrated Flight Equipment) flight director display

Research Problems

Experience Level

Flight experience with any particular display configuration can have a large effect on the results of a display evaluation, and different results are frequently found for experienced pilots as opposed to novice pilots or non-pilots.

A primary consideration when evaluating a display is the ease with which a non-pilot can learn to use it. Not only will his original learning occur more rapidly on a superior display, his terminal level of performance on such a display also will be higher. With respect to the motion relationships on an attitude indicator, what the non-pilot considers as the expected movement of a display symbol, resulting from a corresponding movement of the pilot's own aircraft, will have a large effect on how quickly he learns to use that display.

The pilot population typically overlearns the use of any conventional display configuration. Therefore, it is imperative that a pilot already skilled in the use of a display employing one frame of reference can readily transition to a new display using a different frame of reference.

Although a new display may prove to be substantially superior to an old configuration for non-pilots, the effect of habit interference due to extensive experience with the old configuration may outweigh this advantage for an actual flight system.

Of particular importance is the effect of stress on a pilot's ability to perform on a new configuration. Although a pilot has seemingly made the transition to a new display configuration with little trouble, in a stressful situation he may revert to former, and now inappropriate, control responses. The contention may be made that a display which utilizes motion relationships compatible with the pilot's response tendencies will offer less chance of the occurrence of such a reversal for all levels of pilot experience.

Research Environment

The experimental environment in which a flight display evaluation is conducted must be considered when an attempt is made to extrapolate the findings to real life situations. As in the case in any experimental program, a tradeoff must be made among realism, experimental simplicity, and cost. Experimental evaluations of attitude indicators have ranged from laboratory studies which had little realism, but which were relatively easy to conduct because of their simplicity, to actual in-the-air flight experiments costing relatively large sums of money. To date no experimental program of adequate scope has been conducted in a realistic flight environment involving operationally meaningful tasks to provide complete and conclusive answers to basic questions concerning display motion relationships.

Most of the studies cited used aircraft simulators in their experiments. Some of the studies used motionless simulators which afford the realism of the cockpit environment but are still suspect in that no kinesthetic or vestibular cues are present. A study in which these cues were found to have an effect on relative performances while using moving horizon and moving aircraft displays was conducted by Guy Matheny, Dora Dougherty Strother, and Marvin Willis of Bell Helicopter in 1963. Studies conducted in moving-based simulators have the advantage of providing certain kinesthetic and vestibular cues; however, these cues are usually limited and never precisely correct. Even with the advantages of motion, the results of simulator studies are still suspect.

In questions of dynamic control-display motion relationships, the ultimate research environment for the purpose of extrapolating to operational flight situations is the aircraft itself in flight. Along with the element of realism comes the difficult problem of experimental control. The experimental design and procedures used in flight experiments must be sufficiently sophisticated to determine or balance the effects of extraneous variables to the largest degree possible.

Pilot's Confidence in the Display

A particularly important aspect of the research environment is the confidence the experimenter manages to instill in the subject. For example, vertigo may result from a contradiction between the information the pilot receives through his proprioceptive senses and through his visual sense, particularly if the pilot has reason to question his visual frame of reference. The real problem in flight arises when the aircraft accelerates about its roll axis at a level below the pilot's vestibular and kinesthetic thresholds. If the pilot is scanning other instruments during this time, when he shifts his attention back to the attitude indicator, he will find the display portraying an unexpected attitude. There will then be a conflict between the pilot's proprioceptive senses, which tell him that he is flying straight and level, and his visual sense, which tells him that he is in a banked attitude. The pilot might then initiate a sharp control movement to correct the undesired attitude shown on the display. This control movement would cause a suprathreshold angular acceleration from what his proprioceptive senses have been representing as a wings level condition, thus giving the sensation of rotating for the first time. His conflict and confusion obviously are compounded, for one sense tells him positively that he is correcting an undesirable situation, and the other sense tells him positively that he is moving into one.

Whether the pilot believes his display or his proprioceptive sensations, to a large degree, depends on the pilot's confidence in the display itself. In 1949, Johnson, Matheny and Williams at the University of Illinois investigated a subject's obedience to rotation-indicating displays as a function of his confidence in the displays.

They demonstrated that the pilot's confidence or lack of confidence in a display, especially when there is a conflict between his senses, can have critical and at times surprising effects on his performance. Ideally, a visual display should give the pilot information that agrees with his proprioceptive senses and still portrays the aircraft's situation correctly. Such a display would reduce the conflict between the senses which results in vertigo. It was precisely this conflict that Fogel hoped to resolve with his frequency-separated kinalog display.

Three Conclusions

The Problem Is Real

The incidents reported by Fitts and Jones are but the visible portions of an iceberg. Domestic and military accident reports, scope camera films from air-to-air interceptors, and the everyday experiences of students and instructors of instrument flight allow a more comprehensive estimate of the incidence of both momentary and persistent control reversals associated with the misinterpretation of conventional attitude and steering displays. The frequency is higher than is generally recognized, and the consequences include increased pilot training requirements, reduced operational effectiveness, and losses in lives and equipment.

The Evidence Is Flimsy

Experimental findings reported range from suspect to inconclusive. The best experiments from the standpoint of scientific rigor have been conducted in fixed-base simulators, the applicability of which is suspect in questions involving physical motion. There has been no conclusive flight experiment dealing directly with the basic issues discussed.

The Questions Must Be Answered in Flight

It is evident that rigorous and comprehensive experimental research is required as a basis for any rational change from current motion relationships in aircraft instrument displays. It is essential that certain critical experiments be conducted in flight to eliminate the possibility of drawing spurious conclusions from a simulated flight environment. Both the speed of learning by relatively inexperienced pilots and the ease of transition of highly experienced and currently proficient pilots must be measured. Flight tasks must be operationally realistic and representatively difficult and stressful. Performance measures must be relevant to successful real-life flight operations. Ultimately these crucial flight experiments should be repeated in both fixed-base and moving-base simulators to evaluate the suspect but as yet undetermined validity of experimental results from static and dynamic simulated flight environments.

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Time-Sharing Computer for Shock Design Significantly Upgraded

Significant progress has been reported in the development of a time-sharing computer program designed to improve shock design. The work is being performed by the Electric Boat Division of General Dynamics under an Office of Naval Research contract jointly funded by ONR and the Naval Ship Systems Command. Called the Dynamic Design Analysis Method (DDAM), the program concerns the dynamic effects on a floating or submerged structure and is intended to provide an analysis capability to achieve increased shock resistance of vessels and equipment. It is being developed for use by shipbuilders and equipment manufacturers to meet Navy shock-resistance specifications.

Important modifications to the program planned for immediate implementation will significantly upgrade the program. Specifically, it will soon be possible to have rapid input and selective interactive output, *e.g.,* a user would be able to call the program from a remote point, describe a particular structural configuration in which he is interested and ask that the solution be placed in an output file. This file could then be selectively interrogated by the user to examine particular points of interest, such as data on maximum stresses or deformation or even the entire output. As a result of these innovations, it should be possible for the average user to make realistic solution tries at approximately five-minute intervals as opposed to the present situation which consists of a half-hour to two hours of required time. These changes should greatly facilitate effective use of the DDAM program by the ever-growing number of contractors and Navy users.

Optical Image Deblurring Methods

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The Office of Naval Research is sponsoring part of Professor Stroke's work in optical image deblurring to enable the Navy to restore sharpness to out-of-focus images obtained in surveillance missions. Perfection of the holographic (whole-picture) techniques used will allow salvaging blurred pictures from deep sea probes, space missions, aerial reconnaissance, astronomical observations, and other photographic missions difficult or impossible to repeat. The technique has been extended to motion-blurred photographs in addition to those which are out of focus.

Greatly sharpened images may be extracted from photographs which have been blurred either by accident or deliberately (for instance when coded in view of special image processing applications). In simple words, it has recently become truly possible to turn a bad photograph into a good image in a great number of situations, including cases when the photographs were blurred by motion, imperfect focus and by atmospheric turbulence.

Two of the most dramatic image-deblurring results are shown in Figures 1 and 2. Both figures illustrate the application of the powerful holographic image-deblurring method first described by Stroke and Zech in 1967 under the name of "holographic Fourier-transform division image-deblurring method" (1). In contrast with ordinary holography, spectacular as it is in its 3-D imaging applications (2), the holographic image-deblurring methods require considerable photographic care.

Spatial Frequency Components

The principles of optical image deblurring may be quite readily compared to the electrical signal filtering methods, such as those used in high-fidelity sound reproduction equipment. Most radio receivers and sound-reproducing systems permit one to "compensate" for "distortions" at the "high" and at the "low" ends of sound frequency spectrum. The resulting musical reproduction is thus adjusted until it appears most

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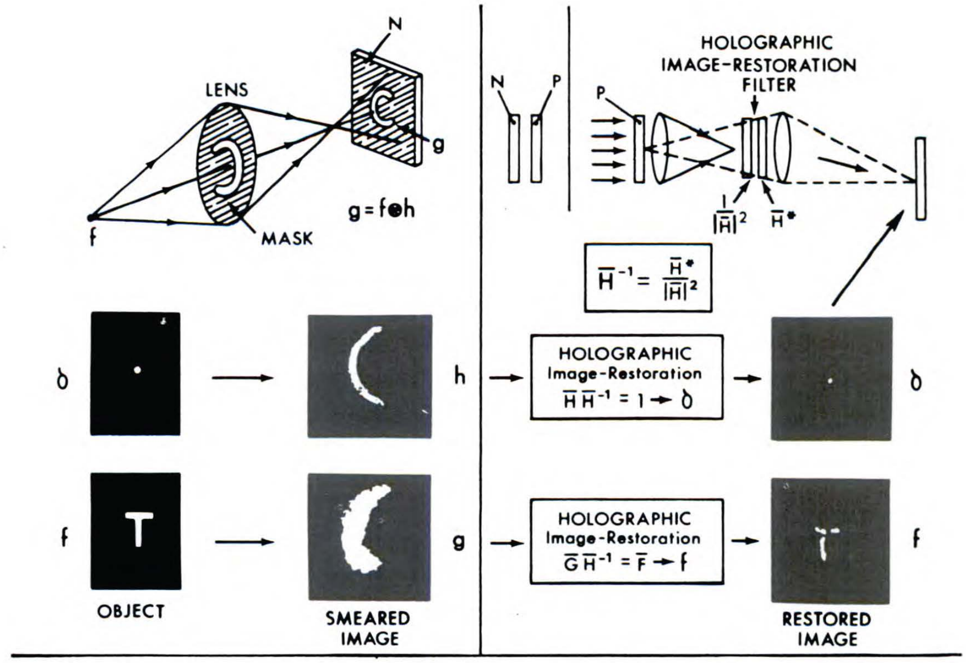

Figure 1 — Holographic image restoration

acceptable to the listener; for instance, in terms of tones which he recognizes as being most familiar to him. Needless to say, the acoustical frequency "equalization" procedure does not in any way increase the "information" contained in the pressed phonograph recording or the magnetic tape. Rather, the acoustical information is made to be displayed in a form more acceptable to the ear of the listener.

Quite similarly to the acoustical sound "frequency-equalization" procedure, the optical "image-deblurring" procedures consist in suitably acting on the *spatial frequencies* in the blurred photograph, in a way which permits one to display the photograph in a form more readily recognized by the eye of the observer.

It is well known, in acoustics, that a complicated *tone*, such as one produced by an entire orchestra, may be broken up into a sum of component *temporal frequencies,* ranging from about 20 cycles per second up to 20,000 cycles per second. A particular complex tone is thus characterized by the amplitude of each of the many frequency components which enter into its composition, as well as by their relative "phase."

Quite similarly, in optics, a complicated *photograph,* such as one obtained by a camera, may be broken up into a sum of component *spatial* intensity frequencies, ranging from about zero lines per millimeter up to 200 or 300 lines per millimeter, in ordinary photography (up to more than 1000 lines per millimeter in microscopic photography). A particular photograph, or any part of it, is thus characterized by the amplitude

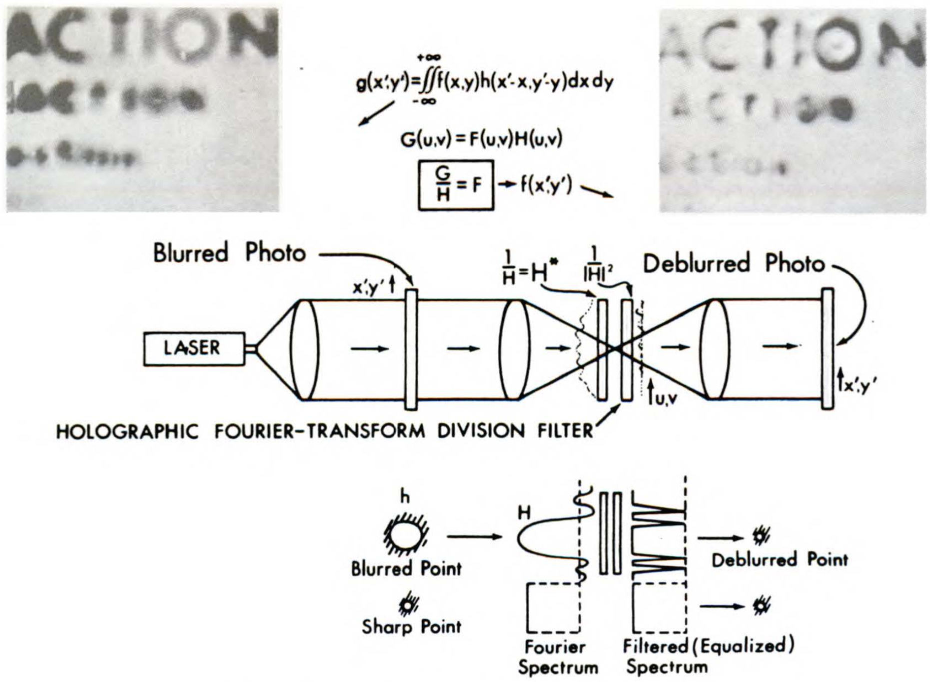

Figure 2 — Holographic image deblurring

of each of the spatial frequency components which enter into its composition, as well as by the relative position of these component sinusoids (that is, by their relative "phase").

When a photograph becomes blurred—for instance, by one or several of the causes listed before (imperfect focus, motion, and so on)—the spatial frequency components in it are changed in comparison to a sharp (unblurred) photograph. Most generally, it is the *high* spatial frequencies (the ones with the greatest number of lines per millimeter) which become *most strongly attenuated* in a blurred photograph. Thus, a blurred photograph may be characterized by an absence of a large part of the high spatial frequency "spectrum" in comparison with a sharp photograph. This means, in particular, that the component spatial frequencies are not only attenuated, but also shifted relative to each other (their "phase" is changed).

Recently, in 1967, G. W. Stroke and R. G. Zech (then at the University of Michigan) showed that the phase shift could be effected, in the general case, *without computation,* directly by photographic (holographic) means from the experimental "blurred" image of a single point, as photographed under the conditions of use of the original photographic system. The phase shift appears in the form of position variations in the "fringes" which form the holographic grating; *i.e.*, the hologram. It may be of interest to illustrate the phase-shifting, grating-like nature of holograms by means of a representative hologram, such as that which we show in Figure 3. The hologram was recorded in the well-known

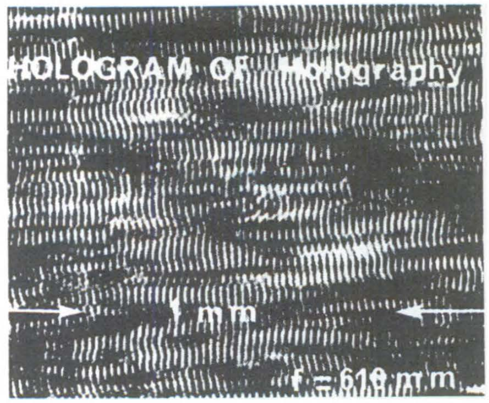

Figure 3 — Shown here is the phase-shifting, grating like nature of holograms; the picture was taken in the "lenseless" Fourier-transfer holography arrangement.

"lensless Fourier-transform holography" arrangement first described by Stroke in 1965 (see Figure 4). In this case, the "object" was the word "HOLOGRAPHY," about 20mm long, placed at about 17mm from the "point reference" source as shown. The "lensless Fourier-transform" spherical reference-beam holograms are characterized by the rather widely spaced "carrier" fringes (in the case shown, perhaps 80 fringes per millimeter), which are quite readily recordable even on fast (*e.g.*, Polaroid film) emulsions, in extreme cases. In contrast, the frequently-used "off-axis" plane reference-beam holograms require special fine-grain emulsions, such as the outstanding Agfa-Gevaert "Scientia" of KODAK 649F emulsions.

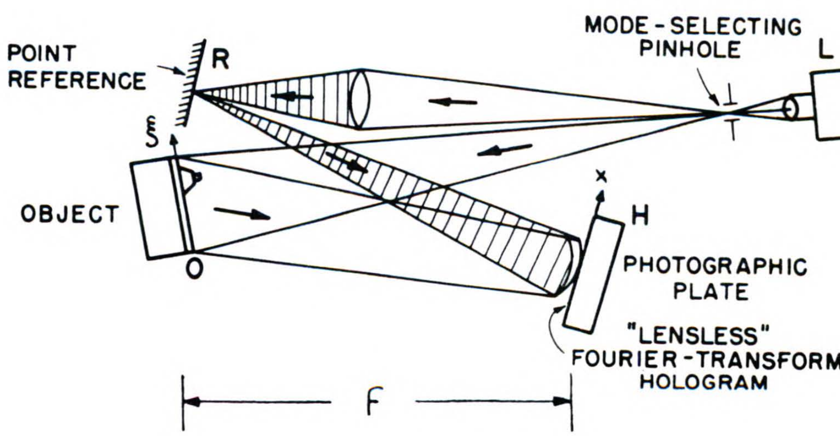

Figure 4

Stroke and Zech thus showed in 1967 that the spatial-frequency image-deblurring filter could be produced, in the most general case, directly from the experimental blurred image of a single point, in the form of a *holographic Fourier-transform division filter*. The general principle of the realization of the holographic filter is summarized succinctly in Figure 5.

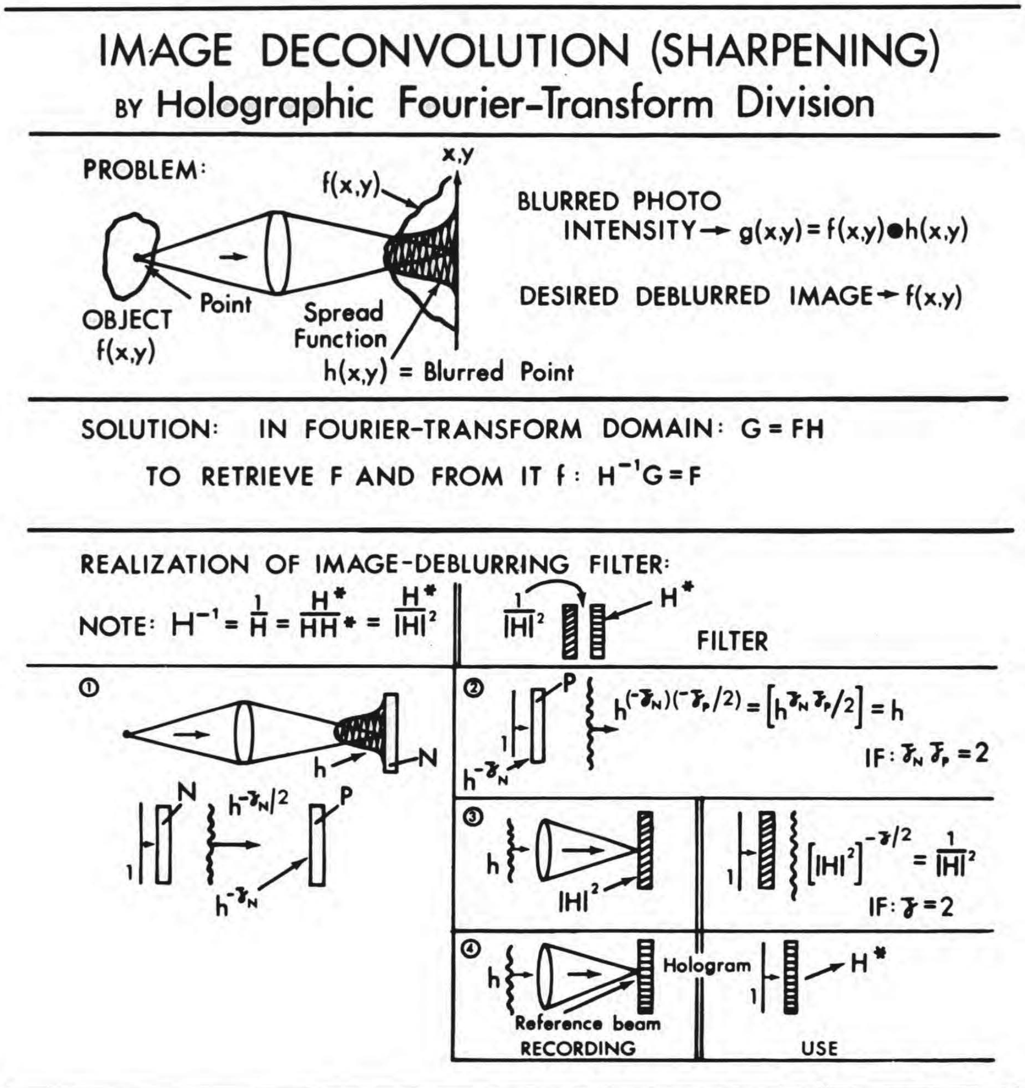

Figure 5

Principles Via Equations

Experience has shown that the holographic image-deblurring method may be most readily understood with the aid of illustrative diagrams, such as those of Figure 2 and Figure 5, even though the mathematical background may require considerable development beyond the scope of an elementary introduction such as this. (See *e.g.* Ref. 2.)

The general principle of the holographic image-deblurring method is summarized in the equations shown in Figure 2 and in Figure 5. In the equations, the functions G(u,v), F(u,v) and H(u,v) are the so-called spatial Fourier transforms of the functions g(x,y), f(x,y) and h(x,y). It can be readily shown that these Fourier transforms may be obtained as illustrated in Figure 2. When a photographic transparency is illuminated by a collimated beam of laser light, the Fourier transform of the field transmitted through it appears in the focal plane of the lens, as shown.

It is the realization of the required Fourier-transform division filter which presents the key to the image deblurring problem. Basically, we can show that the "holographic Fourier-transform division filter" (shown in Figure 2) may be realized directly from the experimental "point spread function" which, as we know, is nothing but the image of a point, as obtained in the system under the conditions of its use.

In other words, the "point spread function" (described by h(x,y) in Figure 2) is the image of a point, in the object field, *blurred* by one or several of the image-blurring causes (including aberrations and diffraction). It is the "point spread function" h(x,y) which is used to produce the holographic image deblurring filter 1/H.

Photographic Considerations

The general principle of the realization of the holographic Fourier transform division filter 1/H from the experimental blur function h(x,y) is given in the diagram of Figure 5. In that figure, the letter N stands for "negative," and letter P for "positive." From the figure it may be understood that very careful photographic processing is required in the realization of the "computing" filter, since the required gammas can only be obtained if the corresponding great care is observed with the aid of well-known photographic precautions.

Two photographic considerations are of a particularly crucial importance. First of all, the equations in Figure 5 show that the mathematical performance of the various positives and negatives which are used in the production of the holographic filter require very careful realization of appropriate "gammas," such as: $\gamma = 2$ and γ N γ P = 2.

It should also be clear, in this context, that the "gammas" referred to have to do with special arrangements in the illumination and in the use of the particular negative (respectively positive). For instance, in section (1) of the filter realization in Figure 5, the illumination of the negative N is obtained by a focused point of white light, in producing the "spread function" h(x,y), that is the "blurred" image of a point. But the negative may be illuminated either in white light or in laser light, to produce the copy positive P, as in section (2) of Figure 5. Next, the positive P will be used by illumination with a collimated beam of laser light, as shown in (3) and (4) of Figure 5, to produce the two components, respectively, $1/[H]^2$ and the hologram (component H*), which form the Stroke-and-Zech holographic Fourier-transform division filter 1/H. The required gamma sensitometry must thus be carried out under the actual conditions of use, in the configurations used, in order to obtain the desired performance.

Second, an additional photographic achievement had to be carried out, in order to make photography successful as a computing tool, in the form proposed by Stroke and Zech. This has to do with extending the dynamic range of the films used (in our case the Agfa-Gevaert Scientia plates), so as to make them cover the dynamic range *with* the required gammas. It is well known in the photographic community that films used with gammas such as those mentioned (*e.g.*, Ref. 2) have a very small dynamic range (about 1.5 on the logarithmic exposure scale). However, it can be readily shown (see *e.g.* Ref. 2) that the spectrum of a photographic transparency (as displayed in the "Fourier spectrum" plane of Figure 2) contains information extending over a range of 3 to 4 on the logarithmic exposure scale.

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Reprinted from *Industrial Photography,* May, 1970.

Newly Developed High Sensitivity Strain Gauge

For the past several years an Office of Naval Research metallurgy program contractor, Dr. J. B. Shaw at Westinghouse, has been investigating the brittle fracture of some of the body-centered cubic refractory metals, particularly molybdenum and molybdenum-niobium alloys, for potential use at high temperatures, such as are encountered in turbojet engines. In using conventional strain gauges to detect deformation in these materials at −196°C (a temperature where these materials are completely brittle), he found he could detect no slip or plastic deformation just prior to fracture. Since well-accepted theories dictate that some deformation must take place prior to brittle fracture of materials, he theorized that fracture followed deformation too quickly for the deformation to be recorded separately by conventional gauges, which have time responses no faster than 200 microseconds. Since no commercial gauges with faster time responses are available and since he wanted to examine minute areas, he embarked on a strain gauge development program to meet his needs. This work has resulted in piezoelectric strain gauges which are 100 times more sensitive than conventional strain gauges and give virtually instantaneous time responses. Their use should allow a more definitive understanding of the deformation and fracture behavior of refractory alloys.

The newly developed strain gauge is also a potentially important monitoring device that can warn of an impending failure in a material. It can detect slight plastic or permanent yielding in structures, such as submarine pressure hulls or aircraft structures, which must operate below yield stress, and it can monitor cumulative plastic strain, which often is a precursor of fatigue cracking.

On the Naval Research Reserve

Research Reserve Reorientation

The Research Reserve reorientation plan is now well along. Recruiting of new members has been limited to those officers possessing the qualifications needed to be responsive to the research mobilization requirements of the 30 naval activities supported.

Individual officers have updated their qualifications questionnaires ensuring that the recorded qualifications reflect the actual qualifications attained. The qualifications of the individual are then matched with the mobilization billets. This phase will be completed not later than April 1971 when the revised mobilization assignment document is distributed by the Naval Reserve Manpower Center at Bainbridge, Maryland.

Increased emphasis has been placed upon the contributory role of the reservist. The use of the special talents of Research Reservists in a peacetime role can assist the Navy in many practical areas. Projects are being started while on active duty for training and being continued throughout the year while on active drill status. For others the active duty for training period is being used in support of unit projects. The end result is that the Navy has benefited from the peacetime efforts of the reservist.

Texas Research Reserve Companies Sponsor Seminar

A most enlightening weekend seminar on "The Soviet Challenge" was held at College Station, Texas. The seminar, sponsored jointly by Naval Reserve Research Companies 8-3 of College Station, 8-4 of Houston, 8-5 of Austin and 8-12 of Dallas, was hosted by NRRC 8-3.

A most timely and stimulating program was presented by an invited panel of distinguished military and civilian speakers. CAPT Oliver L. Norman, USN, Director of the Special Studies and Presentations, Office of the Chief of Naval Operations, led off the program with a film and slide presentation of Soviet military, naval and maritime capabilities. He was followed by Dr. Frank N. Trager, Professor at New York University and the Naval War College, who gave a presentation on Global Strategy concepts. RADM James B. Osborn, USN, Director Navy Offensive and Defensive Weapons, and RADM John D. Chase, Deputy Commander Military Sea Lift Command, spoke on current strategic aspects of the Soviet military and maritime buildup. The program was concluded by Mr. Norman Polmar of Lulejian Associates and Editor of the U.S. Section of Jane's Fighting Ships, who gave a detailed slide presentation of the current Soviet Naval capability.

NRRC 5-9 Unit Receives Award

Naval Research Reserve Company 5-9, Naval Research Laboratory, Washington, D.C., placed first among Research Reserve Units in the Fifth Naval District and second among all Phased Forces Units in the district for Fiscal Year 1970.

A plaque was presented at an award ceremony by RADM James O. Cobb, USN, Commandant, Fifth Naval District.

CDR R. H. Kyser, USNR, Commanding Officer, Naval Reserve Research Company 5-9, receives congratulations from CAPT E. W. Sapp, USN, Director of NRL

(Continued from inside front cover)

Signal processing converts the received acoustic signals into a hologram (a scrambled version of the image). The hologram is then reconstituted into the true image and displayed in real time. This is accomplished by another component developed by Bendix for the system called a coherent light area modulator (CLAM).

In this device the linear electro-optical effect of a special type of crystal is used to phase modulate light *via* a scanning electron beam that records information as a change pattern on the crystal. The hologram is written on the crystal, and reconstruction is obtained by passing a laser beam through the actuated crystal. The image is magnified by associated optics and displayed on a television screen. The resolution is presently 200 lines per millimeter, but it is expected to achieve 400 lines per millimeter in the future.

Research Notes

Effects of High Pressures on Blood

A special instrument able to measure changes in the viscosity of blood at the high pressures encountered in naval diving operations has been developed by Dr. James Martin, an Office of Naval Research contractor at the Newark College of Engineering. The ONR-sponsored study is concerned with the effects of high pressure on the viscosity of blood. A change in viscosity could effect the rate of blood flow through the capillaries, the rate of tissue perfusion and consequently the rate of gas exchange between the blood and tissues. This could be important in terms of improved decompression schedules for divers.

The special viscometer devised by Dr. Martin to perform this research can operate under high pressure, measuring the variations in viscosity of blood as it flows through the capillaries and as the pressure is changed. Preliminary studies in glass tubing at about 50 atmospheres (about 1,650 feet) have shown a significant decrease in the viscosity of blood, which was an unexpected result. Much more work has to be completed on this problem before anything definitive can be stated.

Reduction of Stress on Pilots Ejected from Aircraft

A research program aimed at developing means for the prevention of fractures of the vertebrae in Navy pilots who eject from planes has promising results. The program is being conducted at Wayne State University, Detroit, Michigan, under an Office of Naval Research contract, with funds provided by the Bureau of Medicine and Surgery. The research is concerned with effective repositioning of the body load on the spinal column so as to minimize the effect of forces exerted on vertebral bodies during high onset rates of acceleration. Research to date has resulted in the development of a device that is effective in minimizing peak strains on the anterior aspect of the vertebral body and also indicates a redistribution of the load over the entire vertebral body. The device, about two inches thick, produces spinal hyperextension during vertical acceleration. Through use of this device, for which a patent has been applied, the compressional strain on the lumbar vertebrae can be reduced by as much as 40 percent.

Tunable Millimeter Traveling-Wave Maser Achieved

Significant progress has been made in the development of a tunable millimeter wave maser in a research program conducted by Nobel Laureate Professor Charles H. Townes at the University of California at Berkeley supported by the Office of Naval Research. Tunable, sensitive detectors usable in the newly opening millimeter wave portion of the electromagnetic spectrum are essential as receivers in communications, detection and guidance systems of the Navy. The study at Berkeley is directed to the evolution of a traveling-wave type of maser, with particular emphasis given to characteristics of broad-band dispersive structure elements in the maser cavity. A traveling-wave maser tunable over the range 12.5 to 13.5 millimeters with a very low noise figure has been evolved. This unit employs a ruby crystal and a dispersive slow-down structure as main elements in its fabrication. Tuning is accomplished by varying the magnetic field (about 5000 gauss) in the region of the ruby crystal. The noise figure for this receiver is so small that its application in communication and radar systems will result in increased range and very reliable performance in those systems.

High Temperature Composite Materials

A unique technique for producing composite materials with high temperature stability has been devised by ONR contractor Professor R. W. Heckel, Drexel University. The initial fabricating steps are conventional: he implants the reinforcing wires of one metal in the binder matrix of the other by winding and hot pressing. To gain the high temperature stability, Heckel then employs an elevated temperature anneal to grow an intermetallic compound in place of the wires. This step requires interdiffusion of the matrix and wire atoms, and the diffusion time required depends on the temperature, wire diameter, atom mobility, and the degree of stability required. Heckel has recently demonstrated the feasibility of this method using a nickel wire-aluminum matrix composite. Annealing at 600°C for 100 hours produced uniform rods of $NiAl_3$ in place of the nickel wire in the aluminum matrix as interdiffusion of the aluminum and nickel took place. The elastic modulus improved from 10 million psi (pure aluminum) to 15 million psi for the composite. However, due to an unknown reason the tensile strength did not increase significantly from the treatment. Assuming that the latter difficulty can be eliminated, this type of composite will offer several advantages over other composite materials: high temperature degradation of the reinforcing phase due to interdiffusion is avoided; no severe limitation exists on the volume of the reinforcing phase; and plastic deformation can be used to form the composite to a particular shape prior to the interdiffusion treatment.

A Reference File of Biological Underwater Sounds

Two investigators at the University of Rhode Island have recently published a book entitled *Sounds of Western North Atlantic Fishes: A Reference File of Biological Underwater Sounds*. The book is the result of a comprehensive study supported by the Oceanic Biology Program of the Office of Naval Research.

Using a taxonomic organization, the book treats nearly all the known noise-making fishes of the Western North Atlantic. Each species is discussed with respect to such characteristics as distribution, habitat, behavior and sonic mechanism. In addition, a sound spectrogram and oscillogram are included with each species thereby making the book unique. The book should be a particularly useful reference for those dealing with marine bioacoustics both in the Navy's operating and scientific communities.

Understanding High Intensity Laser Propagation

Ruby and neodymium glass materials have the potential for producing a very powerful pulse laser but are not reaching that potential because the material fractures at certain high intensities. The reasons for this are not known, but the possibility of obtaining information on the damage mechanism has opened up as the result of research on laser atmospheric propagation at the University of Southern California under the joint ARPA-ONR laser program. The research study at USC is concerned with the problem that when a laser beam propagates through the atmosphere at very high intensities, the propagation characteristics change radically and produce non-linear effects. Dr. Wagner at USC has been engaged in examining these phenomena theoretically in order to predict these effects which have a direct bearing on military applications of high-powered laser beams.

Since non-linear theory has many variables, Dr. Wagner developed a computer program to accomplish this, taking into account computational instabilities. This computer program can now solve the system of equations which describe the propagation of high intensity beams through gases. The computer technique can be used to predict the propagation effects of a very intense laser beam whose characteristics have been exactly defined. This makes it possible to see in what way these effects may cause the fracture of solid state materials at various high intensities and can lead to an understanding of why this happens. Dr. Wagner's theoretical work has been used to predict the self-focusing effect, a non-linear phenomenon occurring in a solid state laser.

Increased Efficiency in Shipping Bulk Petroleum Products

Under an Office of Naval Research contract, Texas A&M researchers, working with the Defense Supply Agency, have produced a report entitled, "A Tentative Proposal for a Shipping Plan of Bulk Petroleum Products by Sea-Going Tankers."

The Defense Fuel Supply Center of the Defense Supply Agency procures 18 bulk petroleum products for the Department of Defense and plans for the world-wide distribution of these products. The Military Sea Transportation Service controls the fleet of tankers used for transporting the petroleum from port to port. There are approximately 20 supply ports and 100 destination ports. As indicated by the title, the above report offers a computer algorithm for helping to manage in an optimal way this complex operation. This is a situation where increased efficiency could result in very substantial savings.

Currently Texas A&M is preparing to demonstrate its techniques using actual data furnished by the Defense Supply Agency. Future plans include the extension of this work to other shipping problems of the Military Sea Transportation Service.

Use of Electricity to Heal Bone Fractures Faster

The first documented evidence that electric current makes bone fractures heal faster has been established by a Navy study. The study was conducted by the University of Pennsylvania Medical School in conjunction with the Philadelphia Naval Hospital under a contract with the Office of Naval Research, with funds provided by the Navy's Bureau of Medicine and Surgery. Evidence that electric current is beneficial to the healing process of bones was obtained with experiments on laboratory animals. Navy surgeons hope that the research will lead to applications on human patients and thus reduce drastically the hospitalization time of personnel with bone injuries.

It has been previously known that electrical charges play a role in bone growth and healing. Previous investigations, however, have been inconclusive because of the problem of delivering a constant current to the bone. Current provided to the bone decreased as tissue resistance developed. The investigators in the Navy research study solved the problem by developing a compact power pack with a transistorized circuit able to deliver a constant current regardless of changing resistance in the tissues. The power pack sealed in an acrylite plastic case consists of a small battery, field-effect transistors, and resistors designed to deliver a steady current of one hundredth of an ampere. Protruding from the pack are positive and negative electrodes. The tiny power pack is implanted under the skin, with the negative electrode secured directly across the fracture and the positive electrode in a nearby location.

In the experiments fractured leg bones of animals subjected to the current healed solidly within 18 days while similar fractured leg bones not exposed to this treatment required a much longer time to heal naturally. Experiments will continue with a variety of laboratory animals and variations in the placement of the electrodes. In addition to improving the technique of bone healing, it is hoped that these experiments will furnish information on the bioelectric potential of bones—the natural electrical charges that are involved in growth and regeneration of bone tissue. Future experiments may eventually involve human patients suffering from bone nonunion, that is, where the two ends of the bone have failed to join and would normally require graft surgery.

Possible Prevention of Oxygen Toxicity Promised

A promising means of preventing acute oxygen toxicity, a condition that causes convulsions as a result of breathing too high a pressure of oxygen, has developed from a Navy study. The work, performed at the Duke University Medical Center, Durham, N.C., under a contract with the Office of Naval Research, is particularly significant to the Navy because of the value of using oxygen at elevated pressures during the later stages of decompression to speed up the process. If higher partial pressures of oxygen could be used safely the decompression period could be greatly shortened.

Scientists at Duke believe that the toxicity effects result from the excessive oxygen interfering with the process in the body which produces adenosine triphosphate (ATP), the substance necessary to maintain cellular energy levels. The normal metabolic process, by which ATP is converted to ADP (adenosine diphosphate) and then back to ATP, does not function properly in the presence of excessive oxygen, thus lowering the amount of ATP available. Nerve cells in the brain are especially sensitive to a lack of ATP.

Based on experimental evidence, Dr. Aaron P. Sanders of The Department of Radiology, director of the Duke team of Drs. Sanders, W. D. Currie, G. B. Hill, R. Kramer and B. Woodhall, theorized that there is a system in the body which bypasses the normal metabolic process. He speculated that when the body is under stress this bypass could serve as a "safety valve" to replenish rapidly stores of ATP. This was based on the discovery that a component in this bypass system, a substance known as succinate, is a key to an increased rate in ATP production.

The Duke team experimented with increasing the amount of succinate in the body through the use of commercially available compounds of succinate. In this way experimental animals injected with succinate were significantly protected against oxygen toxicity. At the same time, it was found that brain levels of ATP were raised by as much as 21 percent.

Another possible application is to counter the drop in ATP production caused by a lack of sufficient oxygen to the brain, such as occurs when an injury or bodily malfunction restrict circulation to the brain. By inducing increase in ATP level, succinate may possibly prevent brain damage or facilitate brain recovery in such cases.

Experiments are continuing with the objective of determining the correct dosage of succinate and other factors involved in using succinate under various conditions.

Bubble Detection with the Doppler Ultrasonic Flowmeter

Navy decompression tables are based on empirical observations of actual dives and on calculations related to average gas solubilities and tissue perfusion/diffusion rates. But because of the variability in physiological make-up from person to person, some divers will develop symptoms of decompression sickness in spite of the proper use of the tables.

Research is being conducted under an ONR contract to assess the ability of a new instrument, the Doppler Ultrasonic Flowmeter (DUF) to detect gaseous emboli which may form during decompression before such emboli induce symptoms of decompression sickness. The DUF, consisting of cuff-like sensors placed around blood vessels, is designed to detect changes in sound frequency caused by bubbles acting on blood flow velocity. Dr. Kent Smith of the Virginia Mason Research Institute, Seattle, Washington, has implanted Doppler sensors around the pulmonary (lung) arteries, the anterior and posterior vena cavae (veins coming directly off the heart) and femoral (leg) veins of sheep. The sheep are then compressed and decompressed at a rate resulting in clinical manifestations of decompression sickness while using the DUF to monitor bubble formation. In all animals, Doppler changes were observed prior to the onset of decompression sickness, generally just in the anterior vena cave, then in the pulmonary artery. The Doppler signals continued to be present 24 hours after the animal was decompressed.

The use of the DUF may prove to be a valuable contribution to the safety of naval divers.

New Weather Buoy

Naval Research Laboratory scientists have developed a remotely controlled buoy weather station that has proved to be most successful in monitoring weather conditions in remote areas of the ocean.

The buoy, which houses the weather station, is designed to be towed to any location in the ocean and moored in place. The buoy is instrumented to transmit such weather variables as wind speed and direction, as well as air temperature and barometric pressure.

The buoy station is presently being used in conjunction with four other NRL-developed land weather stations at the Atlantic Undersea Test and Evaluation Center (AUTEC) Range near Bermuda. These weather stations are interrogated by AUTEC through a Central Control Station, which receives and records the weather conditions from each site. This new system provides AUTEC with a reliable and economical method for obtaining the important weather information needed for missile and torpedo testing.

The most significant characteristic of the buoy is an outstanding reliability derived from the system's uncomplicated instrumentation and rugged design. These combined factors allow the buoy to remain on station for an extended period of time on a trouble-free basis.

An unusual feature of the system is a tensiometer, an instrument used for measuring mooring forces, or strains on the buoy's mooring lines. This device also transmits an alarm if the mooring fails in any way. A wave sensing device will be installed in the future to give the buoy the capability of sensing wave height and total wave energy.

The instrumentation for the land and buoy stations, as well as the Central Control Station, was designed and developed by the Automatic Systems Section, Ocean Sciences Division, NRL. The section is headed by Walter A. Von Wald, Jr. Mr. Von Wald was assisted in the project by Thomas E. Marshall, III, James Boyce, and Charles Lauter, Jr. The program is supported by the Naval Air Systems Command and the Naval Ship Systems Command.

Two-Dimensional Image Processing

Robot Research, an ONR contractor, is investigating two-dimensional image processing for Naval Reconnaissance. In the past, two-dimensional image processing has proven to be very awkward and time-consuming, even on faster modern computers, with the result that many implementations fall back to one-dimensional form corresponding to the conventional time-series scanning process. In order to partially overcome this limitation, a scheme for quasi-two dimensional processing has been devised. It consists of a scan orthogonal to one dimension of processing, itself capable of being processed. The result is an area process equivalent to one quadrant out of four, with the possibility of expanding to all four quadrants by simple time delay units. An experimental verification of this type of processing is currently under consideration. If successful, it could lead to real-time processing of high density pictorial data aboard an aircraft, which cannot now be accomplished.

Direct Imaging Acoustic Microscope

Stanford University researchers supported by the Office of Naval Research have reported progress on a direct imaging acoustic microscope. In this instrument an acoustic wave, generated in a solid crystal, is transmitted to a thin liquid cell containing the object. The forward scattered acoustic waves from the specimen are processes in a second crystal, using acoustic-electromagnetic wave interaction to focus on a photographic film, thus creating an image of the object being studied. This system is the subject of continued evolutionary research. It gives high promise of application to microscopy. It is potentially available for viewing objects such as airframe metals and other nontransparent bodies where optical microscopes are not usable. Further, no specimen damage is involved.

Army Utilization of ONR Research

The United States Military Academy, West Point, has requested permission to use a paper titled "The Role of Values in Psychological Operations" that was published recently under an ONR Group Psychology Programs Contract with Dr. Dean Havron, Human Sciences Research, Inc. The Academy plans to reprint and distribute to cadets and staff officers over 800 copies of this report. The Army will use the material as supplementary reading in the leadership course taught at West Point. This paper compares the cultural values of Vietnamese and Americans which influence the outcome of interactions between military and civilian representatives of these two cultures.

Aircraft Flight Management and Control Systems

In striving for air-superiority, reliance on aerodynamic design approach would probably yield narrower margins of superiority in future combat aircraft. To increase the performance margin in air-superiority, means are being explored to implement the advantages of an Energy Management System of flight control optimization in the vertical airspace. A computer analysis (for a hypothetical aircraft with the performance characteristics of the F-111B) contained in a technical report by Honeywell, Inc., ONR contractor, shows the gains that may be achieved by using an Energy Management System optimized flight path in the vertical airspace *vs* the nominal flight path in the vertical airspace:

a. 19% time saved in a full afterburner minimum time climb to 30,000 feet.
b. 28% time saved in a military power minimum time climb to 30,000 feet.
c. 13% fuel saved in a military power minimum fuel climb to 30,000 feet.
d. 212% range extension in an intercept mission from sea level to 30,000 feet, accelerating to 1.83M in minimum time.

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First ONR-AIAA Research Award in Structural Mechanics

Stanley B. Dong, associate professor of engineering and applied science in the Mechanics and Structures Department of UCLA, has been awarded the first jointly sponsored ONR-AIAA "Research Award in Structural Mechanics." The award includes full support for a year through Office of Naval Research.

Dr. Dong earned the honor for "his pioneering contributions to the analysis of shell-type structures made of composite materials" and for his outstanding proposal for research in this area, titled "Dynamic and Stability Characteristics of Laminated Anisotropic Shells and Plates Including Transverse Shear and Normal Deformations." This subject vitally concerns the naval structural-mechanics community in connection with submersible, surface, and air vehicles.

During this coming year, Dr. Dong will extend composites and familiarize himself with critical problems in naval structural mechanics. It is anticipated that he will report results of his research as a special address at the 1972 AIAA Structures, Structural Dynamics, and Materials Conference, to be held in San Antonio.

A panel within the AIAA Structures Technical Committee, chaired by Roger A. Anderson of NASA Langley Research Center, screened entries for the award. The Panel consisted of Robert J. Kroll of the Univ. of Cincinnati, William A. Langen of the Naval Air Development Center, Johnsville, Melvin J. Rich of Sikorsky Aircraft, and Charles W. Bert of the Univ. of Oklahoma, panel chairman. Preliminary planning and coordination with ONR was carried out by Francis W. Niedenfuhr of the Advanced Research Projects Agency, Nicholas Perrone of Catholic Univ. and ONR, and John M. Crowley of ONR.

It is planned to make the Research Award each year to foster excellence in structural-mechanics research and to enable the recipients to conduct research of an advanced and original nature relevant to Navy problems. A certificate, full-time support for approximately a year, travel, and support for special expenses accompany the award.

For detailed information on submitting research proposals for the second ONR-AIAA Research Award in Structural Mechanics, write to Professor Charles W. Bert, School of Aerospace, Mechanical & Nuclear Engineering, the University of Oklahoma, 865 Asp Ave., Room 200, Norman, Oklahoma 73069.

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