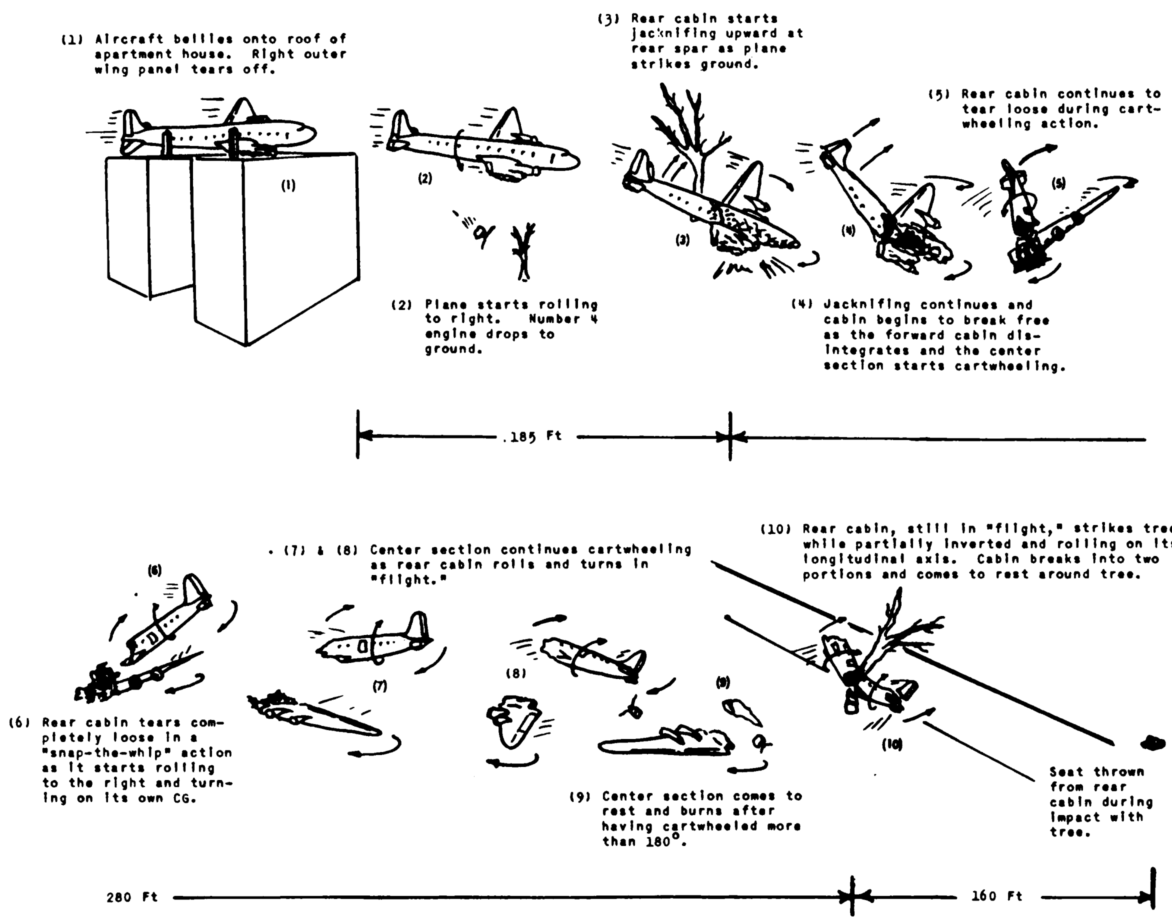
OFFICE OF NAVAL RESEARCH AUGUST 1956

RESEARCH REVIEWS

NAVEXOS P-510

DEPARTMENT OF THE NAVY
WASHINGTON, D. C.



Analysis of crash of DC-6 transport plane at Elizabeth, N.J.

Prevention of Injuries in "Unpreventable" Aircraft Accidents

Dr. Freeman H. Quimby
Head, Physiology Branch, ONR
and
A. Howard Hasbrook
Director, Aviation Crash Injury Research
Cornell University

Safety activities in aviation, until recent years, have been devoted solely to accident prevention. This was a particularly constructive approach because most accidents in the past followed definite patterns. These patterns, once ascertained by thorough investigations, permitted remedial action to be taken to prevent the reoccurrence of accidents from known casual factors. For example, in the early development of aircraft engines, engineering know-how had not progressed to the point where nearly infallible engine performance could be expected as it is today. The same is true of the problems encountered in the operation and use of early radio and navigational aids. In addition, the lack of scientific analysis of world-wide weather conditions contributed to the occurrence of accidents much more in the past than today.

Engine trouble, communication difficulties, weather conditions, and other factors appeared and reappeared through accident investigation as causative factors in accidents. Preventive measures developed over the years have virtually eliminated these reappearing, or pattern factors—such as those mentioned above—as causes of airplane accidents. In fact, accident prevention programs have been so successful that by 1955 a person was approximately forty times safer in a scheduled U.S. airliner than he was in his own automobile on a passenger-mile basis. The statistics are so good that they are actually hard to believe.

In 1953 domestic and foreign airliners flew over 600,000,000 mi. These airplanes, on the average, flew 18,000,000 mi per accident, and 100,000,000 mi per fatal accident. For every 1,000,000 passengers flown, there were only 2-1/2 fatalities. Good as this record is, however, it is not good enough, and the likelihood that it can be improved from the standpoint of accident prevention is not great. The substance of this standstill is largely human error. For example, the occasional, inadvertent error in maintenance, design, construction, operation, or piloting does not lend itself to "prevention procedures" because such errors are already so rare that prevention techniques cannot be expected to markedly reduce the accident incidence from its present rate. Human error as an accident cause, particularly if it is the only error of its type ever known to have been committed, is one which has a high improbability of reoccurrence. The probability of reoccurrence is even less if such a human error occurs as a link in a chain of "error circumstances" which are in themselves highly improbable of reoccurrence. Such accidents, therefore, might be thought of as being indeed "unpreventable."

Thus, some accidents continue to occur as the record—and the newspapers—show. The causes of these, barring defects in design of new types, as in the British "Comet," are largely in the unpreventable category. They are "sports" or chance combinations of special circumstances, which would not occur again as a group of factors likely to be reproduced in other accidents. Even when determined, the causes are complex and provide little or no information on which preventive procedures against future accidents could be established.

Thus, the assumptions for proceeding with this article are that:

- Aircraft accident prevention is a highly developed and effective science,
- Accident prevention has been exploited to the near maximum,
- Contemporary aircraft accidents—from a "where do we go from here?" point of view—may be regarded as "unpreventable."

"Hanging their hats" on these assumptions, flight safety experts can look elsewhere for ways of reducing the damage to human beings involved in accidents which do—and will—occur.

NEW AWARENESS ON PASSENGER PROTECTION

The time arrived many years ago to do more for passenger protection than the mere provision of the standard seat belt. The idea of designing airplanes (Research Reviews, Nov. 1953) to prevent injuries and fatalities when crashes do occur—whether judged preventable or not—fits appropriately into the scheme of all flight-safety endeavor as well as into the current facts and anticipated growth of air travel. There is little reason to expect that the number of aircraft accidents in the future will decrease. There are nearly 100,000 civil airplanes registered in the United States and there are many more to come. Air traffic, enhanced by military training operations, is growing by leaps and bounds. Higher operational speeds may make the newer airplanes more hazardous; speeds near trans-sonic are being guaranteed by the jet transport manufacturers. These new transports, in coach versions, will expose as many as 168 passengers to injury or death in the event of an accident.

In the past twenty-one years, not counting calendar year 1956, approximately 230 pilots and 1300 passengers were killed in scheduled domestic airline operations. In addition, more than 140 pilots and 620 passengers were injured. Accident prevention procedures were vigorously practiced during these years, and for the sake of argument, the crashes which produced these casualties may be classed as unpreventable. Regardless of this, however, it is safe to assume that some of the casualties were preventable—had the airplanes been designed to protect the passengers from the consequences of deceleration and impact.

With an eye to this problem and to the future of aviation, the Office of Naval Research began sponsorship nearly ten years ago of a civil plane accident-injury analysis project at Cornell University. The project was called Crash Injury Research and dealt specifically with the problem of reducing fatalities and injuries in airplane crashes involving impact forces suspected of being well within the tolerance of the human body. The objective of this program was the improvement of the "state of the art" of crash-survival design. The Civil Aeronautics Administration, the Air Force, and the Navy's Bureau of Medicine and Surgery soon joined ONR in the support of this endeavor.

PLANNING FOR PASSENGER SAFETY

Originally, there was no intention of studying military airplane accidents. The philosophy underlying the Air Force and Navy support was that any research or activity which would improve aviation in general would ultimately improve military aviation as well. Civil and military airplanes have a common supply in industry, and safety-design concepts, once established and adapted, should be reflected in all airplanes. The supporting agencies were also specifically motivated by the desire to increase the confidence of the public in the safety of flying. Such confidence was, and is, necessary in order to provide a pool of young men for entry into both civil and military flight-training.

The credit for the idea of crash-injury research does not belong to the supporting agencies but rather to Mr. Hugh De Haven, who, representing no one but himself, introduced to those who would listen the concept of survivability in aircraft accidents (Research Reviews, 15 May 1948). Mr. De Haven may not have been the first or only one to point out the possibility of designing for survival in accidents, but he was certainly the first to emphasize and re-emphasize the need for a study of accidents and accident casualties to identify the lethal features, components, and cabin appointments of airplanes which were responsible for injuries. Once identified, these items could be removed or corrected in design so that injuries and fatalities from such causes would be reduced in future accidents. In other words, the aircraft could be designed for crashes so far as passenger and crew protection are concerned.

The argument was soon discovered to be well founded. It was clear from the first few accident analyses that needless fatalities and injuries occurred because the airplanes were either not "crashworthy" or were not delethalized in the cabin and cockpit areas. However, there was lack of interest and even resistance to this new aspect of flying safety. There were those who believed that every accident was different, and that patterns of injury and injury causes could not develop from the study. In fact, many believed that escape from injury or fatality in accidents was a matter of pure luck. Engineers were intent on performance, airplane manufacturers and the airlines had their own special fears and, in addition, there was too little crash-injury data at the time to depend on. All were preoccupied with other problems in the rapidly growing industry. As more information accumulated by De Haven's group became available, however, the merits of this research became obvious. The first long study on 1,000 light plane accidents showed that one could almost tell the make of an airplane by the manner in which occupants were injured or killed in the crash. This kind of evidence, so direct and unanswerable, has had the desired effect of changing negative or apathetic attitudes to ones of obvious positiveness.

Metamorphosis has indeed set in, but the "big change" is not yet here. While industry is still designing airplanes primarily to meet other requirements, and, while some airplanes are still being produced with built-in "booby traps," there is now emerging among almost all flying-safety authorities the general principle that, if the passenger is adequately tied down to the seat, and the seat to the floor, the occupiable areas are delethalized, the occupants can survive a crash involving very high impact forces—forces comparable to those which might be involved in a fall, for example, from a five-story building. Under certain conditions, it has even been shown that the human body can withstand impact forces equalling total loads of from 10 to 15 tons without serious injury. Of course, the cabin must remain intact to permit survival—in other words, the accident must be basically survivable.

Catastrophic, "high-angle" impacts at high speeds, such as collisions with mountains or mid-air collisions and explosions, of course, do not lend themselves to this kind of study. More often than not, such accidents are too severe to be survivable under any circumstances so far as realistic design is concerned. No amount of safety devices for passengers will predictably save lives in accidents where the aircraft is torn to pieces.

The men of Aviation Crash Injury Research concentrate on immediate cause of injuries and fatalities in selected airplane accidents which involve survivable conditions of crash force. In the main, this "survivable condition" simply means that the severity of the accident allows for theoretical or actual survival of at least some of the occupants. This relates directly to the inherent strength of the human body and its resistance to crash force under optimum conditions. These optimum conditions are such as not striking or being struck by objects of such shape or force as to exceed the "time-pressure tolerance" of the various portions of the human body. The time-pressure tolerance has to do with the magnitude of force which can be imposed for a given time on a given area of the body without serious injury. This, for example, is the difference between the load of the body during rapid deceleration against the back of an aft-facing seat as compared to the body being forced against an ice pick under the same conditions. Differences in duration or rate of force application also enter into the picture.

Human tissue tends to resist tearing and rupture under loads of short-time application and, in many cases, trauma is not produced under limited force conditions unless the application of the force continues over relatively long periods of time. Crash loads sustained in survivable accidents fortunately are of extremely short duration—varying between 1/200 to 1/10 of a second. These conditions prevail frequently in such accident types as aborted take-offs, "short landings," "overshoots," and wheels-up landings and ditchings. Where ground contact speeds of less than 200 miles an hour, and impact angles of less than 15° nose-down are involved, force applications to the body can be reduced or distributed in such a way as to prevent death and serious injury. The problem is one of learning how to design the cabins, cockpits, seats, restraint devices (Research Reviews, Jan. 1953), and other components (Research Reviews, Oct. 1952) so that force application can be reduced to non-injurious levels.

Structural-injury associations are, of course, "after the fact"; that is, the lethal components of the airplane are identified after the lethality has been produced (Figure 1). Many design faults, which are seemingly of negligible importance in an individual accident, may take on increasing significance as structural-injury correlations develop over hundreds of accidents. By showing, in accident after accident, that

Figure 1 - Rigid steel tubes of seats installed in Curtiss C-46 plane were the cause of severe fractures of the legs of several cabin passengers.

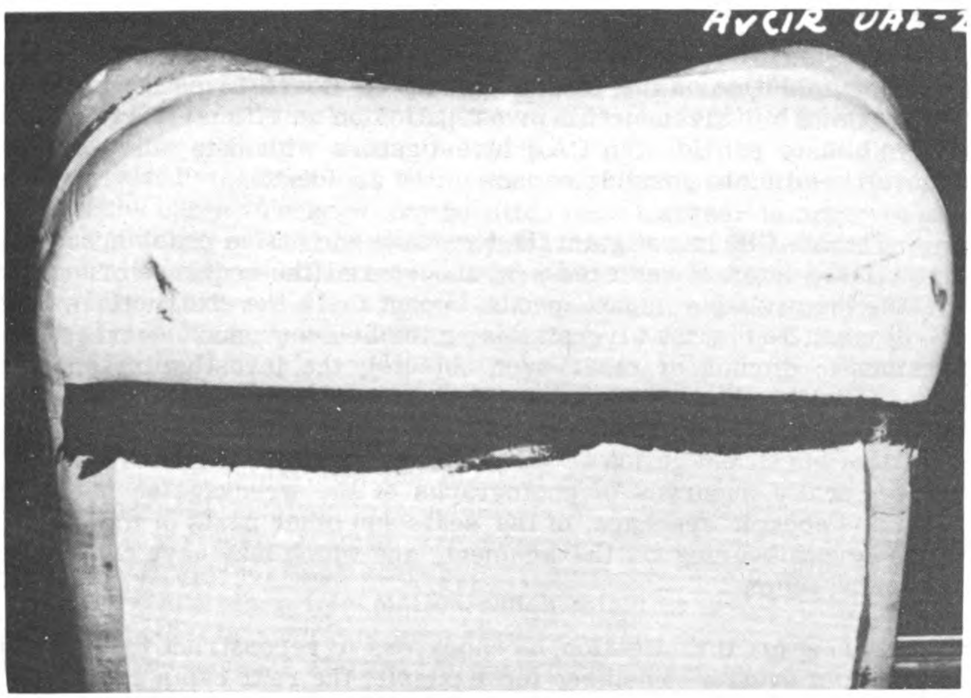


Figure 2 - Delethalized seat has been designed with dural tubing of a continuous configuration covered with energy-absorbing material to lessen the impact force on a passenger's head.

the same items are responsible for the injuries and deaths, it is then possible to design (Figure 2) against these conditions in new airplanes, and even to correct some situations in planes already in operation.

Finding the cause of an accident is, in itself, a complex job. Finding the cause of injuries in accidents, wherein upwards of over a hundred people may be involved, is even more complex for it involves not only the investigation of mechanical features but requires a detailed examination of injuries and associated medical data as well as the difficult job of associating—by analysis and deduction—injuries with specific mechanical items in design which caused the injuries. By way of showing some of the highlights and complexities of crash-injury investigation and analysis, it may be interesting to the reader to follow some of the sequence of events which take place in such an investigation.

First, the Aviation Crash Injury Research (Av-CIR) investigator is notified by telephone of a crash; this notification may take place at any time of the day or night, and he therefore must be on "24-hour call." Upon notification, he determines whether the crash will yield useful information in relation to designing for survival in future accidents. If the crash is determined to be one of a survivable nature, the investigator departs immediately for the crash scene, taking with him all the needed field investigation equipment—cameras, tools, accident-injury reporting forms, "cold weather" clothing (if it is winter and the crash is in an exposed area), and other paraphernalia.

Sometimes the investigator's travel to the scene of the accident involves the use of trains, buses, jeeps, helicopters, and even snowshoes.

As soon as he arrives at the scene of the crash, he is assigned to an official position on the Civil Aeronautics Board investigating team. This permits him to conduct his investigation on an official status and also allows him to provide the CAB investigators with data which he may uncover relating to possible causes of the accident.

The Av-CIR investigator first reviews the entire crash scene with his primary interest centered on what occurred (the sequence of accident events—the probable impact speeds, impact angle, the obstructions (Figure 3) contacted by the aircraft during the accident, such as trees, embankments, ditches or other such objects); the investigator is not interested in the cause of the accident—he is only interested in what happened during the accident and what caused the injuries. During the course of his investigation at the scene of the accident, the investigator takes literally hundreds of photographs of the wreckage scene—of the cabin and cockpit wreckage, of the seats and other parts of the aircraft which have a bearing on the accident, and which may have contributed to causing injury.

During his investigation, he endeavors to reconstruct the probable sequence of events: whether, for example, the rear cabin section tore off to the right or left, how it rolled, and in what direction it may have hit other obstructions. This information provides data on the directions of crash force imposed on the structure of the aircraft, the seats, and on the occupants.

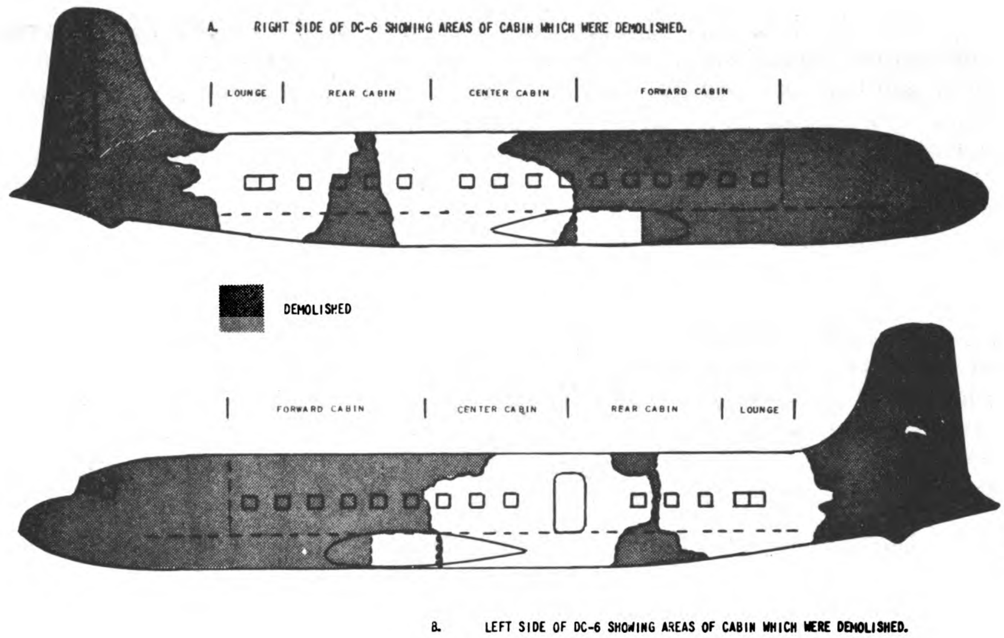


Figure 3 - Diagram of demolished areas of a DC-6 transport plane that crashed at Elizabeth, N. J. The break in the rear of the cabin was caused by impact against a tree. Three directions of crash force were sustained by the aircraft and passengers during this accident.

His next job is to collect, from the wreckage scene (which may involve an area of terrain of up to 300 ft in width and 1500 ft in length) all of the pieces of wreckage which may have contributed in one way or another to the ultimate cause of injury. Pieces of the seats and floor are "jigsawed" together into their pre-crash positions, and major protions of the cabin wreckage may be fitted back together in order to provide a "picture" of what happened during the crash. Indications of body contact with various structures, such as seat-backs, window frames, or other objects are noted for future reference in the subsequent analysis of the accident-injury aspects of the crash.

During subsequent evenings or after all the on-the-scene work has been completed, the Av-CIR investigator visits the local hospitals and mortuaries and interviews the medical personnel who are concerned with the persons involved in the accident. Survivors of the accident, who are not too seriously injured, are interviewed to ascertain where they were sitting, whether their seats broke free or not, who they were sitting next to, and any other information which might be useful in placing the location of other occupants of the aircraft and the possible causes of their injuries. The persons who were killed in the accident, or died soon after, are often examined in order to obtain data on the apparent gross injuries, and when autopsies are performed the investigator asks to attend as an observer.

The Av-CIR investigator also sits in with the CAB investigators during the interviews of observers of the accident—if any are available—to obtain further evidence of what may have happened during the crash. This information is treated with great caution, however, because observations made by other than experienced and qualified observers are frequently too inaccurate to be of value. Subsequent Av-CIR analyses are always based completely on only the information obtained from experienced and qualified investigators and medical personnel, rather than from observations made by so-called "lay" persons.

His job in the field completed, the investigator then returns to the project center, where follow-up questionnaires and medical forms are forwarded to survivors and their attending physicians who were not interviewed at the accident locale, particularly those who were uninjured, or injured to only a minor degree, and who had continued their journey by the next available airline flight.

During the next few weeks, the photographs are processed, and then a detailed meticulous process of analysis is undertaken on the medical data, questionnaire information, and the pictures, as well as the descriptive and verbal material collected during the on-the-scene investigation. Diagrams showing the pre-crash location of the occupants in the aircraft are drawn up and the progressive sequence of crash events are pictorialized (see Frontispiece). Photos of the structural items which caused injury are selected from the hundreds of available photos and are integrated with the text of the Av-CIR report. In addition, pertinent medical information is "tied together" in relation to the structural causes of injury in the report in order to draw engineering attention to the details of design which can cause injury in survivable crashes.

Certain Av-CIR analysts specializing in impact force calculations investigate the data and develop a concise statement of the force conditions involved in the accident—and imposed on the occupants; these are referenced in relation to their being of a survivable or non-survivable type.

Finally, the completed rough draft of the report is reviewed by key personnel of the project for validity, clarity, conciseness, and reading ease. Corrections are made, and the final report is then produced and distributed to military and civil safety groups in the United States and in other countries. Copies of the reports are also sent to design engineers of companies designing and building airplanes, seats and other interior components, and to the airline operators.

Use of the data gleaned from this and other accidents does not stop, however, with the issuance of these crash-injury reports. Much of the data—including photographs—is also used for inclusion in crash-survival design manuals, and for portions of engineering discussions and addresses made from time to time in the development of crash-survival design concepts throughout the engineering field. Some of the material is also used in lectures and courses given by Av-CIR personnel in the training of military and civilian accident investigators.

Although it has not been mentioned previously in this article, crash-injury investigation requires—as an essential part of its work—the cooperation of the examining physicians and pathologists in order to obtain accurate and reliable medical data. Without such data, the project's work would come to a standstill. Thus, advances that have been made to date in the field of crash-survival design have stemmed in great part from the valuable assistance which the medical field has so willingly contributed.

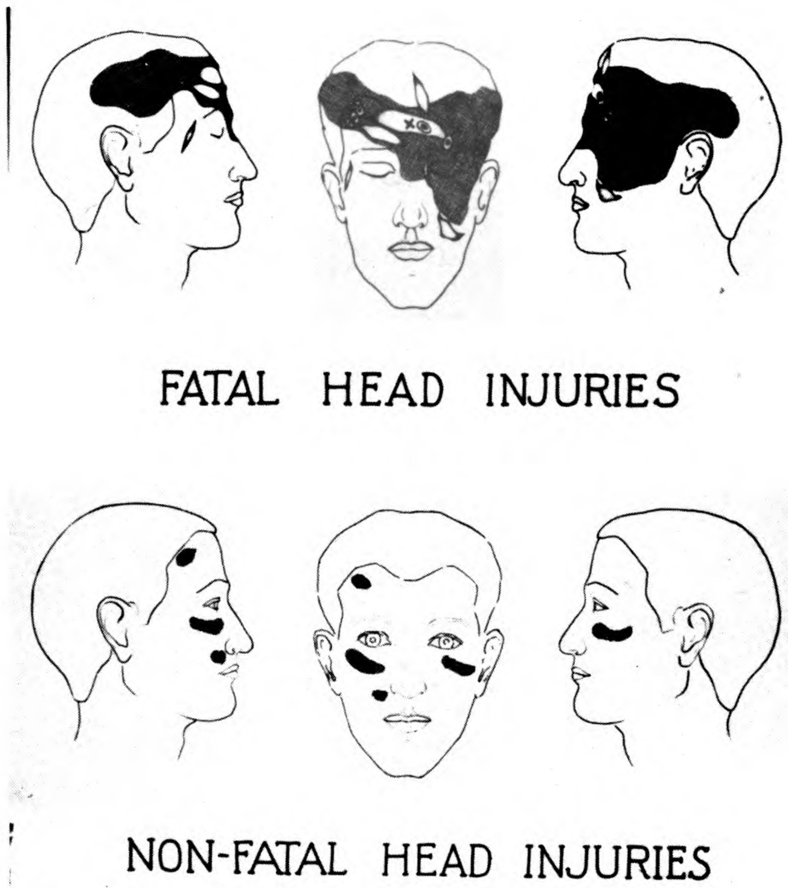


Figure 4 - A composite of the regions of the head where fatal and non-fatal head injuries were sustained by the 22 fatally injured and other passengers in the C-46 accident.

It can be seen from this that crash-injury research is a tedious, difficult, and complex job which requires the abilities of many people with diversified experience—accident investigators, structural engineers, human engineers, analysts, physicists, and doctors (Figure 4). These people have all contributed to the saving of lives in future "unpreventable" accidents.

Every danger of a military character to which the United States is exposed can be met best outside her own territory--at sea. Preparedness for naval war--preparedness against naval attack and for naval offense--is preparedness for anything that is likely to occur.

CAPT Alfred T. Mahan

Figure 1 - During 1950, the staff of the Office of Naval Research was headed by RADM T. A. Solberg (center), Dr. Alan T. Waterman, and CAPT John B. Pearson, Jr.

Ten Years of Naval Research

The Decennial of ONR

On 1 August 1946 President Truman signed Public Law 588 which had been passed by the Seventy-ninth Congress. This law established the Office of Naval Research to plan, foster, and encourage scientific research in connection with its paramount importance as related to the maintenance of future naval power and the preservation of national security.

During the last decade ONR has been singularly successful in bringing together the scientific community of this country and our great naval establishment. At the beginning of this period, basic research and advanced study in most of the sciences were in need of encouragement and support. From the outset, ONR recognized that it could best solve its own problems and plan and organize its own program of research by helping to restore health and vitality to scientific research in the country as a whole. The problem of overcoming the scientist's distrust of any bureaucratic direction of research, especially by a government agency whose whole mode of operation depended upon authoritarian control, was very formidable.

ONR established workable policies that fully recognize and respect the scientist's need for independence and freedom. This resulted in part from a long tradition of Navy utilization of scientific knowledge. Solution of this problem provides the key to the achievement of the Office of Naval Research during its first ten years. Virtually all its other and more obvious achievements result from this one.

ONR is the Navy's representative in the world of science, and a spokesman for science in the councils of the Navy Department. Its mission is to make available whatever science has to offer which might result in modern weapons, devices, and techniques so that now and in the foreseeable future the United States Navy will be superior to any in the world.

To do this ONR must know, on the one hand, the needs of the Fleet. What advances should we be making in submarines? What kinds of new radar and sonar equipment do we need? What kind of aircraft should the Navy have?

On the other hand, ONR must know what is going on in science that will help to meet the needs of the Fleet. It must know the latest theories concerning the physical forces acting on a moving body underwater, such as a submarine; about cosmic-ray activity and very-high-altitude weather conditions for high-speed, high-altitude flight; the areas scientists are exploring in order to become aware of new findings that might hold some promise of use to the Navy.

ONR's program began with the activation of a series of basic research projects in the physical, biological and naval sciences. Then, as now, the staff (Figure 1) evaluated the programs on the basis of the Navy's needs, scientific merit, and budget limitations.

The year 1954 marked the beginning of an era of changes in the Navy's administrative setup for research and development. These changes are all in the direction of a more formal integration and coordination of research and development. The Office of Naval Research became the central point for coordinating the many development programs being carried on by the technical bureaus. The Chief of Naval Research now combines the research and development budget requests of the Bureaus and the Marine Corps into a single appropriation.

The real heart of ONR's work is its contract research program. About four-fifths of its research is carried out through contracts with universities, with commercial and industrial laboratories, and with non-profit laboratories and institutions.

Through its position in the scientific community, ONR has succeeded not only in keeping the Navy in the front ranks of science, but it has kept scientists interested in problems peculiar to the Navy and has maintained a nucleus of these specialized scientists working on current Navy projects.

For example, the Navy needs to know about environmental conditions in all parts of the world to prepare for possible land, sea, and air operations; it needs to apply geography to military problems. ONR's geographic research on little-known areas, particularly coastal areas, has been used by both the Navy and the Marine Corps. New information obtained through geographic research provides a source of reliable, basic knowledge, ready and available as the Navy's needs arise. Thus, Task Force 43 (Operation DEEPFREEZE) is using information from a project begun in 1952 to delineate the coastal features of Wilkes Land, Antarctica.

As a result of ONR's ceaseless efforts, geographers are thinking increasingly in terms of research that will benefit the Navy and are prepared to apply their skills and knowledge to the solution of naval problems.

A great variety of hydromechanics research has been supported to solve many of the pressing problems that arise during the development of high-performance weapons and vessels. Contractors seven years ago began to investigate the potentialities of hydrofoil boats (Figure 2) for naval applications. The excellent speed and seaworthiness of hydrofoil craft have been demonstrated in all types of waves. Hydrofoil boats up to 50 tons can now be designed and sail boats equipped with hydrofoils have been successfully tested. A contract for a prototype hydrofoil landing craft has been awarded.

Scientific investigation is the root of continuous improvement of military equipment and of effective techniques for their use. Program analysis groups therefore continuously survey the scientific activity to insure there are no gaps in the research program. They try to channel ONR's research funds into those areas most likely to produce usable results. In view of the nature of basic research, such a plan is always difficult. Basic scientific research seeks to find the underlying principles that govern physical phenomena. These principles form the basis for subsequent development of better products for the Navy and the nation.

Figure 2 - Test of hydrofoil research craft at U. S. Naval Air Station, Patuxant River, Md.

The first program of basic research sponsored by the Physics Branch in 1946 was the study of low temperature physics, or cryogenics. This program consisted of research in superconductivity, cryomagnetics, superfluidity, specific heats and calorimetry, thermodynamics, and thermometry. This program is considered by many outstanding physicists to have been the finest example of government-sponsored academic research to date. As a result of the cryogenics program, liquid helium became easily and cheaply available and techniques for its use lost their esoteric character. Subsequently research in solid state physics was joined to cryogenics research. This union, with its almost revolutionary consequences, laid the foundation for much of the later work on the hydrogen bomb.

Just last year a series of electronics tasks supporting radio astrophysics and related research was initiated. This dramatic, relatively new science studies details of solar emission. Seemingly pure and far-removed from practical applications, it is already making its contribution to navigation, communications, and other areas of naval importance.

ONR's contractors frequently develop a new idea until the principle is either proved or disproved. Then the Bureaus take over and use the basic information for their particular requirements. For example, the Air Branch develops fundamentally new concepts in the field of aeronautics that are used later by the Bureau of Aeronautics. It supported early research on very light, one-man helicopters. The KH-15 was built with adjustable linkages that could be easily varied during flight. This helicopter demonstrated outstanding flying qualities in free flight after less than 10 minutes of ground tie-down testing. This is particularly noteworthy since very small helicopters are characterized by lack of stability, excessive control sensitivity, or both.

Recent research efforts came to fruition this year in the actual flight testing on a high-performance military aircraft of boundary layer control systems (Figure 3). BLC involves taking power, in the form of compressed air, from the jet engines. Through a system of ducting, it energizes the "dead" air adjacent to the surfaces of the wings and increases their lifting power. Reduction in take-off and landing speeds for high-performance aircraft has been demonstrated by flight tests with a F9F-4 aircraft for the Bureau of Aeronautics. Under ONR contract, six different circulation control systems have been successfully flight tested on light planes and are available with modifications for application to service type aircraft.

As a result of ONR's studies of noise reduction, the Bureau of Ships established seven groups in naval shipyards to work on ship and machinery noise-reduction problems. Precise study of the effects of wave motion upon given hull shapes at varying speeds involves extremely complex mathematical operations. The mathematical research performed by ONR contractors has provided new knowledge of differential and integral equations of value in solving the ship designer's problems.

Research programs produce a wealth of information. To get this information to the proper place, ONR provides for individual contacts throughout the Navy. This continual working-level association is the heart of its technical information network.

One method of bringing people together to discuss their problems and learn of the latest developments in a specific field is by symposia. Since 1946 the seven symposia on undersea warfare have permitted the exchange of ideas between operating forces and civilian scientists and engineers. During one symposium strong recommendations were made for the initiation of the low-frequency underwater detection research program.

These symposia promote the cross-fertilization of ideas that come from contact with many different scientific disciplines and engineering fields. In classified areas of research, such as underwater acoustics, these symposia serve as a substitute for professional society meetings.

Figure 3 - Tufts of woolen yarn affixed to the skin of a Pusher Airplane AG-14 demonstrate air flow over wing and fuselage. A F9F-4 has proved the value of boundary layer control.

Figure 4 - "Free flight" research.

Research results are also made available to the other services and frequently adopted by them for development. Fundamentally new concepts in aeronautics are constantly studied. One such concept, that of vertical take-off and landing (VTOL) is now being developed by the Department of the Army in cooperation with ONR. The first research work on convertiplanes in this country was sponsored by ONR in 1948. The Air Force is developing an experimental aircraft, the XV-1, based on these VTOL investigations begun in 1949. Still undergoing flight tests, it has flown a speed range from 0 to 193 mph.

Theoretical research performed over a period of years in several countries, coupled with existing knowledge led to development of a prototype of a simple, wingless aircraft, "The Flying Platform" (Figure 4). The Army Transportation Corps is now adapting it to their specialized requirements.

Project SQUID, a program of research in basic science bearing on the problems of jet propulsion (Figure 5), began in 1946 as a cooperative

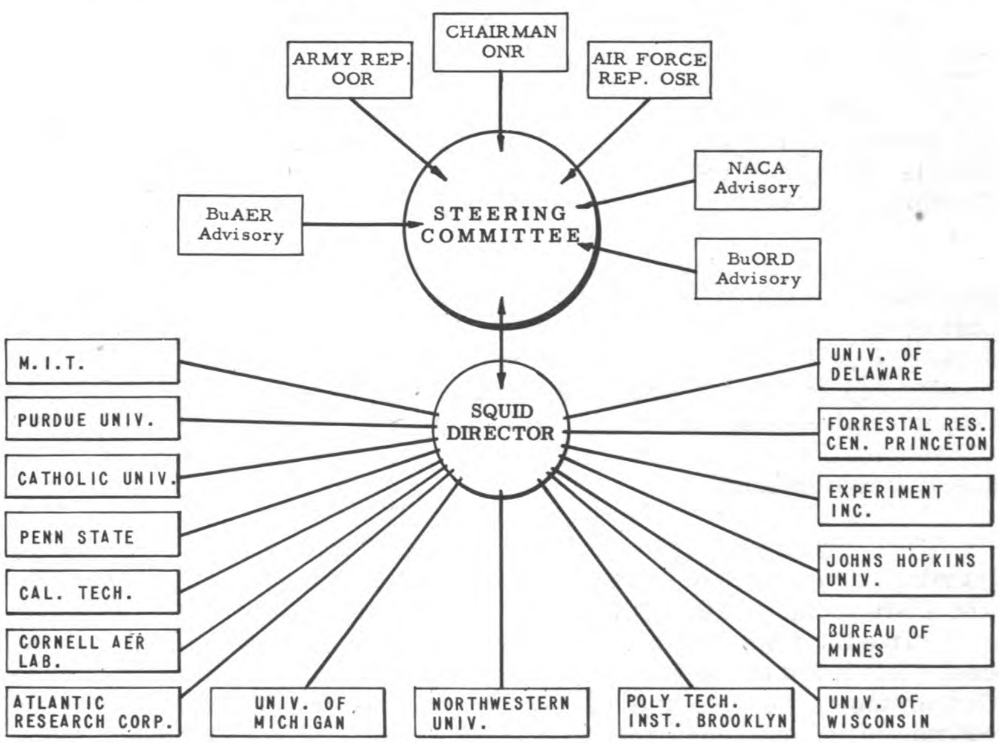


Figure 5 - Technical organization, Project SQUID.

venture on the part of the Bureau of Aeronautics and ONR. The other services have adopted ideas, results, designs, views, and devices that originated or were nurtured in SQUID. A 12-volume set of books initiated by SQUID covering most of the present unclassified knowledge in jet propulsion and high-speed aerodynamics, started in 1949, is nearing completion. Work on the air-turbo-rocket has reached the development stage and the Air Force is pursuing application of this engine for its specific needs.

The history of the shock-tube program is particularly significant, due to the fast-growing popularity of the device, once called "the poor man's wind tunnel." Ten years after the original group was started at Princeton, ONR supports six shock-tube tasks at universities and one at the Naval Ordnance Laboratory. Results are used by the Air Force, NACA, and the aircraft industry.

ONR joins with the other services in co-sponsoring relatively large tasks. For example, it has co-sponsored with the Army and the Air Force electronics research at Massachusetts Institute of Technology, the Research Laboratory of Electronics, the Cruft Laboratory, and others.

These three-Service tasks serve as efficient flow channels for interchange of information on specific research; establish unified service operations at working levels; and provide nucleus research centers to permit build-up of applied laboratories in case of a national emergency. The Lincoln Laboratory at M.I.T., originally a basic Air-Defense research group at M.I.T.'s Research Laboratory of Electronics, is well recognized as an important contribution of the three-service, non-government, laboratory-type of operation.

ONR's vigorous program of electronic digital computer development led to development of the Institute for Advanced Study's electronic computer—the ancestor of an extensive family of computers. The Whirlwind computer, developed at M.I.T., has made a major contribution to the development of the SAGE system of continental air defense. Whirlwind is still one of the fastest machines in operation. Its magnetic core memory is probably its most striking contribution to the art.

As the three services are only as effective as the personnel who man their equipment, research on human factors has comprised a large part of the ONR program (Figure 6). Papers presented at a conference at the University of Michigan in 1950 were published as a volume, "Groups, Leadership and Men." This book, summarizing the experimental methods and principles of social behavior, is widely used in the personnel operations of the Armed Services as well as in social science research and operations in general.

The psychophysical characteristics of the human operator in performing numerous complex military tasks have not been overlooked. The ONR-sponsored BENOX report was the first attempt to evaluate and anticipate the impact of high-intensity jet noise upon personnel and operations. It led to the formation of the Armed Forces-National Research Committee on Hearing and Bio-Acoustics. Personnel training must be constantly changed and modified to keep pace with new weapons and

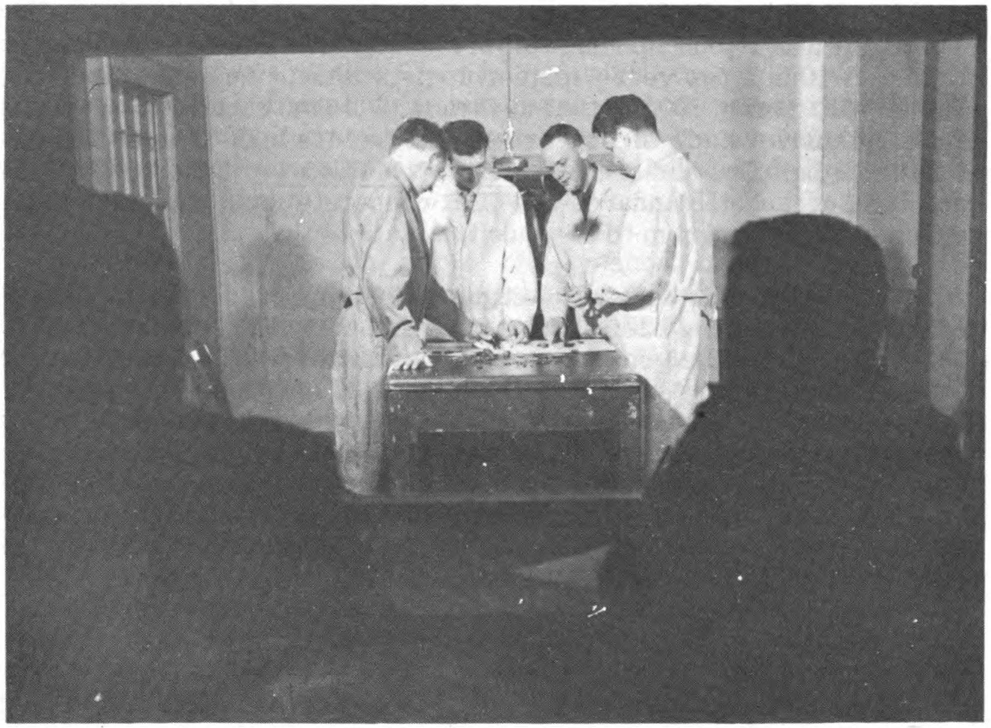


Figure 6 - An ONR psychologist observes unseen through a one-way mirror as the four men react in a group-problem solving situation.

techniques. ONR constantly strives to anticipate these trends in order to prepare for adequate personnel training.

By keeping in close contact with the scientific community ONR is able to provide a base for rapid mobilization in times of emergency. During the Korean emergency, for example, Naval Research Reserve Unit One, a volunteer research reserve unit, was quickly mobilized for active duty. This group of biologists, working as a team, studied fatigue in combat.

Scientists who have worked on ONR-sponsored programs constitute a pool of skilled men who are available as the occasion arises for special work for the three services. One such group has actually conducted field research in remote and foreign areas, often under rigorous climatic conditions, for the Geography Branch. For the most part these trained observers have acquired broad first-hand and specialized knowledge of these areas; they have developed special ability to conduct research under difficult, strange or extreme conditions. Recently many of the more than 200 scientists experienced in Arctic projects have assisted the Navy in Operation DEEPFREEZE, the Air Force in construction and supply of the DEW line, and the Army in its Greenland operations.

ONR also works with other government agencies. One of its most important programs in this respect was initiation of the application of electronic computation to dynamic meteorology. Since 1946 this project has grown into a complete operational program of numerical weather forecasting under joint sponsorship of the Navy, Air Force, and Weather Bureau. Within a few years meteorologists should be able to forecast weather with nearly 100 percent accuracy. ONR's contribution to this year's intensive study of hurricanes will include high-altitude photography from balloons and rockets (Research Reviews, June 1956). The National Bureau of Standards and ONR cooperate in an extensive basic instrumentation program to advance the state of the art.

Nuclear physics research, begun in 1946, prevented a time lag of two years in acquiring basic information and helped to restore a supply of essential scientific manpower. The program was so vast that the Atomic Energy Commission joined with ONR in 1947 to begin a continuing co-sponsorship of basic research that has become one of the major basic research programs of the country. A close, salutary working relationship exists between personnel of the two agencies. Development of a whole family of accelerators has resulted from the program. Cosmic rays have been studied at many latitudes from the equator to the Geomagnetic North Pole on both land and sea.

Certain early tasks in aeromechanics research matured rapidly in response to the advancing needs of actual aircraft; their growth demanded more financial support than ONR could give. This led to joint support of many tasks with NACA and the Air Force, and eventually to sole support by these agencies. Many of the original ONR contractors are now working very productively in NACA and Air Force programs.

Many results of ONR research are classified, designed to answer specific military problems. Many benefits, however, occur from this research that are beneficial to the nation at large. New basic scientific information eventually benefits all society. Scientists working under the contract-research program publish their findings in professional journals when they are not essentially military. These findings then funnel down to the public through better production techniques, better materials, and better products. ONR also turns over much of its information to industry to encourage more efficient production at rates that will benefit the government.

ONR foresaw the demands that a successful computer development program would make on mathematics and mathematicians. From the beginning it embarked on an ambitious program in numerical analysis; it trained programmers and coders. ONR constantly advocated more research and training in what was then considered a most unattractive field by the mathematical community. The Institute for Numerical Analysis at UCLA, doing contract research, attracted some outstanding mathematicians. It is interesting to note that as computer centers spring up all over the country, the numerical analysts who are the mainstay of the ONR program are repeatedly approached to take over their directorships.

Publication of the Digital Computer Newsletter gives industrial and academic people involved in computer research and development up-to-date information on the state of the automatic digital computer art in this country and, to some extent, abroad. Its published reports have been particularly valuable as a reference. This information has helped to develop computers (Figure 7) designed for its specialized requirements and to use numerical analysis to solve its complex problems.

Research in the biological and psychological sciences produces innumerable benefits for the civilian economy. In these areas the benefits are often immediately apparent whereas in other research the carry-over comes later.

A revised concept of the nature of burn shock brought about a new treatment. As all functions of the human body are regulated and co-ordinated in some way by the nervous system a broad program in neuro-physiology was initiated in 1946. Data obtained have made possible the development of new agents and procedures for relief of fatigue and pain, for the promotion of alertness and rejuvenescence, for the control of autonomic imbalance, for the treatment of tension and anxiety, and for surgical repair and rehabilitation (Figure 8).

Special studies in the field of flying safety, undertaken to improve military aviation, led to design principles and concepts that have been adopted by all experts in flying safety. The program has had a profound impact on the aviation industry throughout the world. Travelers in many modern transport airplanes enjoy safety measures developed under this

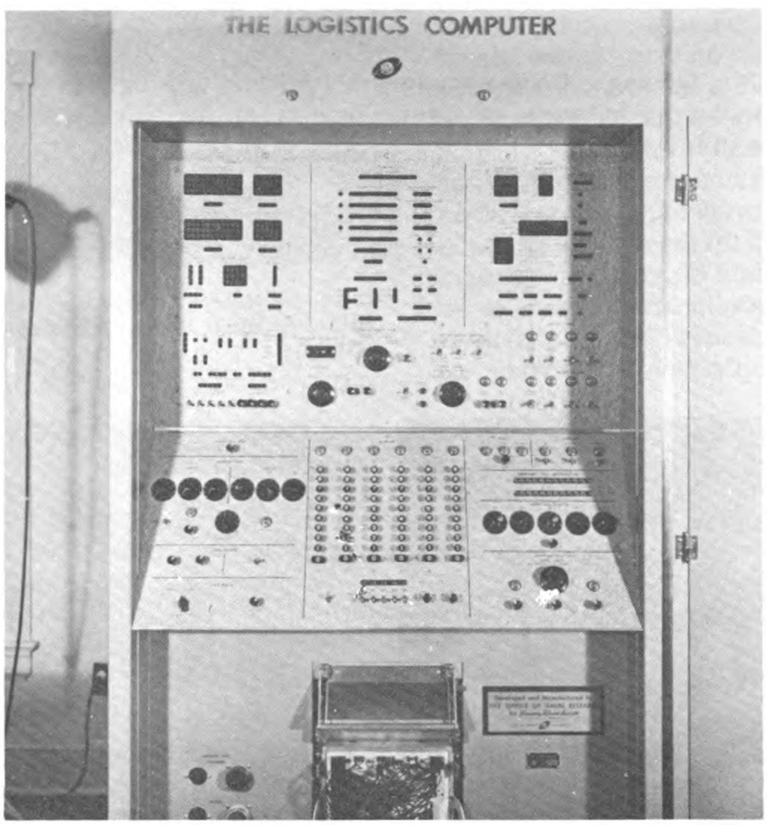


Figure 7 - This computer located at George Washington University was developed to process large quantities of data through comparatively simple mathematical operations.

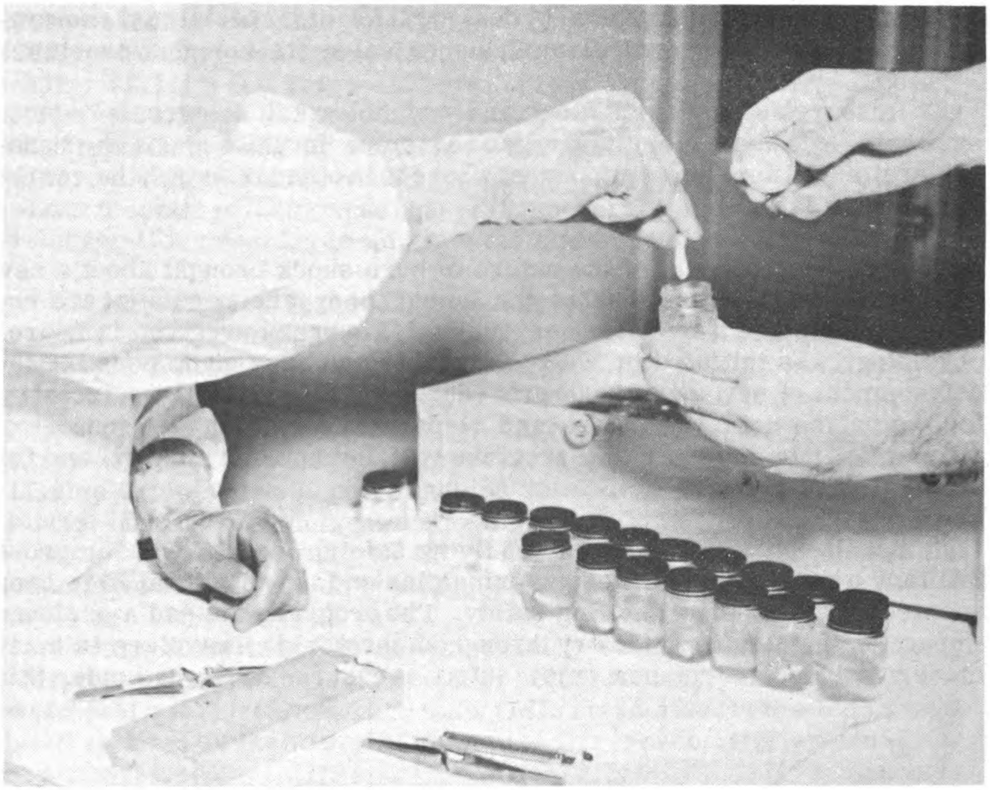


Figure 8 - Through ONR-sponsored research, progress has been made in the techniques of tissue preservation; here a technician places a piece of human cartilege into a preservative.

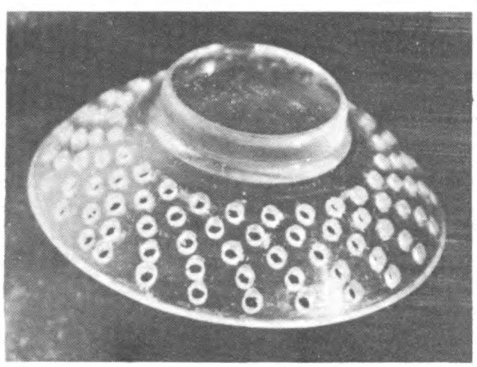


Figure 9 - A plastic "artificial" cornea now being used for sight restoration in animals.

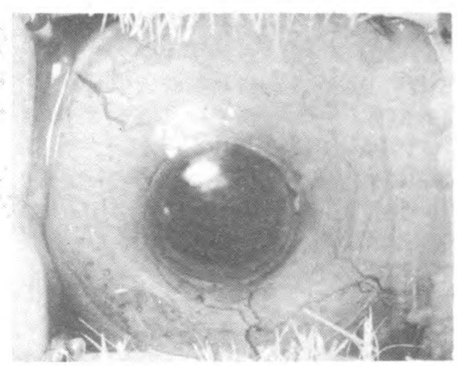


Figure 10 - The eye of a rabbit eight months after an operation in which the holes in the corneal layer has remained patent, permitting sight through plastic.

program. Manufacturers of new type aircraft now on the drawing boards are taking advantage of advice and recommendations provided by these crash analysis experts.

Medical advances include development of blood plasma expanders, new techniques for tissue preservation and transplantation, new antibiotics, plastic "artificial corneas" (Figures 9 and 10) to replace damaged corneas have been successfully tested in animals.

Growth of the Laboratories of Bacteriology (Figure 11), University of Notre Dame (LOBUND) is due in large measure to ONR's support. Here animals are raised in a completely germ-free environment. Thus it has been possible to prove a long-held hypothesis that bacteria cause tooth decay. Germ-free animals fed a sterilized cariogenic diet have no caries. Control animals raised in a normal environment and eating a regular diet have caries.

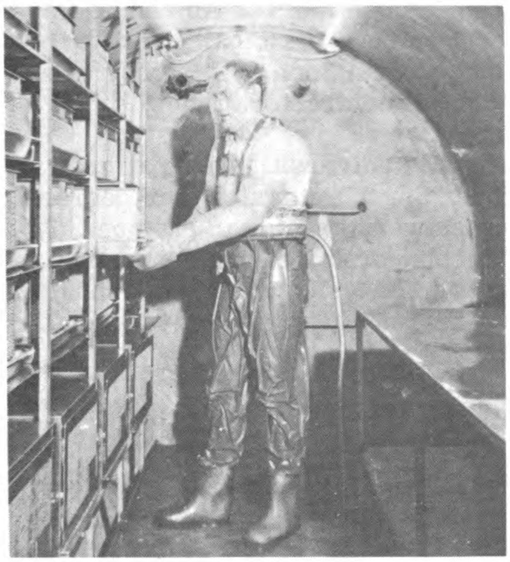


Figure 11 - In a germ-free tank at the Laboratories of Biology, University of Notre Dame (LOBUND), a technician works with research animals.

Study of marine organisms, a part of the hydrobiology program, is directed in part toward preventing damage to wooden port structures, to metallic substances subject to corrosion, and to ship hulls. Marine borer attacks cause annual damage of $850,000 to wooden structures in waters surrounding the United States. Scientists are busily searching for a method to prevent such attacks. Survivors forced down at sea need to know what marine life to avoid and what can be utilized—particularly for food. Hydrobiological research helps to provide this all-important information.

Many developments in commercial aviation stem directly from the work done by ONR's contractors. Presently, in cooperation with the Bureau of Aeronautics, ONR is supporting research on development of aircraft instrumentation (Figure 12) that will permit aircraft to operate in all kinds of weather with a minimum of cost in equipment weight and pilot training and a maximum gain in reliability and efficiency. A transparent, flat-plate television tube will replace many instruments in today's cockpit and permit safer flight.

The core of any nation's scientific resources has always been in its centers of learning, the colleges and universities. There most of the real pioneering work in science is still carried on. There men and women search for new knowledge about the universe, often with no thought of practical application, but simply because they are driven by an urge to know more about the world. Their discoveries lie at the basis of all the development and engineering work that leads to new products and new processes.

This program has been mutually beneficial to the scientific community and ONR. For example, research in the mathematical sciences has provided statistical contributions to the solution of current, concrete military problems. Indirectly it has aided the military in the development of a quickly-mobilizable reserve of professional statisticians familiar with the use of statistics in military applications. The program has provided intellectual stimulation to scientists for it has opened up new problem areas that require basic theoretical work in statistics and probability.

Many ONR investigators have received outstanding awards including the Nobel prize. Most recent recipient of this award was Dr. Linus Pauling for his work in determining the structure of a limited number of proteins by X-ray diffraction methods. Many play important roles in scientific organizations. Three past presidents of the American Psychological Association, for example, have been principal investigators on ONR contracts. The American Mathematical Society's Bacher prize, awarded every five years, has gone to ONR contractors twice.

The contract research program with universities also affords an opportunity for students to do research leading to their advanced degrees. At war's end, less than 30 Ph.D. degrees were granted in physics. Today, due in a large measure to ONR's sponsorship of basic research in physics, approximately 115 Ph.D. degrees in physics are given annually. Tomorrow's scientists and engineers can only be trained through basic science carried on in the universities.

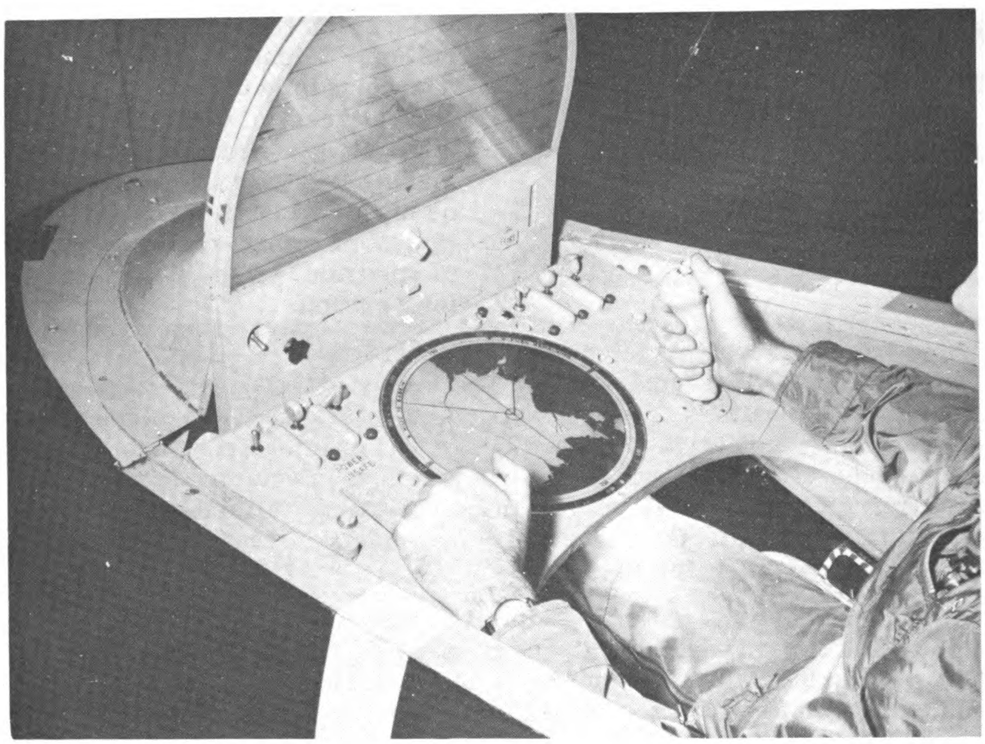


Figure 12 - Mockup of aircraft instrument panel and controls utilizing flat television tube. Features designed here may well be in future airplanes.

ONR's impact on the scientific community includes:

1. Release of immediate financial pressure on creative scientists—more money for supplies, equipment and assistance,

2. Support for post-doctorate personnel,

3. Support for retired, but still productive scientists,

4. Development of a pattern for administration of government support to basic research. Red tape held to an absolute minimum,

5. Training of administrators. (Two program directors of the National Science Foundation were first administrators of ONR contracts),

6. Stimulation of scientific communication by support of conferences, symposia, foreign and domestic travel,

7. Freedom to pursue study with a minimum of interference.

Cordial relations have been maintained with the scientific community abroad. A branch office in London provides constant liaison and keeps ONR scientists informed of the latest foreign scientific developments and trends. The Acoustics Branch early recognized that opportunity to make a major contribution to underwater sound (see article in this issue, "How Fast Does Sound Travel in Sea Water?") could best be obtained through a cooperative effort with British research and development in this field. Opportunities were provided for personal contact of technical people at the working level with a most salubrious effect.

ONR's work is increasingly recognized abroad as evidenced by awards presented to its contractors. A Yale scientist, working on a long-range program in radio astronomy has received the gold medal of the British Royal Society for his work on this program.

ONR is assisting foreign scientists with their research projects. Nuclear emulsion packages were flown for a group of European scientists during SKYHOOK launchings in Texas last year. Eleven scientists, members of CERN, the European Organization for Nuclear Research, wrote the Chief of Naval Research:

> "The undersigned, on behalf of eleven European laboratories engaged in research on cosmic rays, wish to express their gratitude to the Office of Naval Research for its valuable help in arranging for the exposure of stacks of photographic emulsions at high altitude.
>
> "In thus making it possible for us to take advantage of high altitude balloon flights, the O.N.R. has made a significant contribution to scientific cooperation at the international level. We feel sure that important results will flow from this type of collaboration."

The Office of Naval Research will conduct many experiments during the International Geophysical Year—particularly in the upper atmosphere. This area of research has been actively studied by ONR ever since its organization. Its earliest upper atmosphere research project, HELIOS, started in 1946, envisioned a manned flight to the stratosphere. A cluster of 100 balloons would carry the manned gondola to the stratosphere as one step in a series of upper-air research and exploration programs using manned and unmanned craft. The state of the art of balloons, however, had not advanced sufficiently to make this manned flight possible.

To learn more about cosmic rays, temperature and density of the atmosphere, and other related data, scientists needed an instrumented laboratory that would remain aloft longer than the rockets then used to obtain essential data. Research produced the plastic SKYHOOK balloon since used extensively to probe the upper atmosphere (Figure 13). The data brought back has helped scientists piece together a better description of conditions to be encountered byyond the earth's atmosphere. This information has already made it possible for man to fly to heights undreamed of a few short years ago.

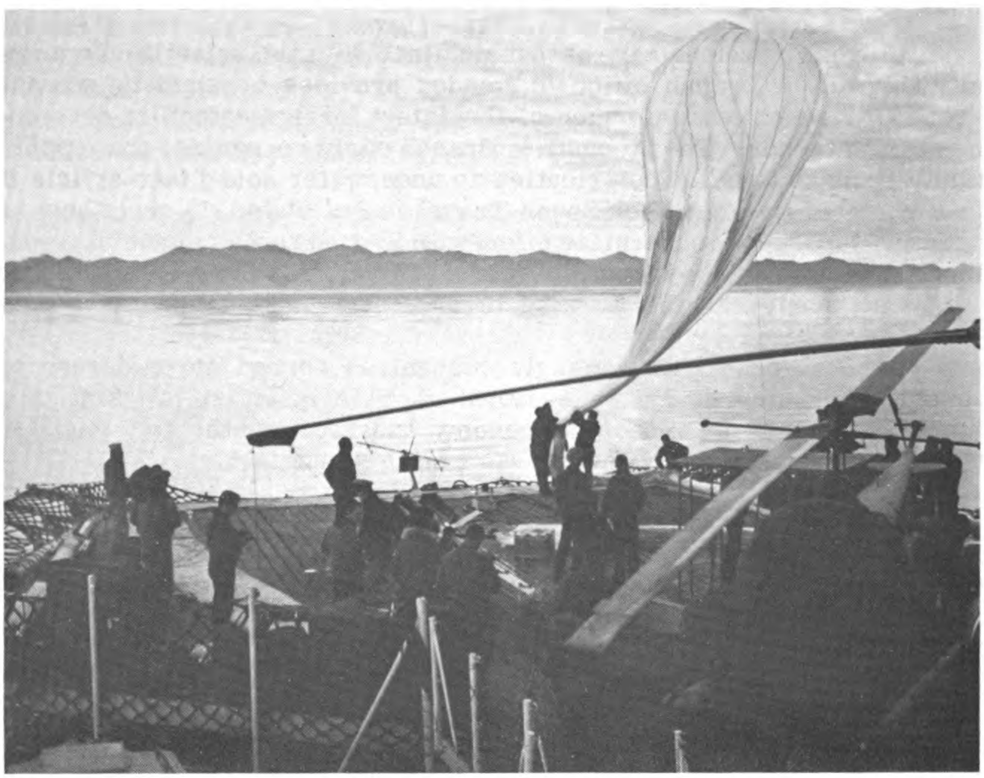


Figure 13 - Launching a SKYHOOK balloon from shipboard in arctic waters. The object was to obtain information on cosmic radiation, as well as temperature, density, and pressure of the upper atmosphere.

In pursuit of basic knowledge of the upper atmosphere ONR has utilized new tools and techniques. Because of its vast experiences in this phase of research, that began with Project HELIOS, the Chief of

Naval Research was designated to produce and launch a small, unmanned scientific satellite as a part of the U.S. contribution to the International Geophysical Year.

Thus, ONR, since its inception, has represented the Navy in science, coordinated naval scientific research, maintained liaison with the scientific community both in this country and abroad, and cooperated with other government agencies in furthering basic research. It has supported scientific research in nearly every major scientific field and its research results have made possible a new Navy, second to none. Countless significant benefits have also accrued to the civilian economy.

ONR will continue to be deeply involved in science in order to keep abreast of scientific progress and ahead of its competitors. A hundred years ago, when science was a casual, slow-moving effort, the Navy could afford to wait to adopt a new piece of machinery until an inventor had worked it out. Today, however, scientific research is a broad, organized, expensive, fast-moving effort. No longer can the Navy afford to be a mere spectator, standing by to purchase the results, if they appear useful. It must actually be in science. It must conduct its own research and support the work of others. Thus, the Office of Naval Research will continue its support of basic research to meet future emergencies that will require the nation to be self-sufficient in all fields of science.

The period from 1 August 1956 through 31 July 1957 will be designated as the Decennial Year of the Office of Naval Research. This period will provide a fitting occasion for the Office of Naval Research to evaluate its past contributions to our national defense and to make definitive plans for the coming years.

The various intra- and extra-Navy symposia, conferences, publications, etc., that are traditionally sponsored by the Office of Naval Research will, during this Year, be of pointed significance to the Navy's interests in research and development.

10-Year ONR Employees

Wilbert Annis
Frances D. Baker
Cecil W. Barlow
Charles E. Burns, Jr.
Lewis W. Butz
John M. Crowley
Nancy E. DeMaria
Mary L. Dorko
Adele S. Easley
Mary J. Gallardo
John J. Gorman
Lucille L. Gossage
Keith C. Harder
Marguerite H. Harris
Lydia M. Homann
Raymond F. Hossfeld
Frank B. Isakson
Bernice M. Judy
Carl A. Lejonhud
Edward McCrensky
Margaret M. McDermott
Robert S. Milans
Victoria K. Morris
Gerald D. O'Brien
Orr E. Reynolds
Randal M. Robertson
John T. Schrott
Fred Schulman
Donald C. Snyder
Edward E. Sullivan
Wanda Z. Swaney
Ruby Ward
Hazel M. Waters.

How Fast Does Sound Travel in Sea Water?

Vital Navy operations depend on prompt and highly reliable knowledge on the speed of sound in the sea. It is not enough to know that the speed is in the range of 4600 to 5140 ft per sec in large natural bodies of

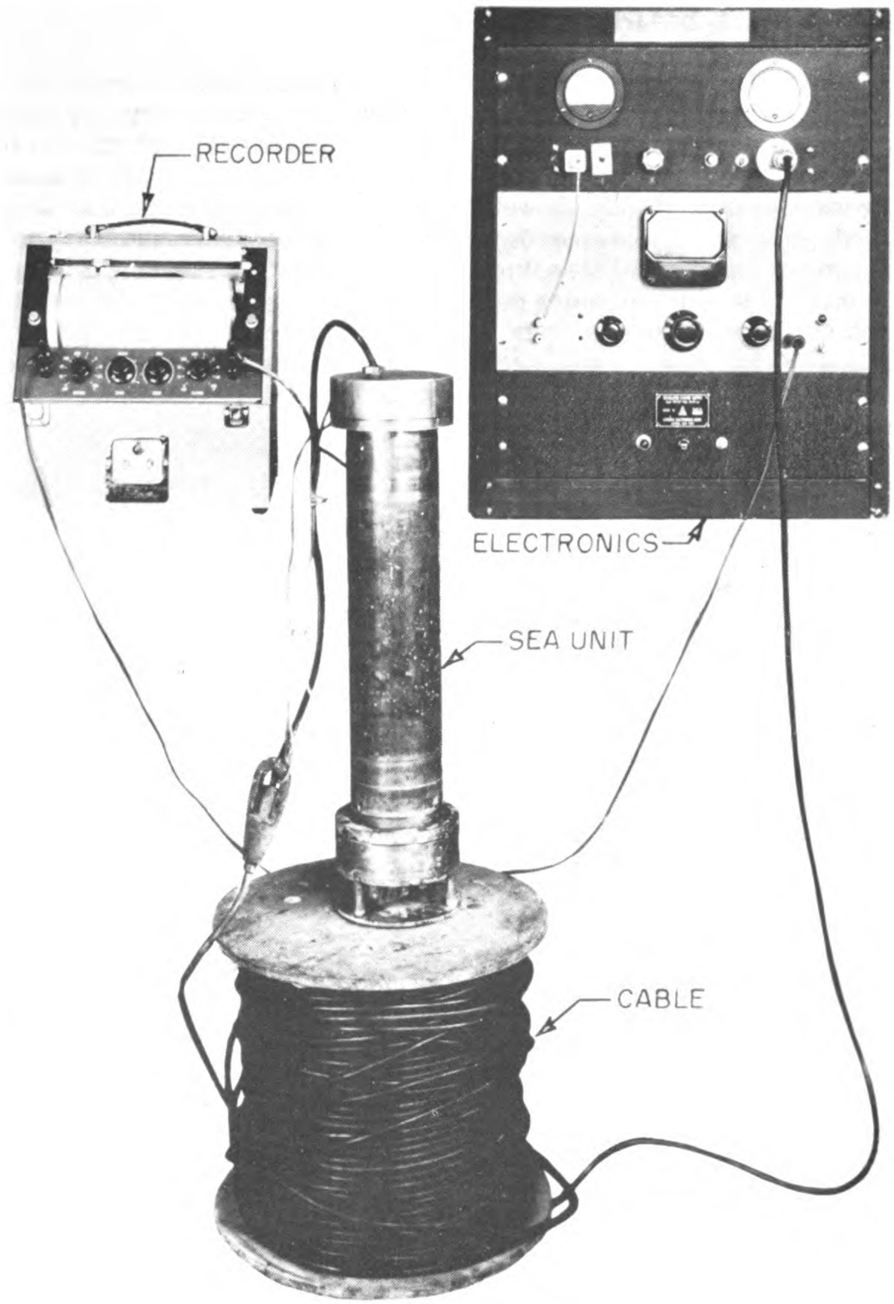


Figure 1 - NBS-ONR Velocimeter Mark II.

water, and that factors such as salinity tend to vary the velocity of sound from one part of the sea to another. In a Navy operation, responsible officers want to know on the spot, and instantaneously, what the velocity is, and they want to know it for a wide range of depths which may change constantly during the time an operation is coming to a climax. Any conning officer who has sweated out the detection of a submarine—in an exercise or as the real thing—can appreciate the importance of a reliable reading on the speed of sound in the water he is traveling through at the moment.

The velocimeter (Figure 1) has been developed and tested as an automatic instrument that almost instantaneously gives the velocity of sound in sea water. This highly reliable instrument has been designed and constructed at the National Bureau of Standards, and more recently tested at the U. S. Navy Underwater Sound Laboratory, in New London, Connecticut. The work of developing this instrument was sponsored by the Office of Naval Research. The NBS-ONR velocimeter will provide answers promptly on the speed of sound to depths as great as 300 ft. Readings come in values that are immediately useful—the speed as a function of depth or the speed as a function of time.

It has long been known that variations in sound velocity occur with changes in temperature and, to a lesser extent, with changes in the salinity of water. Sound velocity also increases about one ft per sec for each 55 ft of increase in depth. Several other factors, not all of which are well understood, influence the velocity of sound in the sea. The velocity gradients resulting from these variables produce curvatures in the rays of sound being propagated in the sea. In some instances, reflections are produced if, as is often the case, the thermal or salinity gradients are abrupt. Instruments generally employed by the Navy to give information on sound velocities depend upon a measured temperature and an assumed salinity. The NBS-ONR velocimeter, on the other hand, is independent of these variables in that it affords an almost instantaneous meter reading of the actual sound velocity.

Essentially, the new instrument consists of transmitting and receiving transducers which are located side by side. The pair of piezoelectric transducers are polarized barium-calcium-lead titanate crystals. The acoustic path is from one crystal to a reflector, then back to the other crystal. In all, the path is about 10 cm. The signal applied to the transmitting transducer is a negative spike with a rise time of about 0.05 microseconds and a duration of about 0.1 microseconds.

The received pulse, which is distorted because of a transducer response and absorption by the liquid, is reshaped by an amplifier and used to lock-in the blocking oscillator. Then the scale is expanded by beating against a crystal-controlled local oscillator so that the final frequency range is from 0 to 1 kilocycle.

The depth transducer is a strain-gage type pressure element. The unbalance dc voltage from the bridge circuit drives the X-axis of the recorder so that the chart presents a plot in terms of speed of sound versus depth.

It is necessary to exercise care in making sure the velocimeter is properly calibrated. Since the attenuation characteristics of sea water are almost independent of salinity, the instrument may be calibrated in pure water for which the speed of sound is accurately known as a function of temperature.

Preliminary tests of the Underwater Sound Laboratory were made on Dodge Pond Lake in October 1954. The technicians of the Laboratory were thus afforded opportunity to become familiar with the instrument and how to handle equipment in a sea test. In January 1955, a series of sea tests was made off the coast of Florida. The NBS-ONR velocimeter

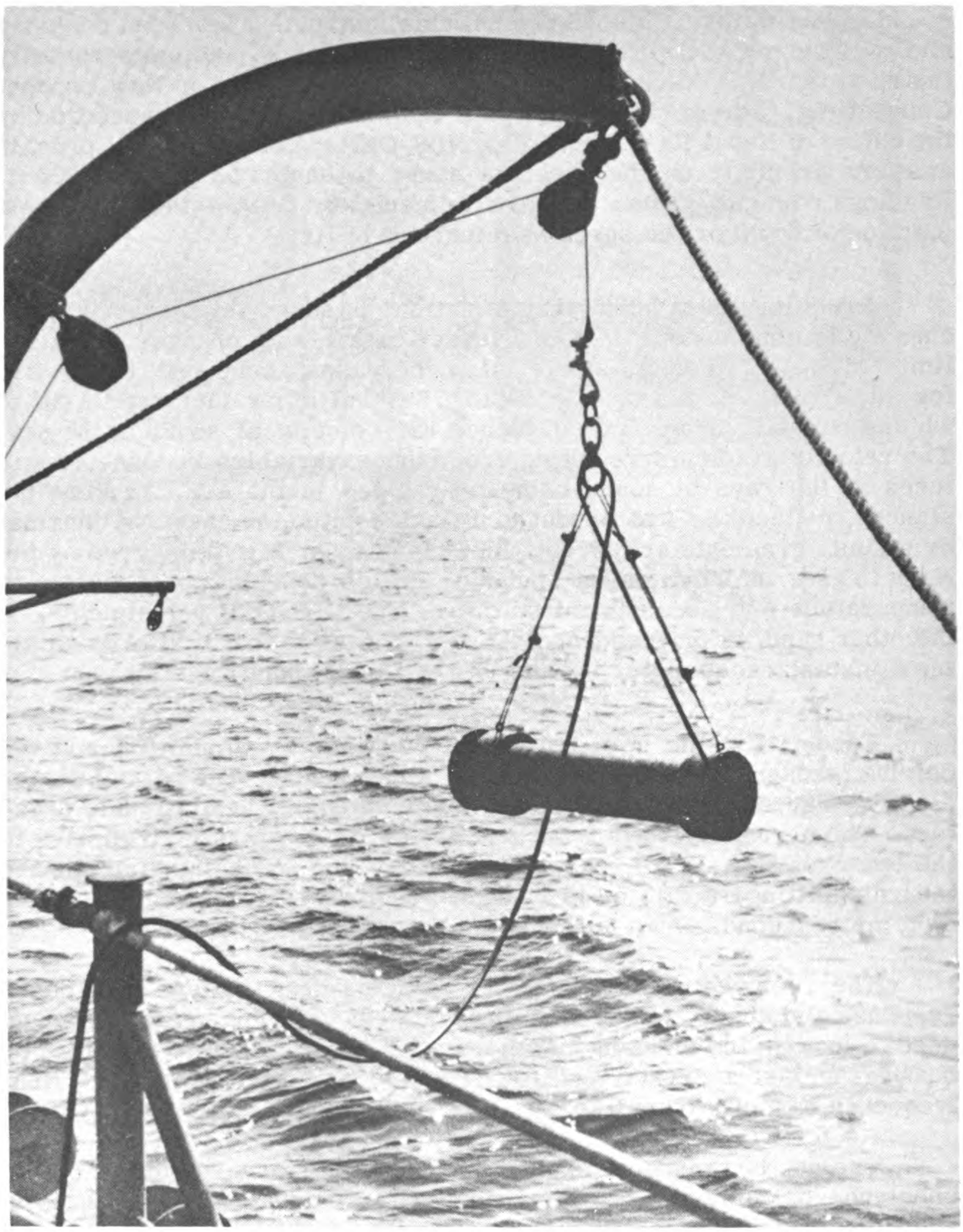


Figure 2 - NBS-ONR Velocimeter in use at sea.

Mark II was one of five sound velocity meters tested. A report of the U. S. Navy Underwater Sound Laboratory—dated 3 August 1955—concluded that of all the instruments studied, the velocimeter could be adapted for naval use with the least amount of redesign and development.

Other performance tests (Figure 2) were held on Chesapeake Bay with the instrument demonstrating its ability to plot water temperature and salinity against the depth of the water in the Bay. Because of its high accuracy and almost instantaneous response, the velocimeter is expected to be a useful addition to underwater signalling and detecting apparatus. It should also prove to be a valuable research instrument in oceanography.

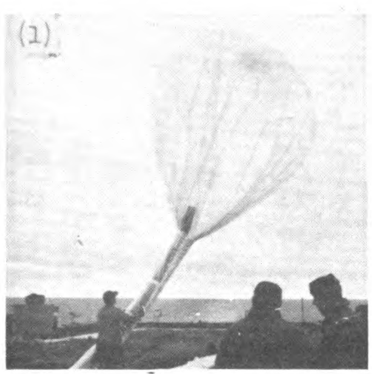
Balloon-Supported Rockets Launched

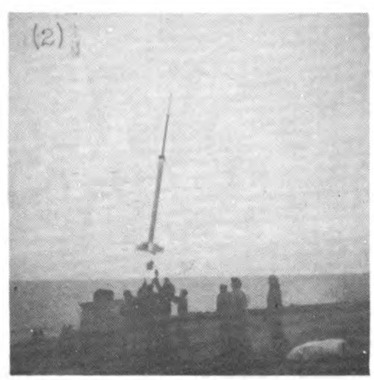
As a preliminary to upper atmosphere research to be conducted during the International Geophysical year (IGY), the Navy is launching 10 balloon-supported rockets or "rockoons" from shipboard some 200 to 400 miles west of San Diego. The IGY is a major international scientific effort covering many fields of investigation, and scheduled to run from 1 July 1957 through 31 December 1958.

The purpose of the launchings of the Rockoons is to investigate the affect of solar disturbances, including solar "storms" or flares on the electromagnet radiations from the sun which in turn effect radio communications. The program is under the direction of Dr. Herbert Friedman of the Naval Research Laboratory.

Plastic balloons 68 ft in diameter, supporting 12-ft-long rockets carrying an instrument payload of 20 lb, are being utilized for the investigations. This rocket-balloon combination floats above the ocean until a solar flare is observed. Then a radio signal from a transmitter aboard the ship fires the rocket. In the next 90 sec to two min, the rockets reach altitudes of perhaps 60 to 70 miles within the ionosphere and radios back to the observing station aboard the ship data on the strength of X-ray and ultra-violet radiations from the flare.

Rockets and rocket-balloon combinations have been used by United States scientists during the past ten years to add to man's store of knowledge about the upper atmosphere. An extensive program using rockets and rocket-balloon combinations is planned as a part of the United States' participation in the IGY. The overall program for the IGY is sponsored by the U.S. National Committee for the IGY of the National Academy of Sciences and by the National Science Foundation.





Sequence of Rockoon take-off from shipboard: (1) Balloon starts ascent and (2) lifts rocket to start long upward flight.

On the Naval Research Reserve

The Office of the Special Assistant (Research Reserve) missed a deadline last month. The report of the First Annual Seminar in Aviation Medicine held at Pensacola, Florida, should have made the July issue. Our apologies to LCDR Henry Imus and to the Naval Air Training Command and the Naval School of Aviation Medicine whose joint contributions made the seminar possible. Herewith are reports on two of the three seminars held in May and June:

Research Reserve Seminar in Aviation Medicine

This seminar, the first in its field for the Research Reserve, convened on 14 May 1956, with thirty-five reserve officers in attendance (Figure 1). Its purpose was to afford to members of the program an opportunity to see and hear about the research going on in and under contract to the Navy, and its applications to the practical problems of modern flight.

The response of the participants testifies to the general excellence of the lectures and demonstrations. As an indication of the scope of the presentations, they included the physics and physiology of high-speed, high-altitude flight, the effects of radial and linear acceleration and deceleration, and the problems of high-intensity noise.

Among the demonstrations, the most memorable perhaps was a day observing flight operations on board the USS SAIPAN (CVL-48) (Figure 2). Others included bail-out procedures and the landing trainer at Whiting Field, helicopter operations at Ellyson Field, and the "Dilbert Dunker" at the Survival Unit, Naval Air Training Command.

The members of the Research Reserve are indebted for this seminar, to a greater degree than any other, to the efforts of one man. LCDR Henry Imus, MSC, USNR, Skipper of Naval Reserve Research Company 5-10, Bethesda, Maryland, conceived the idea, worked out the

Figure 1 - Reserve Officers at Seminar in Pensacola, Fla.

agenda, obtained approval from the Commanding Officer, U. S. Naval School of Aviation Medicine, the Chief of Naval Air Training, the Chief of the Bureau of Medicine and Surgery, the Chief of Naval Research and the Chief of Naval Personnel, coordinated the preparatory work, and served as chairman of the seminar.

The seminar, of course, would not have been possible without the wholehearted support of the Commanding Officer and staff of the School of Aviation Medicine and the personnel and facilities of the Naval Air Training Command. It is a major addition to the growing list of Research Reserve Seminars.

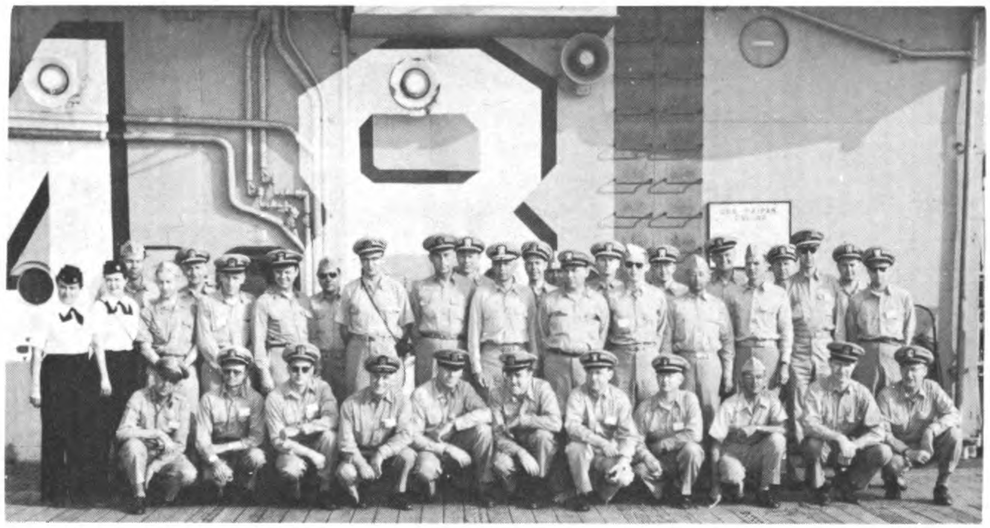


Figure 2 - Reserve Officers at Seminar on Naval Aviation Medicine visit the USS SAIPAN.

Nuclear Sciences Seminar Presented at Brookhaven National Laboratory

The Naval Research Reserve in conjunction with The Atomic Energy Commission and the Brookhaven National Laboratory presented the Fourth Annual Nuclear Sciences Seminar at the Brookhaven National Laboratory, 3-17 June 1956. The seminar, attended by seventy-five Naval Reserve Officers, was planned and directed by Naval Reserve Research Company 3-9.

The two-week course, although oriented toward the life sciences, biology and medicine, provided an opportunity for those officers with other interests to meet with senior staff members of the Laboratory to discuss matters related to their particular fields. The interest shown in this on-the-job type of training indicates that such instruction within the framework of a seminar program can provide much specific information of value to the participants.

The program was opened with a message of welcome by CDR John S. Medd, USNR, Commanding Officer of Naval Reserve Research Company 3-9. After receiving greetings from the Chief of Naval Research and the Commandant, Third Naval District, the group heard Mr. E. L. VanHorn, Manager of the Brookhaven Area, Atomic Energy Commission, on "The Mission of the Atomic Energy Commission"; Dr. L. J. Haworth, Director of the Brookhaven National Laboratory, continued the program with "The Associated Universities, Inc., and the Brookhaven Laboratory."

Figure 3 - Group which visited Grumman Aircraft Engineering Corp.

As at previous seminars, the participants were afforded the opportunity to visit the specialized facilities of the Brookhaven Laboratory. A group split off during the course of the seminar and visited the plant of the nearby Grumman Aircraft Engineering Corp. at Bethpage, L. I. (Figure 3). The wide scope of the training presented is illustrated by the following list of topics from among those comprising the complete program:

A Review of Nuclear Physics
Tracers in Organic and Biochemical Research
The Interaction of Radiation with Matter
Meteorological Aspects of Fallout Prediction
Radiation Genetics
  Physiological Effects in the Mammal
  Biochemical Effects in the Mammal
Fallout Countermeasures for Industrial Facilities
Radiation Exposure Limits
Personnel Monitoring Instruments and Procedures
Radiation Survey Techniques
Isotopes in Research
Pharmacology and Radiation
Neutron Capture Therapy
Carbon-14 in Metabolism Studies
Iodine Isotopes in Medical Research
Isotopes in Studies on Hypertension
Gallium in Research Therapy
Effects of Radiation on the Immune Response
Pathology of Ionizing Radiation
Diagnosis and Treatment of Acute Radiation Illness
Handling of Mass Casualties
The Internal Radiation Hazard
Permissible Doses and Calculated Risks

U. S. GOVERNMENT PRINTING OFFICE : 1956 O - 393771

Officers in attendance at Brookhaven National Laboratory Seminar.

In This Issue

COVER PHOTO: VADM Harold G. Bowen became the first Chief of Naval Research on 1 August ten years ago. He brought to this new post a wealth of naval experience as well as years of intimate, first-hand association with military research and development. The energetic development of radar at the Naval Research Laboratory during the critical years immediately before World War II was under the guidance of the then RADM Bowen, USN.

RESEARCH REVIEWS endeavors to report briefly highlights of technical progress in research by Navy laboratories and contractors and the development of important naval research facilities. Articles which meet these broad criteria and possess a good degree of readability are welcomed. Manuscripts and changes of address should be sent to Code 740, Office of Naval Research, Washington, D. C. . . . Research Reviews is listed for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. Subscription price: $1.50 per year in U. S. and Canada; $2.00 per year, foreign; $.15 per individual copy.

Approved by Bureau of the Budget, 28 February 1955