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RESEARCH REVIEWS

Anniversary Issue

DEPARTMENT OF THE NAVY

WASHINGTON, D. C.

From the Chief of Naval Research

ONR is the focal point of a network that carries heavy traffic in ideas. Scientific concepts, engineering terms, and needs of the Fleet meet and react with one another in our offices. An organization so immersed in the complex of modern science and technology should forsake the language of the specialist at times to speak of its work in general terms.

Research Reviews was begun 9 years ago to meet this need. It is written for a wide and diverse audience: The immediate family of ONR and its laboratories; the engineer and administrator in bureaus, offices, and laboratories throughout the Navy Department; our contractors; and the officers and men of the Fleet.

The Navy has many technical publications to convey information from specialist to specialist, and from specialist to user, within a given field. Research Reviews is unique. Its purpose is to create awareness, and through awareness, understanding, of the Naval research program as a whole. This has called for a determined effort to present articles that will be welcomed and understood by readers in hundreds of different specialties who, on a professional level, "don't speak the same language."

This has been a criterion for Research Reviews during these 9 years. Its articles by contractors and by ONR and other Navy personnel have often created interest beyond the Navy and the scientific community. Many have formed the basis for broader press coverage of ONR's work by science writers who read Research Reviews regularly.

Since this is the Decennial Year of ONR, and 8 February the date of our Decennial Banquet, this issue consists of articles that represent highlights of its 9 years of publication. It is a cross section of Research Reviews—which is a cross section of Naval research.

R. Bennett

R. BENNETT
Rear Admiral, USN

Eleven of the fourteen articles that appear in this anniversary number of Research Reviews were selected by ONR's seven scientific divisions from the 108 issues published since the magazine was launched in January 1948. The other three--"The First Chief of Naval Research," "History of the Research Reserve" and "Before Vanguard"--were written specially for this issue. In a small way these articles suggest the scope and diversity of the basic and applied research sponsored by our Navy since World War II.

The First Chief of Naval Research

VADM Harold G. Bowen—no "mossback"—had been a stormy Engineer-in-Chief (1935-39), a dynamic Director of NRL (1939-41), and, during World War II, Secretary of the Navy Forrestal's right hand for plant seizure and operation. Whether in the midst of the fight for high-pressure-high temperature steam, or fostering radar and atomic-energy research, or settling labor disputes, he was a man who got things done. But he was also a thinker, a man who found time to consider deeply fundamental Naval problems and to come up with realistic solutions.

One thing that bothered Admiral Bowen was patents. The Naval bureaus had had a past history, in some important instances, of letting Navy inventions slip through their fingers into commercial hands. By the 'thirties the Department had a Patent Section, but it did not cover adequately the field activities. At NRL, Bowen set up a rigid patent-protection procedure and established a local patent office. He also took steps to remove the slight taint of "commercialism" that had formerly discouraged civil servants from obtaining patents.

While Admiral Bowen was Director of NRL he thought a great deal about the need for a high command to coordinate and direct the total research effort of the Navy. He reiterated his idea whenever a person of influence would listen. Consequently, when the Office of Patents and Inventions was established in October 1944—according to recommendations contained in the Dearborn Report (Mr. R. J. Dearborn, President of the Texaco Development Corporation and Chairman of the Committee on Patents of the National Association of Manufacturers, made a survey of the patent situation in the Navy at the request of Secretary Forrestal)—Admiral Bowen was ordered to take command. A thorough revamping of the Navy patent system and a multimillion dollar saving in royalty payments followed.

The recommendations of the Dearborn Report were extended further on 19 May 1945 with the establishment of the Office of Research and Inventions. This new bureau-level office embraced not only the Office of Patents and Inventions, but the Secretary's old Office of Research and Development, the Naval Research Laboratory, and the Bureau of Aeronautics' Special Devices Center. A directive of February 1946 allowed ORI to assume coordination of Naval research contracts granted by the various bureaus. Admiral Bowen was the first Chief of the Office.

ORI was established by a directive of the Secretary of the Navy. Although the directive was later confirmed by an Executive Order of the President, the Office still lacked the permanence of a legally constituted body. This was taken care of on 1 August 1946 by Public Law 588 of the 79th Congress, which created the Office of Naval Research within the Navy Department. Its head became the Chief of Naval Research.

Admiral Bowen, in his autobiography, mentions the following as being among the men who helped most in bringing ONR into being: Mr. Dearborn; RADM Lewis L. Strauss, now Chairman of the Atomic Energy Commission; the Honorable H. Struve Hensel, Assistant Secretary of the Navy under Mr. Forrestal; and RADM Luis de Florez, who brought the Special Devices Division (and its $24,650,000 in contracts) into the organization. Great credit is also given to Dr. Alan T. Waterman, now Director of the National Science Foundation, who was ONR's first Science Director.

That's how ONR got underway. Today, after a decade of successful operation, the main office in Washington directs the spending of $55,941,000 annually (fiscal year 1957) for research. Nearly half of the funds support research and development at ONR's own Naval Research Laboratory, Washington, D. C.; Naval Training Device Center, Sands Point, Long Island, New York; Underwater Sound Reference Laboratory, Orlando, Florida; and Naval Biological Laboratory, Oakland, California. The balance of the money is applied to 1,500 research contracts with colleges and universities, industrial laboratories, and government experimental facilities. The contracts are monitored by ONR branch offices in New York, Boston, Chicago, San Francisco, and Pasadena. In addition, an information-exchange and liaison office is maintained in London.

Thinking Abilities

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One of the most critical problems of any organization is how to select an individual whose mental qualifications fit the needs of a specific position. Probably the most-needed people, as well as the most difficult to find, are those who can think effectively. How to identify individuals with potentialities for distinguished thinking, how to develop or improve their talents, and how to use them most effectively, are problems which have faced psychologists for some time. But before we can answer any of these questions, we must know more about the nature of thinking procedures, how they develop, and how they are used in practical situations. In other words, some basic research must be done.

In the past, the psychologist's answer has usually been summed up in one concept of "intelligence." Individuals whose thinking one should expect to be of a high calibre and great effectiveness could be selected by means of intelligence tests. A high IQ was regarded as the answer to the problem of the prediction of genius. The observing layman, however, has had good reason to doubt this simple solution. He has been aware of the fact that the person with high IQ does not necessarily show good judgment or common sense, nor does he necessarily make a good leader or a good inventor or planner. On the other hand, some persons with not particularly high IQ may show superiority in one or more of these directions.

The layman's skepticism of the IQ as the answer to all talent problems is now recognized by many psychologists to be based on good reason. The IQ tests were designed to predict which children will excel, and which ones will not, in school learning, and this means school learning of the bookish type. IQ tests are most heavily loaded with questions testing the ability to know and to understand words. It is rapidly becoming recognized that man has many talents, not just one, and that while IQ tests are very useful as far as they go, we must go well beyond them if we are to assess all the useful talents of individuals.

It was first recognized that there are many non-intellectual abilities that are not touched by IQ tests and yet that are important in many vocations, such as clerical, mechanical, and other relatively non-verbal pursuits. It is just now being realized that even in the area of intellect there are many aspects that have not been given sufficient weight in IQ tests. Intelligence has often been defined as the ability to think, but intelligence tests have not stressed thinking as much as they should. It has been discovered that there are a number of thinking abilities, not just one.

We know that this is true because of certain experimental facts. We know that two individuals of equal age and education, and perhaps of equal IQ, are not equally capable of solving different kinds of problems. One person may find problems of type A very easy and he does them rapidly and accurately, but he finds problems of type B very difficult. Another person finds the relative difficulties with these two types of problems to be in the reverse order. Still a third person may solve them both equally well. If this is true for a population of individuals, the correlation between scores on two tests, one composed of type-A problems and the other of type-B problems, would be close to zero. We conclude that there are two different thinking abilities involved. This illustration can be extended more generally. Some thinking tests have high correlation (persons who score high in one tend to score high in the other), some have intermediate correlation, and some have none whatever.

Factor analysis is a complicated statistical method used to determine from correlations of test scores what the underlying abilities or factors are. Research in the Army Air Force during World War II showed at least 25 distinct abilities in the classification tests they had developed. Only a few of these were intellectual, including verbal comprehension, associative memory, visual memory, visualization, judgment, and the like. Some of the non-intellectual ones were spatial orientation, perceptual speed, psychomotor coordination, psychomotor precision, and psychomotor speed. Some of the abilities were found to be more important in the training of a pilot and others in the training of a navigator, while others were important in the training of both. These discoveries made possible a more rational approach to the procedures of selection and classification of different kinds of personnel.

In the Air Force results were indications of several possibly important factors in the area of thinking abilities, but the conclusions concerning them were not very decisive. Since the war, there has been undertaken at the University of Southern California some intensive research on thinking abilities, under contract with the Office of Naval Research.* This research was begun more than three years ago under the title of "Aptitudes of High-Level Personnel." The "high-level" personnel studied were research scientists, inventors, and supervisory and administrative personnel, both civilian and military. To simplify our approach to the problem, we arbitrarily divided the entire area of thinking abilities into four more manageable sub-areas. These were designated as the domains of reasoning abilities, creative-thinking abilities, evaluative abilities, including judgment, and planning abilities. At the time this article was written, two factor analyses had been made in the domain of reasoning abilities, one in the domain of creative abilities, and one in the domain of evaluative abilities. Underway is an analytical study of planning abilities as well as a more comprehensive study cutting across the domains of reasoning, creativity, and evaluation. There have also been some preliminary attempts to relate the factors discovered to the performance of research scientists, engineers, and military officers.

I shall report here only some of the more significant conclusions indicated by the results of the project thus far. In fairness to earlier investigators, it should be said that not all of these findings are entirely new. It is the first time, however, that the area of thinking abilities has been investigated so extensively and intensively, and many of the findings are definitely new.

*Those chiefly associated with the writer in this research project, in alphabetical order, are: Raymond M. Berger, Paul R. Christensen, Andrew L. Comrey, Russel F. Green, Alfred F. Hertzka, Norman W. Kettner, Gordon Taaffe, and Robert C. Wilson.

One of the important aspects of reasoning has to do with relationships. The individual sees relationships, he uses relationships, and he tests relationships. There seem to be at least three abilities that have to do with grasping or comprehending relations between things or ideas. One ability involves perceiving relationships between things we see and another involves perceiving relationships between ideas. This distinction seems to indicate a difference between good "concrete" thinkers and good "abstract" thinkers. Just how far-reaching this difference may be is still to be determined. The tests that bring out these factors in reasoning involve rather simple relationships. When there is a system of relationships, or a pattern of ideas to be grasped, we find still another ability involved. Thus, the power to have elaborate and intricate conceptions may be a unique ability.*

We use relationships in the solution of problems. In a broad sense, problems are of many kinds. Let us restrict ourselves for the moment to the kind commonly known as arithmetic-reasoning problems. These are encountered quite generally in scientific and technical work. There is a unique ability for handling this type of problem, but it has been very difficult to pinpoint the particular aspect of such problem solving that has most to do with the factor involved. In solving such a problem there are many steps. One must first understand the problem. One must think of possible steps needed in its solution. One must be able to select the most promising steps and to reject the others. More specifically, in the strictly arithmetic-reasoning problem (to which the factor is not confined), one must decide what numerical operations are required. The actual computing processes, we know, are dependent upon another factor, the facility with numbers. Our present efforts are directed toward determining more exactly what unique thinking ability the arithmetic-reasoning problem entails.

The term "reasoning" may suggest to some readers the process of drawing inferences or logical conclusions. Analysis shows that there is a distinct factor or ability connected with logical conclusions drawn from premises. We are not certain which of two aspects of this operation is more important for the interpretation of the factor; whether it is an ability to draw logical conclusions or whether it is an ability to evaluate conclusions from the standpoint of logical necessity after they have been drawn. The evidence on this point is inconclusive, at present, but the factor has been tentatively defined as sensitivity to logical necessity. This emphasizes the second aspect, the ability to evaluate the logical correctness of conclusions.

There is another ability having to do with the drawing of conclusions, but not conclusions strictly of the logical type. The conclusions in this case are drawn to complete an analogy. The good test of this ability presupposes that the relationship involved in an item has been easily grasped. For example, the item might be "Automobile is to highway as aircraft is to ________." An acceptable response might be "air," or "skyway," or "runway." The main task is the fulfillment of a relation.

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*Space does not permit describing tests which would give more substance to the names of factors. In a few instances, however, tests will be briefly characterized.

Still another factor in the domain of reasoning has to do with the use of symbols. Assigning symbols to stand for ideas and then manipulating the symbols to come out with answers seems to offer a unique task. This is the kind of activity required in mathematics and in symbolic logic. It may be that this is an acquired ability dependent upon the study of algebra and other mathematics. Whatever it is, this is an ability in which individuals differ, and it is distinct from other abilities.

In the domain of creativity we find some quite different types of abilities. This statement should not be interpreted to mean that none of the reasoning factors mentioned previously play a part in creative work, for many of them undoubtedly do. The circumscription of the domain of creative abilities is an arbitrary one for the purposes of investigation. It will be recognized, however, that an individual may have a high degree of almost any of the abilities mentioned above without becoming a creative thinker, such as a theoretical scientist, inventor, or creative artist or engineer.

It was hypothesized, first of all, that the person who is recognized as creative is likely to be more sensitive than most to the existence of problems. He is the questioning person with unusual readiness to spot the unusual, the defective, and the deficient. Analysis shows that people do differ systematically with respect to seeing that problems exist, either in common gadgets like the telephone and the refrigerator or in social institutions such as education or divorce laws. It may be that this is neither a necessary nor a sufficient condition for making a creative individual, but it is expected that a high degree of this ability will be one predisposing condition.

It was expected that, everything else being equal, the creative person can produce more ideas per unit of time than the non-creative person. Study was therefore made of the differences between individuals with respect to fluency of thought. Two factors that may have relationship to different kinds of creative production were found. One has to do with the facility for calling up words to meet specified requirements of meaning (for example, naming words that mean the same or that mean the opposite). This kind of fluency probably has relationship to creative writing. Another fluency factor concerns the rapid flow of ideas to fulfill a specified need. This can be assessed in individuals by a simple test like asking them to name, in eight minutes, all the uses they can for a common brick. Another simple test of this ability asks individuals to name the consequences of some hypothetical change such as everybody suddenly going blind.

The creative thinker should be a flexible thinker. He should not get into ruts but should readily strike out in new directions. Analysis shows two distinct factors that look like types of flexibility. One kind of flexibility shows up during the solution of problems in a test where the method of solution changes drastically and frequently. The other kind shows up in a test where change in direction is not necessary but the examinee shows such changes anyway. The former we have called "adaptive flexibility" and the latter "spontaneous flexibility." Adaptive flexibility is probably very important for the theoretical scientist, who must be ever alert to the need for new types of solutions and ideas. Spontaneous flexibility should be important for certain kinds of writers and for pun makers. Too much of this trait would probably be a handicap to anyone who must do much goal-directed thinking as in problem solving.

The trait most commonly associated with creativity is that of originality, the ability to have novel ideas. It was hypothesized that this trait exists in graduated amounts in different individuals. Objective signs of it might be found in the tendency of an individual to give uncommon responses to test items. In one type of test, frequency counts were made of every response made to every item in a group of about 400 young men. Every response was then given a weight in proportion to its rarity of occurrence in this population. In another type of test, the examinee must see connections between remotely related ideas. For example, in listing consequences to the event of everyone going blind, some responses are in the form of immediate or obvious effects while others are more remote in time or in sequence of events. The number of the remote type given was taken as a score for originality. A third type of measure attempted was to score responses weighted according to degree of cleverness exhibited. The responses were titles the examinee suggested for short stories. Factor analysis shows a unitary ability or trait of originality. It also shows that the three methods of testing are about equally effective for measuring it.

The examples given of factors in the domains of reasoning and creative thinking are perhaps sufficient to demonstrate the rich variety that exists among thinking abilities. There are also factors in the domain of evaluation and judgment. It is possible that factors of reasoning, creativity, and evaluation will account for much of the difference between individuals in planning performance, but the investigation of that domain will provide opportunity for the discovery of unique abilities if there are any.

Some of the implications of finding quite a number of thinking factors may be pointed out. It is not certain that these abilities are completely independent or uncorrelated, but they are distinct and in time will be better defined. The question "How well can this person think?" should be asked with respect to each of the factors, for it should be expected that individuals will be uneven in their thinking abilities. It is the rare person who excels in all of them. It is even possible to find a few very weak abilities combined with a number of strong ones in the same individual.

The kind of thinking performance we should expect of a person will depend upon the pattern of his strong and weak points. It will also depend upon his motivation and his temperament, which we have intentionally left out of our investigations. Where individuals can work in teams, as in group-research projects, certain strengths in some of them can compensate for weaknesses in others. In terms of team performance, it would be well to see that every necessary trait is covered by strength in at least some of the members.

As to long-range benefits, the first important consequence of discovery of unitary abilities in the general area of thinking is that we are provided with a new set of descriptive concepts. The first need in predicting and controlling events in any field is for workable and dependable concepts. How well the factor names contribute to the understanding of thinking processes remains to be seen. The indications are that some gain has been made in this direction.

Down-to-Earth View of Space Flight

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In many respects, the rocket capitol of the United States is White Sands Proving Ground, N. M. Here, in the 40-mile-wide basin between the San Andres and Sacramento mountains, rocket vehicles designed and built in widely different parts of the country are tested and fired. This is where the Viking established a record altitude for single-stage miles, the highest altitude reached by a man-made vehicle. Among the rocket technicians who meet and discuss their work there is a saying: "You have either just had trouble, or you are now having trouble, or you are about to have trouble." A few successful flights have received wide publicity, but the public seldom learns about the many rockets which do not fulfill predictions. Nor is it explained that great odds were overcome to produce a record flight—a flight that would have been prevented by the failure of one component in several thousand. In a rocket everything must work. This realization leads to a down-to-earth attitude toward space travel.

Why is it so difficult to go much higher than we have been? It is because the engineers have caught up with the scientists and have almost exhausted our store of basic knowledge. The time lag between the discovery of a new material, technique, or principle and its utilization has become increasingly short. The public has come to expect a constant flow of products, each more wonderful than its predecessor. But the engineer who has always drawn his ingredients from the cupboard of basic research now finds that the cupboard is bare. He must wait for new ingredients.

This is why plans for space travel and designs for space ships are based on a meagre store of scientific knowledge and a large amount of speculation. Of course there is a place for speculation if it is clearly labelled "speculation" and if its purpose is to stimulate interest in the subject. But a great deal of harm would probably be done to this country's defense effort and to the cause of space flight itself if the United States were to undertake any of the fantastic projects for a space ship that have been proposed in the last few years.

We can illustrate the difference between the speculative and the scientific approaches to space travel by imagining two scientists, whom we shall call "Scientist A," and "Scientist B." Scientist A is holding up a ladder which extends far into the sky. A typical American, whom we shall call "Taxpayer," approaches and engages him in conversation.

Taxpayer: "What are you doing with that ladder?"

Scientist A: "Do you see that light high in the sky? That light is called space travel and I intend to climb this ladder to reach it."

Taxpayer: "I notice that many of the rungs are missing."

*Dr. Rosen is now Technical Director for Project VANGUARD.

Scientist A:	"Don't worry about that - I will supply the missing rungs as I climb.
Taxpayer:	"But how will you balance yourself?"
Scientist A:	"I will climb so fast that I will reach the top before the ladder topples. Then I will hang from the light and I won't need the ladder any more."
Taxpayer:	"Well, let's see you climb it."
Scientist A:	"I forgot to tell you - I need ten billion dollars before I can start."

And before Scientist A can finish that sentence, the taxpayer has disappeared. Now we see Scientist B, who is building an immense pyramid, block by block. Construction is not far advanced and the highest block is only a few yards above the ground. The taxpayer approaches.

Taxpayer:	"What are you doing?"
Scientist B:	"Do you see that light ---- ?"
Taxpayer:	"Your friend, Scientist A, told me about it. Are you trying to reach it? Is that why you are building the pyramid?"
Scientist B:	"Yes ---- and it's very hard work. Sometimes I have to search all day to find one block, and when I need one of a particular size and shape, it may take weeks or months to find it."
Taxpayer:	"Are you going to ask me for ten billion dollars?"
Scientist B:	"Heavens no! I wouldn't know what to do with that much money. But I could use a few million dollars for modern equipment. You see, as the pyramid grows higher, it becomes increasingly difficult to lift the blocks."
Taxpayer:	"I can't see any return for that investment. Your progress is too slow. I will be gone and forgotten before you get close to space travel. But don't be discouraged. If you ever get to the place where you need only a dozen more blocks, I will buy that dozen!"

Where do we stand today with respect to space travel? To answer this question let us consider the feasibility of building a manned earth-returnable rocket on the basis of what we have done, rather than what we think we can do. A manned earth-returnable rocket is a vehicle which carries one or more human beings as passengers, and which includes provisions for ensuring the safe return of these passengers to the earth's surface. It is not considered essential that the vehicle itself return in a useable form.

Altitude is the primary factor in any consideration of the feasibility of a manned earth-returnable rocket. Two altitudes, 15 miles and 50 miles, are significant because they define the boundaries of three regions that can be considered separately. These are the regions between the ground and 15 miles, where feasibility has actually been demonstrated, the region between 15 and 50 miles, where feasibility can be shown, and

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the region above 50 miles, where a decision on feasibility is not possible today.

According to recent unofficial but reliable reports, a Douglas Skyrocket has reached an altitude of 15 miles and its pilot has returned safely to the earth's surface. For an altitude of 15 miles, then, feasibility has actually been demonstrated.

Feasibility can be shown for a manned earth-returnable rocket that reaches an altitude of between 15 and 50 miles, even though no human has ever reached these heights. Rockets have been built which can ascend 50 miles and which can carry the necessary payload involved in transporting a human being. The significance of the 50-mile height is that parachute recovery has been successful only below this altitude. Entire Wac Corporal rockets and instrument sections from Aerobees have been recovered by parachute from altitudes up to 50 miles. Moreover, the accelerations encountered on the powered ascent are within the tolerance limit of human beings and the maximum velocity is sufficiently low so that, for a vertical ascent, the vehicle skin temperature will not tax the capacity of known materials and techniques of construction. The most important feature of a flight to less than 50 miles is that its duration will be brief—a matter of several minutes. For this reason, many of the difficult problems that would be involved in higher flights (effects of cosmic and solar radiation, meteor collisions, free fall in a vacuum, etc.) will be ignored. Moreover, because the flight will be so short, it will not be necessary to make elaborate provision for the necessities of life: Food, oxygen, elimination of wastes, and maintenance of ambient temperature.

The most important problem in this region will be one of reliability of the rocket, for on this depends the man's chance for survival. The concept of reliability must enter into the design of every component, sub-assembly, and operating system of the vehicle. The factors of safety here are entirely different from those presently used in the design of sounding rockets. The probability of returning a man safely 99 times out of 100 is a very much smaller number than the probability of a safe return 1 time in 100.

Above 50 miles the situation is entirely different. Attempts at parachute recovery of instruments have not been successful. Depending upon the altitude to be reached, the accelerations could be beyond human tolerance limits and vehicle skin temperatures above the melting points of available materials. The Viking rocket, which reached an altitude of 136 miles, could have carried a man, but no one could have insured his safe return. In fact no one could even have calculated the probability of his survival; there are too many "unknowns" at this stage of the game. For example, if the duration of the flight is long, the effects of cosmic and solar radiations must be considered—a difficult problem, since the nature and quantity of these radiations in outer space have not been fully determined and we are only beginning to study their effects on living cells. Another risk hard to assess is the probability of meteor collisions; although this hazard has been estimated and various schemes proposed for eliminating it, none have ever been tested.

Besides these "unknown" difficulties there are some which are very easy to predict, though they are not so easy to solve. For example, in a long flight elaborate equipment requiring a continuous power source will be necessary to provide the human passenger with the necessities of life. Such equipment, as well as that needed for guiding the vehicle, will have to be automatic in operation because the long flight would probably impose terrific physical and physiological strains on the passenger. Thus, many machines will have to perform a great diversity of functions with precision. A tremendous amount of investigation, measurement, and test will have to be conducted before one can assess the magnitude or importance of most of the problems involved. At present, we cannot even estimate the feasibility of building a successful manned rocket because of insufficient information.

If we cannot build a space ship today, what can we do to advance the cause of space travel? The answer is that we can discover the ingredients for future engineering and thus replenish the cupboard of basic research. Before we can attempt to transport human beings in a ship that orbits around the earth, we must produce a practical, reliable, unmanned satellite. To do this we need better, more efficient rocket power plants, and unfortunately our progress in recent years has been slow. Anyone who can operate a few machine tools can build a rocket motor and make it work; it is one of the simplest engines for converting chemical energy into mechanical energy. But no one fully understands the theory of combustion in a rocket motor—one reason why every rocket manufacturer in the country is having difficulty in improving his product. We need more research on fuels, on high-temperature metals and ceramics, and on novel methods for cooling the inner walls of rocket motors and the outer skins of high-speed airframes. Finally, we need more and better sounding rockets—rockets which can ascend far above the pedestrian altitudes thus far achieved. Sounding rockets are our best laboratories for space flight research. They are, indeed, the predecessors of future space ships, but they are remote, not immediate ancestors.

Atomic energy has been envisioned as an almost limitless power source for the propulsion of a rocket. The application is important, but its value has been overestimated, for some limitations of present-day rockets still apply. For example, there is a practical limit on the temperature at which a rocket motor can operate, and it matters little whether the heat has been generated by nuclear or molecular reactions. All rockets are propelled by the ejection of matter, and our atomic rocket, like our present rockets, will have to carry a working fluid. The major gain to be achieved from the use of a nuclear power plant lies in the fact that this fluid can have lower molecular weight than the exhaust gases of a chemical combustion. But there are also disadvantages involved in the use of nuclear-powered rockets—for example the danger to instruments and personnel from damaging radiation. Despite such difficulties, the potential use of nuclear power for the propulsion of rockets cannot be ignored. Before we construct the first atomic-powered rocket vehicle, however, we must investigate the uses of nuclear rocket power in the laboratory and in the test pit.

Hand-in-hand with rocket power gains must come progress in the field of electronics. The navigation of a space ship, communication between the ship and earth, and automatic control of the complex equipment necessary for human survival in outer space pose tremendous problems for the electronics scientist.

I will not attempt to list or classify the many other investigations that evolve from our desire to send a human being into outer space—for example, research that falls into the category of human engineering. Many such problems and a few of the answers have been ably presented by Dr. Haber.* This type of research can proceed, in fact, must proceed, concurrently with vehicle development if we contemplate human travel in outer space. Herein lie many years of research for the biologist, physiologist, and psychologist. In this connection, when asked what fields of scientific endeavor are embraced by the subject of space travel, a co-worker of mine replied, "It would be easier to name the fields that are not required." When pressed further he was unable to name any field of science that could be eliminated categorically.

Thus far, research contributing to space travel has been accomplished as a byproduct of other projects—largely military. A better rocket motor is a better rocket motor whether it is intended for a guided missile or for a sounding rocket. Conversely, many investigations which further space travel have been supported because they also contribute to our national defense. The time has come, I believe, for someone or some group to assess clearly the problems involved in space flight and to determine what we are doing and what we could do to make further progress. Such a group should consist of able and respected representatives of government, science, and industry and might be sponsored by the National Science Foundation.

I would commend to such a group the following procedure:

- It should make a thorough study of existing knowledge on space flight and then prepare a list of the problems which must be solved before it can be achieved. Such a list will be lengthy and far from complete.

- It should select from the list those problems which can be tackled with the techniques and tools available today.

- It should examine every project in the country which is closely allied to space flight. Many of these projects are classified for security reasons and could only be revealed to a select group.

- It should recommend to government and industry present and future support for those projects which are making a worth-while contribution to space flight.

- It should recommend the timely initiation of investigations which could yield important results in the near future.

A large share of our scientific talent is now enlisted in the effort to resist and deter foreign aggression. When some of this talent can be

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*In a paper entitled "Manned Flight at the Borders of Space" presented at the Centennial of Engineering, Chicago, September 1952.

released from the task which is so urgent today, and when the country can afford the manpower and money required, the recommendations of the proposed space-flight committee would constitute a practicable program to support work.

Now comes the question—why do it at all? This country should not and, I feel confident, cannot be frightened into attempting spaceflight before it is technically feasible. The alleged military value of a space ship is as speculative as today's space-ship designs. Moreover, we can only speculate about the material benefits that might be derived from the exploration of outer space.

I am reminded of Aesop's Fable about the farmer and his sons. A farmer, being on the point of death and wishing to show his sons a way to success, called them to him and said, "My children, I am now departing from this life; but all I have to leave you, you will find in the vineyard." The sons, supposing that he referred to some hidden treasure, went to work as soon as the old man died with their spades and plows and turned up the soil over and over again. They found no treasure; but this thorough tillage yielded a firmer vintage than they had ever reaped before and more than repayed the young husbandmen for all their trouble.

Similarly with space travel: The knowledge we will have to gain, the techniques we will have to master, the machines we will have to build—these will bring more material benefit to the earth's population than any gold or uranium we may find on Mars or Venus. The value of space flight is in the doing of it.

The Navy's Stake in Underwater Acoustics*

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Since 1945, technology has permitted great strides forward in undersea warfare. More efficient hulls, new kinds of propulsion machinery, a greater knowledge of undersea conditions, and the sharp improvements in underwater communications have permitted broadening the scope of our undersea arm in addition to increasing its striking power. Undersea warfare as a naval science has come of age.

The submarine has enormous potential for carrying out a variety of missions in support of the Navy's historic role—maintaining control of the seas. Allow me to try to summarize the potential military future of the submarine by listing some of the tasks for which it is suited:

- Denying the use of the seas to the enemy by eliminating his surface navy and his merchant marine. This is the traditional role of the submarine.
- To sink enemy submarines and destroy their bases as part of the anti-submarine warfare forces.
- To act as part of the fast carrier task forces and support and protect these forces by serving as sonar-radar pickets.
- To guide and deliver guided missiles to land targets.
- Acting as part of the amphibious forces, to land saboteurs and to effect reconnaissance, to land and support troops, and to provide logistic support on our beachheads under enemy air control.
- To provide lifeguard services and air-sea rescue for our air forces, particularly in water over which the enemy has control of the air.
- To contribute to the continental air defense, as early warning radar pickets, far offshore.

This outline of possible future missions for the submarine emphasizes the growing importance of underwater acoustics research to naval operations. No other technique for the solution of many undersea warfare problems appears to offer the versatility and the over-all effectiveness of acoustics. We have already made much progress through the application of this tool to the problems of detection, tracking, fire-control, quieting, homing, navigation, and communications.

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*Condensed from an address to the Tenth Navy Symposium on Underwater Acoustics.

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The basic means of underwater communication today is sonar. Sonar devices are the eyes and ears of the submarine. In the past, sound gear has been secondary to the periscope as a means of communication for the submarine commander. In the future it will be the primary means of prosecuting an undersea attack. The success of our future submarine operations will rest to a large extent on new and more exact knowledge of the behavior of sound in seawater and the use of this knowledge in development of underwater listening equipment.

With the development of nuclear-powered submarines that can traverse the ocean without surfacing, long-range subsurface navigation is a growing problem. These submarines must have the means for navigating over long distances without ever being able to take a bearing on any celestial body or radiobeam.

Just visualize for a moment the vastness of the oceans, and try to picture the problem of the navigator. He is perhaps several hundred feet below the surface. He is out of sight of all familiar terrestrial landmarks and of the sun and stars. He has been submerged since leaving Boston Harbor or Key West several days earlier. Tomorrow or the next day he must be able to tell the captain exactly when and where to surface, in order to come up directly offshore from a tiny base in the Arctic Ocean. If the destination is an enemy target in unfamiliar waters, the job is even harder.

The submariner of the future may turn to undersea phenomena or physical features for his bearings. He may find the submerged mountain peak or the underwater canyon as comforting and reassuring as the familiar headland or lighthouse of today. There are a number of possible means for underwater navigation of submarines, and our research in underwater acoustics is playing an important role in their development. Navigation by echo sounder using the topography of the ocean floor is one promising possibility. Even today a sonarman in a submarine can pick up a reef or some other obstacle in unfamiliar or poorly charted waters.

Another set of acoustic problems extremely important to the submariner are those involved in quieting. When our submarines are on patrol, we know that the enemy will be looking for them with his own sonar, so it is extremely important to keep down their noise level, in order that they will not be betrayed by the sound of their own machinery.

As you know, keeping down the noise level of running machinery is primarily an engineering problem. But before the engineer can tackle the problem, he must have a standard. He must know exactly what machinery running at what speeds produces the noise, and beyond what point he must do something about it.

Our own Underwater Sound Reference Laboratory at Orlando, Florida has done extensive work in developing standards for acoustical measurement and standards for acoustic devices. This laboratory also offers consulting services to our contractors. Those of you who are encountering problems in this field, and did not know of this service, may be interested in taking advantage of it.

The Navy has recently set up an acoustic testing area specifically for determining machinery noise standards. The requirements for such a test area were very exacting. It had to be an area of quiet, unruffled water, relatively deep and relatively unaffected by marine life. It had to be free of noisy fishing boats or passing ships. Both the Atlantic Coast and Gulf Coast waters are too shallow, and in the warm southern waters of the Pacific, Gulf, and Atlantic Coasts there is too much interference from fish noises. However, Carr Inlet in Puget Sound proved a satisfactory site, and a 110-foot steel barge has been equipped there with the required test instruments. The first series of tests was conducted with the submarine BASHAW, which was recently converted into an experimental vessel employing the latest sound-reduction techniques. A suspended hydrophone recorded the submarine's machinery noise.

Problems connected with submarine operations comprise the largest group of undersea warfare problems. We must also be concerned, however, with others not so directly associated with submarines, but which also form an important part of undersea warfare.

Mines and torpedoes are our primary undersea weapons, and modern torpedoes use acoustic methods for homing on their targets. Acoustically activated mines are important weapons too. Countermeasures against enemy mines and torpedoes also involve underwater sound. Sonar is very versatile as a means of underwater detection, as in clearing minefields. It can be of great assistance to underwater demolition teams trying to locate obstacles in the waters off an enemy beach so they can be cleared prior to landing operations.

As a result of all these operational factors, the Navy has a big stake in underwater acoustics. We must be assured that basic research is being done in the many scientific fields which have a bearing on underwater sound, in order that our development programs can keep on devising and perfecting the equipments needed by our submarines, our escort vessels, our minesweepers, and our demolition teams.

In underwater sound, more than in almost any other scientific field, the responsibility for research designed to meet Navy needs rests with the Navy. The Navy is practically the sole user of underwater acoustic devices, so there is virtually no industrial support for this kind of research. Furthermore, because undersea warfare is a Navy responsibility, the other military services do not perform research in this area.

To maintain a truly comprehensive effort in underwater acoustics—that is, an effort that covers all the areas necessary to meet our obligations to the Fleet—involves a broad span of activities. It can probably be stated that the term "underwater acoustics" is not truly descriptive of the work the Navy supports in this field, or the physicist would have it under control. Actually, the work involves a score of different scientific disciplines. Physics, chemistry, oceanography, the material sciences, and the biological sciences are all important to our program.

The work done in these diverse areas must all be brought to bear upon the Navy's problems in the field of underwater sound. With so many scientific disciplines involved, the work is bound to require a great deal of integration. It is the responsibility of the Office of Naval Research to bring about this integration, and to see that the results of these research programs are made available for use in the development programs carried on by the Navy's material bureaus.

Experimental Tooth Decay in Gnotobiotic Rats

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As long ago as the time of Aristotle, men have been wondering about the cause of tooth decay. More than 2200 years ago, in ancient Greece, Aristotelian writings asked these simple questions:

> "Why do figs which are soft and sweet, injure the teeth? Is it because of their stickiness, that they cling to the gums and because they are soft, that they penetrate the tooth spaces and being warm, quickly cause decay? Also, perhaps because of the hardness of the seeds, the teeth, upon chewing them are soon caused to ache."

Today, in this land, even at the tender age of 2 years, 50 percent of our children have dental decay in one or more teeth. This disease is very common by the fourth year of life and is extremely prevalent thereafter, as long as the natural teeth are present in the mouth. At the age of 16, the average individual has seven teeth (involving 14 different tooth surfaces) already attacked by decay.

At this tremendous attack rate, there just are not enough dentists available in the United States, neither in civilian nor in military life, to keep up with the new dental cavities. The only feasible alternative is an extensive and intensive program of prevention. Yet to prevent tooth decay, a more complete understanding of this disease is absolutely necessary.

Currently, based on fragmentary evidence, it is surmised that dental decay (or caries, from the Latin) is caused by bacterial action on fermentable carbohydrates such as sugar. This fermentative process results in a weak acid capable of dissolving tooth structure. Whether the acid will actually disintegrate the outer covering of teeth depends on length of time of contact. Even though this outer shell of every tooth, known as the enamel, is the hardest substance the body is capable of producing, great damage can be inflicted on its inorganic salt content within 15 minutes after sugars from the food find their way into the natural crevices of the teeth. Whether the bacterial acid remains in contact with the tooth very long depends on many factors. It depends on the kind of dental plaque adhering to the tooth surface. This plaque is a mucinous, gelatin-like film which sticks firmly to enamel surfaces and acts as a shield for bacteria and their acid byproducts—so they can't be washed away by saliva. Decay may occur in a variety of locations on the tooth, although the most vulnerable areas are the natural crevices and fissures as well as the smooth surfaces in contact with adjoining teeth.

Inasmuch as action on the teeth by the microscopic creatures living around the teeth is judged to be of prime importance, a major effort was

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undertaken to study this pathological phenomenon in animals at the University of Chicago years ago. Mouth microorganisms were found to be ubiquitous, that is, they lived and grew everywhere around the teeth wherever food debris and saliva were present. Nor could these microbes be eliminated entirely, even with the most powerful and wide-spectrum antibiotics. The only practical manner in which bacteria could be eliminated from the mouths of small animals used in experimental dental-caries studies was to obtain animals actually born free of all microbes. This could be accomplished only by the use of the Reyniers Germfree System (Research Reviews, Jan. 1948).

Professor James A. Reyniers and his associates developed mechanical equipment functioning as a microbic barrier which enabled small laboratory animals to be born by cesarean section into and exist thereafter in an enclosed environment entirely free of all living microorganisms. Into such a germfree environment single known strains of microbes could be inoculated for special study. In this instance the animal is called "gnotobiotic"—"gnoto," from the Greek, refers to the known, and "bio" refers to life.

The research laboratories at the Zoller Clinic of the University of Chicago had conducted much basic work during the late 1930's and early 1940's in experimental caries occurring in the molar teeth of small mammals, while 100 miles away the Laboratories of Bacteriology at the University of Notre Dame (Lobund) were perfecting their methods of rearing germfree animals. It was only logical therefore that a research team should have been fashioned from among members of both institutions to collaborate in an intensive and extensive study of the basic mechanism of tooth decay. Members of this research team consist of James Reyniers, Philip Trexler, Robert Ervin, Morris Wagner, and Helmut Gordon from the Lobund Institute; and Wendell Harrison, Roy Blayney, and Frank Orland from the Zoller Memorial Dental Clinic.

In the first phase of the project, now completed and published (Journal of Dental Research, Vol. 33, p. 147-174, April 1954), it was possible to demonstrate that white rats when reared under controlled germfree conditions did not develop dental caries—not even on a microscopic level. In contradistinction, the conventional control rats, harboring the usual mixed microbial populations, developed carious cavities when maintained for an average of 150 days on the same kind of diet and sugar water that the germfree animals subsisted upon.

On the basis of these findings, though they were not unexpected, it is believed that this base-line study provided adequate experimental evidence to show that dental decay is not possible in the absence of microorganisms. Conversely, these findings suggested in a negative manner that microorganisms are necessary for dental caries to occur.

The second phase of the germfree animal dental-caries project is still underway, although a number of individual experiments have been completed. This second phase is concerned with inoculating otherwise germfree rats with a single known microorganism. The actions of the microorganism on the rats' molar teeth can be measured by gross and microscopic means.

The question of whether a single microorganism could actually produce typical carious lesions in the molar teeth of the gnotobiotic animal was a problematical one for a long time and this has not yet been completely clarified. Nevertheless, it was observed that under gnotobiotic conditions, rats inoculated with enterococci (a lactic acid-producing, spherical-celled bacterium) did develop caries-like cavities. Some of the early experimental animals in this phase also harbored a second microorganism which, however, appeared to be very inert in its activity. Nevertheless, the preliminary evidence suggested that these enterococci, found normally in the rat's mouth and often in the mouth of man, could initiate and develop carious lesions not very different from those observed in the conventional control animals having a mixed bacterial flora. As a preliminary report, this evidence was published (Journal of the American Dental Association, Vol. 50, p. 259-272, March 1955) and was awarded First Place in the Prize Essay Competition of the Chicago Dental Society for 1955. Further studies with enterococci and other single bacteria are contemplated.

A third phase of the project will be concerned with making changes in the diet. This could be an exceedingly important factor in altering or even entirely preventing tooth decay. The results of such dietary changes would be highly significant in the unique microbic environment of only one or possibly two known bacteria, living and acting on the molar surfaces of these otherwise germfree rats.

A fourth and final phase of this long-range basic project would be concerned with adding various inhibitory agents or substances to a stabilized ecological environment consisting of a constant caries-producing diet and a caries-producing combination of microorganisms.

It becomes apparent that the last two phases of the project might lead to practical applications useful in preventing dental decay in man on a rational rather than on an empirical level as has been the case in the past.

The Refractory Carbides

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The refractory carbides are characterized by such an unusual combination of properties that their use as the main component of special-purpose alloys has a very promising future. The carbides are refractory in that their melting points are in excess of 2500°C and they have a very high hardness which is maintained even at elevated temperatures. On the other hand, considering their refractory nature, these substances have high electrical and thermal conductivities, with values comparable to those of the normal metals.

During the last 20 years, alloys in which the carbides form the principal constituent have had considerable practical application. Yet surprisingly little is known of their fundamental nature or the reasons for their behavior under the very circumstances which make them especially useful. Compared with our knowledge of many other useful industrial alloy systems, our lack of basic understanding of these carbides is striking. There is little doubt that a systematic attack on this problem will lead to valuable new information. Such data may further the development of better cutting and forming tools, or parts which are more resistant to wear and abrasion. Or it may lead to the production of structural alloys for high-temperature service which maintain their strength at elevated temperatures while successfully withstanding the effects of oxidation and corrosion. Moreover, it is possible that through this research some of the strategic elements now employed in alloys of this type may be replaced by others more readily available. Although much has been accomplished by an essentially empirical approach to some of these problems, the need now is for a fundamental understanding of the carbides themselves.

The refractory carbides are compounds of carbon with metals of the fourth, fifth and sixth groups of the periodic system of elements—the "transition" metals. Finely divided crystals of carbide and a relatively small amount of auxiliary or binder metal are combined by the techniques of powder metallurgy into strong, hard, dense bodies, known as cemented carbides.

Elements of the fourth group—titanium, zirconium, hafnium, and thorium (Ti, Zr, Hf and Th), and the fifth group—vanadium, nobium, and tantalum (V, Nb, Ta)—form monocarbides of the MC type with a cubic structure analogous to sodium chloride. That is, the metal atoms are arranged in cubic close packing with the carbon atoms in the interstices. Tantalum, and the sixth-group elements molybdenum (Mo) and wolfram (W) form carbides of the M_2C type, in which the metal atoms are arranged in hexagonal close packing with carbon atoms in the interstices. Wolfram also forms a monocarbide, WC, but in this compound the metal atoms have a simple hexagonal arrangement rather than a cubic structure, such as the other MC-type monocarbides have. The analogous molybdenum monocarbide, MoC, apparently does not exist, at least at oridinary temperatures.

In these different (but closely related) structures, the carbon atoms are in isolated positions and are completely surrounded by metal atoms. There is probably strong metal-to-metal and metal-to-carbon bonding but very little tendency for the formation of carbon-to-carbon bonds. The factors determining these simple atomic arrangements seem to be essentially geometrical rather than chemical. Such structures are found only when the ratio of the sizes of the metal atoms to carbon atoms permits the latter to fit into the holes between the closely packed metal atoms. In the case of the chromium carbides, this ratio is unfavorable; consequently these compounds have a much more complex structure and a lower melting point than the others. This ratio, however, is not the only factor affecting the structure of the carbides for the valence of the metal appears to play a secondary role; this is probably the reason wolfram monocarbide does not have the cubic structure of the fourth- and fifth-group monocarbides.

One interesting feature of the monocarbides is their ability to form substitutional solid solutions with one another in exactly the same way that metallic solid solutions are formed. If a mixture of two carbides is heated, diffusion takes place, and a single homogeneous phase is formed in which the ratio of metal atoms to carbon atoms is maintained at unity and the two kinds of metal atoms are distributed at random on the metal atom lattice. In the case of the cubic carbides, the extent of solubility has been studied in detail by Norton and Mowry,* and the results show that any two carbides are soluble in all proportions, provided that the sizes of the metal atoms do not differ by more than about 15 percent. In the case of the VC-ZrC pair, where the difference is about 20 percent, almost no solubility is observed. This is exactly analogous to ordinary metallic solid solutions where the 15 percent limitation applies; it means that if the stranger atom is either too large or too small, the resulting localized distortion cannot be tolerated by the lattice. Under these circumstances the mixture is more stable than the solution. Thus far, at least, no tendency for ordering or a regular distribution of the two kinds of metal atoms in the carbide solid solution has been observed. On the contrary, if the size difference approaches the 15 percent limit, the solution is continuous at high temperatures but a solubility gap appears at lower temperatures and the homogeneous alloy "unmixes" into two solid solution phases. It has also been observed that the ternary and quarternary solid solutions form readily.

Study of the solubility of the hexagonal WC with the cubic carbides has shown that while the cubic carbides will dissolve considerable WC, the converse is not true—that is, WC will not tolerate an appreciable number of stranger atoms in its lattice. The solubility limit of the cubic solution increases rapidly with increasing temperature, but so far there seems to be no simple relation connecting the magnitude of the solubility with relative atom size.

In spite of the wide commercial use of cemented carbides there has been no systematic investigation of the physical properties of the solid solutions involved. It seems reasonable to suppose that the desirable properties of the cemented carbides themselves could be considerably improved by the proper choice of appropriate solid solutions

*Norton and Mowry: Journ. Metals, A.I.M.E., Metals Trans. 185, 133, 1949.

of two or more carbides, provided the general dependence of properties on composition were known. Yet there is no reliable data on even such a simply measured property as relative hardness. One reason for this, of course, is the difficulty of making suitable measurements on powders and the lack of methods for converting the powders into solid dense bodies without an auxiliary binder metal. Recently, considerable progress has been made in the latter direction and preliminary work is underway in studying the solid solutions.

Studies made on the behavior of the electrical and thermal properties of the solid solutions offer an example of this progress. As has been pointed out, the pure carbides, in spite of their high melting points and hardness are rather good conductors of heat and electricity. In the table these properties of the carbides, measured on solid blocks, are compared with the values for the metals themselves, as reported in the literature. Another study made was an exploratory investigation of two continuous solid solution series, TiC-ZrC and TaC-NbC. Although the data is incomplete, it is clear that in these two series the electrical resistivity and thermal conductivity follow an essentially linear relationship as a function of composition. This is contrary to the behavior of metallic solid solutions, for in these the curves show pronounced maxima or minima at the mid-composition ranges.

Comparison of Electrical and Thermal Properties of Metals and Carbides

Substance	Electrical resistivity (microhm cm)	Thermal conductivity ($cal/cm^2/^{o}C/sec$)
Ti	48	0.036
TiC	105	0.041
Zr	39	0.041*
ZrC	75	0.049
Nb	14.2	0.112*
NbC	74	0.034
Ta	15.5	0.103*
TaC	30	0.053

*Calculated from electrical resistivity on basis of a normal Wiedemann-Franz ratio of 160×10^{-4}.

The temperature coefficient of electrical resistivity and the thermoelectric power of the two series mentioned above was also measured as a function of composition and again the curves were essentially linear. Thus, although the general magnitude of the properties suggests that the carbide solid solutions behave like normal metals, the variation in properties with composition suggest that, on the contrary, they are fundamentally different from the normal metals.

The mechanical properties of the carbide solid solutions have not yet been studied, but this work is in prospect. One difficulty is the preparation of specimens which will be sufficiently dense and homogeneous so that the true properties of the solid solution can be observed.

At present, useful carbide parts are made of cemented carbides. The problem of the cement or binder is of the greatest importance. For one thing, in high-temperature applications, the parts begin to lose strength at temperatures far below that at which the carbides or carbide solid solutions themselves would be affected. This loss is due either to solution of the carbides in the binder or to incipient melting of the binder phase. Our knowledge of the true role of the binder phase and of the basic mechanism of the densification process is still fragmentary, but it is felt that a better binder phase is possible. Moreover, the preparation of strong, dense carbide alloys without auxiliary binders is a problem which should be carefully investigated.

Studies on the resistance of carbide solid solutions to oxidation at high temperatures* indicate that these substances are superior to pure carbides. Since individual carbides vary considerably in this respect a detailed study of the mode of oxidation and its dependence on the composition of the carbide alloy seems to be desirable.

An examination of our present knowledge of the refractory carbides emphasized the tremendous amount of information which is needed if a really intelligent use is to be made of their unusual combinations of properties. Careful and systematic research of a fundamental nature on these unique substances should eventually yield substantial dividends.

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*Redmond and Smith: Journ. Metals 1, 987, 1949.

Oceanography in the United States

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The oceans of the world are a paramount national interest of the United States. From the military point of view this fact is perhaps too obvious to dwell on, beyond stressing that since our current military problems are all extra-continental, they are evidently all transoceanic. Our economic interest in the oceans is less evident because in the past we have drawn most of our resources from the land. Now, however, we are the world's heaviest consumers of material resources and of energy. Furthermore, our population growth and rising living standards are causing the rate of consumption to grow in an exponential way. It is probably safe to state that known world resources are inadequate to support the general world standard of living at the level already enjoyed in the United States. As the demand increases, the exploitation of the resources of the ocean is bound to become of major importance to the United States as it already has to Japan, Norway, England, and several other maritime nations.

Some notion of the extent of these resources can be gained from the calculation that the dissolved solids of the oceans, containing nearly every known chemical element, measure 50 quintillion metric tons, enough to form a layer of material more than 500 feet thick over the land area of the Earth. In terms of energy resources, the importance of the oceans is due to the circumstances that 72 percent of the sun's energy falls on the sea and that, acre for acre, the sea is more productive than the land. Not only does the sea contain enormous unexploited food resources, but these resources are high in protein, which enhances their relative value. Barring an unforeseen turn in the trend of our national development, we can ill afford to procrastinate the vigorous exploitation of the oceans.

At the present time, the Navy is by far the largest consumer of oceanographic knowledge in the United States. This is natural since the ocean is its particular domain. In addition, in the competitive exigencies of war, major tactical advantage frequently results from relatively minor technical superiority. An example is furnished by the see-saw between mine measures and countermeasures. Among Navy activities which draw heavily on oceanography for basic information are the Bureau of Ships, the Hydrographic Office, the Bureau of Ordnance, the Naval Research Laboratory, the United States Navy Underwater Sound Laboratory, the United States Navy Electronics Laboratory, the Chief of Naval Operations and his office, the Fleet Sonar School, the Amphibious Force, the Bureau of Medicine and Surgery, the Bureau of Yards and Docks, the Bureau of Supplies and Accounts, and the Bureau of Aeronautics. It is well to reflect that this demand is largely a phenomenon of the last decade. As the intricacy of naval operations and armaments increases, the need for technical understanding of the sea is certain to grow at an ever increasing rate. Thus it is altogether appropriate that the Office of Naval Research should be the government agency to sponsor and patronize civilian research in the field.

The exploration of the sea under Navy sponsorship has had a distinguished history, beginning with the work of Lt. M. F. Maury in the 1840's and 50's. Yet there have always been some who thought oceanography "a useless piece of extravagance and folly" because the ocean is a region "not only wild and unexplored but uninhabited and worthless." The error of this view has been made increasingly apparent by every returning expedition. Because the sea is the sphere least hospitable to man, it is the last to be explored and understood. Many who turn away from the sea do so hoping that "what we don't know can't hurt us." They are unconcerned that we know less about the ocean basins than about the bright face of the moon. Others are content to use, in a routine manner, such oceanographic contributions as tide and current tables, desalination kits, bathythermographs, and sonar ranging charts without giving credit to the basic science from which these things come. Before long, the "jog-log"* is likely to be on every Navy ship, but few will know that its development grew out of investigations by a theoretical oceanographer studying the dynamic level of the Florida current.

Rather than set up its own laboratory to carry on oceanographic research (one already exists in the Oceanographic Division of the Hydrographic Office) the Navy has chosen to underwrite the cost of projects in several existing civilian institutions. Furthermore, ONR is not closely specifying the kind of investigations to be undertaken, so that basic research, development, and surveys, and exploitation of oceanographic knowledge can be carried out as concurrent programs within each institution. Also, it is recognized that giving a rather free hand to civilian investigators tends to foster healthy competition and leads to special lines of attack by the competing research groups. It is noteworthy that at the present time there is no type of oceanographic work that at least one of the civilian laboratories is not doing successfully for the government. Lastly, one of the greatest needs today is the training of men in the science of oceanography, and that can best be done by institutions which already have instructional staffs.

Where, then, are these laboratories and institutions? Fortunately they are on or adjacent to all three of our major coastlines. Considerable importance attaches to the variation in the character of different environments as, for example, between the deep temperature gradients of the western Atlantic and the shallow ones of the eastern Pacific or between the shallow estuaries of the East Coast and the fjords of the Pacific Northwest. The advantages of having oceanographic facilities in each major type environment are that newly discovered principles can be examined for their generality, equipment can be tested under widely varying conditions, and situations to be expected in various inaccessible areas of the world can be studied by available analogy.

THE ATLANTIC SEABOARD

The Atlantic seaboard with its intense currents, deep thermocline, broad continental shelf, shallow "drowned river" estuaries, and terrestrial climate, is characteristic of the western edges of oceans. Similar situations are found on the Asiatic Coast. Special features are the southward flow of icebergs, the Florida and Gulf currents, the continental slope water, the mid-Atlantic ridge, and the Sargasso Sea. The Atlantic

*Geomagnetic electrokinetograph.

intermediate water mass, partly formed by the efflux of heavy Mediterranean water, defines the SOFAR channel in this region.

The Woods Hole Oceanographic Institution is the major facility on the Atlantic Seaboard, and, by reason of being the oldest oceanographic laboratory in the United States, is the most experienced. Two ocean-going ships are regularly operated, in addition to one which is now on loan from the government, and general oceanographic research is carried out in connection with surveying activities in the North Atlantic which have been continued for 20 years, the longest sustained program yet accomplished in oceanography. Woods Hole has been far more active in research undertaken for the Navy than any other laboratory, particularly in the field of underwater sound. The institution also leads the field in assistance to industry with such problems as pollution. No formal teaching is done, although liaison is maintained with Harvard, M.I.T., Brown, New York University, Yale, Rhode Island University, and Columbia.

The Chesapeake Bay Institute, a fairly new branch of Johns Hopkins University, is strategically situated (near Annapolis) to study shallow estuary problems such as harbor flushing and sedimentation. Two inland waterway vessels are operated in a research program directed toward the development and conservation of the biological resources of the Bay. These studies are, of course, of considerable value to the Navy. As only one instance of this, the mud that affects the "setting" of oysters also affects the setting of mines.

The Lamont Geological Laboratory of Columbia University specializes in marine geophysics and geology and in studies of the propagation of underwater sound. Through arrangement with the Woods Hole Oceanographic Institution, students are trained in geophysical techniques aboard the vessel ATLANTIS. The Laboratory is located at Palisades, New York, high above the banks of the Hudson River.

The Narragensett Marine Laboratory of the University of Rhode Island is located on Narragansett Bay about 5 miles from Kingston. The Laboratory is mainly devoted to the problems of biological oceanography, some of which, such as fish noises, are of interest to the Navy. Biological productivity of the high seas is being studied by means of plankton hauls which have been made regularly by the weather ships. In addition to the training of students, the Laboratory is engaged in a survey of the Bay under the sponsorship of the Hydrographic Office. The Laboratory supports one small research vessel of the New England Dragger type.

The Bingham Oceanographic Laboratory of Yale University is mainly devoted to problems of marine ecology studied in Long Island Sound by means of chartered local fish boats; to quantitative studies of biological productivity; and to the physiology of fishes, with special emphasis on vitamins. The Sears Foundation at this activity publishes the Journal of Marine Research, the only American journal devoted exclusively to this field.

The University of Miami has recently established a Department of Oceanography. The personnel here are using small craft to study the

Florida current and marine biology. Liaison is maintained with the Cuban Navy which is also interested in the oceanography of the area.

THE GULF COAST

The Gulf Coast area is characterized as the American Mediterranean, not only because of its strategic importance but also because, like the European Mediterranean, it consists of a series of deep basins separated by relatively shallow sills. Due to the oceanographic "lapse rate" the apparent temperature of the water in these deep basins increases with depth. The wide shelf area is interesting for its oil resources and because of the enormous discharge of the Mississippi, the world's third largest river. Meteorologically the area is of special interest because of the frequency of tropical storms.

Texas A and M has, in the last two years, organized a Department of Oceanography and has initiated a regular oceanographic survey of the Gulf, using ship facilities cooperatively with the U.S. Fish and Wildlife Service and smaller craft offered by some of the petroleum companies. In the past, considerable marine research has been carried on in the geological, chemical, biological, and engineering departments of the College with the result that the Oceanographic Department is receiving whole-hearted support and encouragement from the rest of the faculty. The Department is one of two in the United States that is offering undergraduate instruction in oceanography.

THE PACIFIC COAST

The Pacific Coast is characteristic of the eastern boundary of oceans the world over and in many respects is analogous to western Europe. Its special oceanic features are the sluggish southerly coastal current, seasonal upwelling, steep shores with a narrow shelf, a shallow thermocline, very low oxygen content, and long-period waves. In contrast to the Atlantic Coast the climate is maritime rather than continental. In the south, evaporation greatly exceeds precipitation and run-off with the result that the flushing process in San Diego Bay, for example, is quite different from anything on the Atlantic Coast. The Puget Sound area constitutes an enormous oceanographic hydraulics laboratory with every sort of condition typical of fjord coastal estuaries such as are found in northern Europe. High salinity gradients, high velocity currents and every conceivable type of turbulence are found here. In case of war, this body of deep water, protected from enemy interference and from sea storms, would be a most valuable testing ground.

The Scripps Institution of Oceanography of the University of California at La Jolla is the chief oceanographic facility on the Pacific. A program in general oceanography is prosecuted, and in addition the associated Marine Physical Laboratory is undertaking a unique program in this important field. Together with the neighboring Naval Electronics Laboratory, the three form the most powerful oceanographic group in the world. Four ocean-going vessels are operated, with a fifth soon to come out of the yard. Scripps maintains the only fully established academic program in oceanography in the United States, although five other universities have made auspicious beginnings and will soon be well recognized. The Ph.D. degree in oceanography is offered at Scripps, as well as special courses, leading to the master's degree, which are given to military personnel.

The Oceanographic Laboratories of the University of Washington at Seattle and Firday Harbor, although founded at about the same time as Woods Hole, were a war casualty. Postwar rehabilitation has been slow, but the University has recently established a Department of Oceanography and a seagoing vessel has been obtained. The Department, like that of Texas A and M, will offer both undergraduate and graduate instruction leading to the Ph.D. in oceanography.

The College of Engineering of the University of California at Berkeley is the foremost engineering facility in the marine field. The group specializes in problems of beach erosion and amphibious operations. However, no work at sea is carried on, so that within the purview of this paper it is sufficient to say that the large and varied program and superb engineering facilities and faculty give to this institution importance of the first rank.

SUMMARY

The Department of the Navy in its sponsorship of oceanography is fostering a real and growing national asset. The program would be of increased significance if more emphasis were placed on marine resources, but perhaps that will become the function of other government agencies. Considering the vastness of the task at hand, the present size of the national effort in oceanography (about 4 million dollars annually) is very modest, and it appears that a modest expansion in the program will not do much more than keep pace with rising costs in our expanding economy. If activity in the science of oceanography is not to be curtailed, support will have to follow the rise in the national income. Normal growth will be limited as well by the rate at which the facilities can be economically expanded and adequately staffed. Until our national effort in oceanography is commensurate with that in agriculture and mining, it cannot be considered in danger of overexpansion.

Bogies at Angels 100

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The trained airmen have a word for it. They call unidentified objects in the sky "bogies." Fliers estimate the height of bogies in units of 1000 feet and call this unit an Angel. Other people call the unidentified objects "flying saucers." As you know, there has been much excitement in the last three years over these objects. Magazine articles have been written about them; indeed, a book has been published entitled "Flying Saucers are Real." They are, in fact, real—but not in the fantastic design or with the supernatural properties ascribed to them.

I believe there are two reasons for all the excitement concerning these unusual objects. First, people like to be afraid. In our younger days we walked through cemeteries as an indication of our courage in the face of great danger. It does no good to tell a young lad that there are no ghosts; he knows that ghosts are real and that he is very courageous in entering the territory which is sacred to these ephemeral individuals. The second reason for the widespread belief in "flying saucers" is, in my opinion, a desire for a combination of a scapegoat and a saviour. We wish to ascribe all our troubles to the antics of "flying suacers." On the other hand, by mastery of these objects, we will presumably have an invincible weapon against a much feared foe.

The problem gets serious when people lose their lives in pursuing these ghosts and when they actually believe that such objects are real. I would like in this article to present factual information concerning what I believe to be the true origin of the "flying saucer" myth.

For several years the Office of Naval Research has sponsored a project aptly called SKYHOOK, which involves the use of large plastic balloons. The scientific justification for this is a need to know about particles called cosmic rays. You may know that the earth's atmosphere is constantly bombarded by particles from outer space (that is, from extraterrestrial sources). Because these particles were first thought to be similar to X-rays and to come from interstellar space, they were named "cosmic rays." One of the results of project SKYHOOK is the knowledge that they are atomic particles and that the distribution of the various atoms in these "rays" is the same as in the known universe. That is to say, hydrogen is the most prevalent element known in the universe. Hydrogen nuclei, called protons, are the most prevalent cosmic-ray particles. Helium is the next most prevalent element, and, also, the second most prevalent cosmic-ray particle. Iron nuclei are the heaviest identified in cosmic rays, but there is no reason to believe that other heavier ones are not present. They are just so rare they have not been observed.

SKYHOOK balloons are unusual. In size alone they are impressive, having a diameter of approximately 100 feet. It may seem to you that a

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diameter of 100 feet is not particularly large, but let me remind you that one of these balloons would envelop an eight-story building. And even though only about 250,000 cubic feet of gas is put into a balloon, it can lift more than 100 pounds payload to an elevation of almost 100,000 feet.

Because cosmic-ray characteristics vary as a function of latitude (and weakly with longitude), it is necessary to make flights from various places, including the ocean. Three cruises have been taken for this purpose, two in the Atlantic and one in the middle Pacific.

Many news releases concerning our cosmic-ray work have been given to the newspapers. In spite of this, ardent aviators have taken off in pursuit of "flying saucers." The most ambitious individual flew up and up until he ran out of air, collapsed from anoxia, and crashed. An immediate press release cautioning aviators against trying to catch balloons at 100,000 feet was published by only a few newspapers in the back pages in small print. Similar incidents, of not so tragic character, occur practically every month.

Although more than 100 balloons have been launched from the vicinity of Minneapolis, Minnesota, the sight of these balloons in the evening sun has been sufficient to stall traffic in that city for long periods of time. If the appearance of these objects causes such a sensation among people who should be accustomed to seeing them, it is easy to understand why the fantastic "flying saucer" stories have been circulated by observers unfamiliar with our work. While the great majority of the balloons are flown from Minneapolis, traveling various distances across the United States, it might be interesting to note that balloons are launched from various other locations as well, such as Chicago, Illinois; White Sands Proving Grounds, New Mexico; and Holloman Air Force Base, New Mexico. This accounts in part for their appearance in many locations.

I have examined hundreds of reports of "flying saucers." One was even reported to be radioactive. Although the "radioactivity" was measured by a competent laboratory, exhaustive examination proved that it was, in reality, caused by a faulty contact in the electronic circuit, whose resistance varied as a function of mechanical vibration. This fluctuation in resistance registered as a large increase in apparent radioactivity.

But such logical explanations have not hindered the circulation of even more fantastic stories about "flying saucers." Just recently a professor of geology at the University of New Mexico attained considerable notoriety by revealing to the Associated Press that he had found a mystical object in the mountains. He did not wish to "trust" the FBI, who, incidentally, would have known what it was. The newspapers were able to make a considerable story by declaring that the Navy and the Air Force were both claiming control of the find. In the first few minutes of confusion it was not known to us whether it was one of our pieces of equipment or one flown by Wright Field operations. A few phone calls soon straightened out the matter, but the newspapers had already conveyed the impression that the two Services were "fighting" over this "secret" object. It was not secret; it was simply a cosmic ray measuring device.

With the aid of a telescope we recently obtained a picture of a "flying saucer" in which one can see the brilliant light of its "atomic" engine, the faint stream of hot exhaust gases pouring from it, and the long, thin lines of its structural members. In reality, the object was a SKYHOOK balloon, measured by theodolite to be at an altitude of about 80,000 feet. To the unaided eye the details shown in the picture would not be obvious. But the balloon was seen as an object moving in the sky with the speed of the winds. These velocities are by no means insignificant, for they sometimes are as great as 200 miles per hour.

In addition to single-cell flights, such as the one just described, balloons are also flown in tandem. These balloons range in diameter from 5 to 20 feet. Because they are tied to a single load line, they fly "in formation." This accounts for the stories of "squadrons of flying saucers."

Actually some of the fantastic stories circulated have occasionally served a rather useful purpose, for they have helped us to locate valuable equipment flown by the large SKYHOOK balloons. Ordinarily they are tracked by ground visual observations, by radio, and by airplanes. In addition, "reward" tags are attached to the apparatus with instructions to call or write the General Mills Aeronautical Research Laboratories in Minneapolis, Minnesota. These laboratories—prime contractors for this work—are constantly developing new types of balloons and doing research on better construction and performance and on better tracking methods. In spite of all these precautions, the balloons occasionally escape us, and in these cases equipment is sometimes located by reading newspapers for reports of "flying saucers." Even so, approximately five percent of the flights are lost for long periods of time or completely.

Of course Project SKYHOOK is not the only source of "flying saucer" stories. Reputable balloon observers have reported unknown objects in the sky as possible "flying saucers." They have forgotten the phenomenon of mirage, by which objects appear to be in positions and to be moving at velocities entirely different from those of the real objects. In some cases, however, pictures have actually been published of reported "flying saucers." The cameramen who took them have forgotten about the phenomenon of internal inflection in lens systems, which produces images on photographic film that have little relation to reality.

Those of you who have sailed the seas realize the difficulty of determining either the distance or the velocity of an unknown object on the ocean. If you recognize the silhouette of a ship to be that of a class you know then you can estimate the distance to that ship and its relative speed. One cause of the fantastic stories you hear about "flying saucers" is that the size of the objects and their distance from the observer are generally not known. People are not accustomed to seeing balloons having the size and velocity of those used in project SKYHOOK, and consequently interpret what they see erroneously.

Imagination is fun, but, as a series of cigarette ads pointed out several years ago, it's more fun to know.

Salmon, Science, and a Sense of Smell

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To commercial fishermen of the Great Northwest autumn means at least one thing—the famous salmon run in which the gamiest fish of the Pacific Coastal waters battle up into the torrential Cascade Mountain streams where they spawn. The fishermen's hope that the salmon will be there in great number fades a little each year as more and more of the migrating salmon go headlong into the great new dams in that area, to die before they breed. Despite the fact that each dam is designed to include fish lifts or ladders, no fishway has yet been devised which can permit an adequate percentage of the salmon to surmount these barriers. Many of the salmon cannot or will not use them. The result has been a marked decline in commercial fishing within the past decades.

The salmon takes his first long swim at a few weeks of age when he starts the trip downstream to salt water. He remains several years in the sea, and then returns to his home waters to spawn. On both journeys he encounters the dams and, at every encounter, the salmon ranks are cut to a fraction of what they were at the journey's beginning.

For hundreds of years the spectacular display of the migrating salmon has captured the imagination of men. The sight of 100 pounds of fish hurtling into the air above a rushing waterfall was part of Indian folklore in the Pacific Northwest long before Lewis and Clark crossed the Great Divide. Its enchantment invests the commercial trade in salmon and increases the lure of the salmon for the modern sportsmen, who try every conceivable method of attaching one to the business end of rod and reel.

To the naturalist the salmon has been something of a mystery. What impulse sends thousands of salmon migrants back from salt water to spend every ounce of strength traversing hundreds of miles of mountain streams to breed in a gravel bed at some headwater? It is instinct, yes. But what subtle influences of water, light, air, or vegetation guide them unerringly to home streams to perform the function by which all species continue to exist?

Young salmon first see the light of day when they wriggle up through the bed of gravel over which their parents spawned. They spend the next few weeks feeding on the many forms of insects and small aquatic animals found beneath the fallen logs and among the weeds that line the stream bottom. Then comes the first of their urgent migratory calls. They begin to travel in search of salt water, as their parents did 4 or 5 years before and as their ancestors have done since time beyond memory.

Once they reach the sea, many become food for larger and more aggressive fish, including older, bigger salmon, killer whales, and a score of other predatory species. During the years in the sea the salmon play at their game of "hide-and-eat" with the inhabitants of the sea. When sexually mature, the survivors again answer the call to migrate. This time they return to the streams where life began for them.

Now it is when the salmon—voracious as it may have been during its years in the sea—turns into an extreme conservationist. From the moment these great salmon, some of which weigh a hundred pounds, turn into the freshwater rivers and begin their heroic nuptial swim up miles of cold, fast water, they cease to eat entirely. Their digestive organs atrophy and diminish strikingly in size. On opening the belly of a breeding male for inspection of content, one finds almost no visible remainder of what was once an active, functional digestive tract capable of digesting fish swallowed whole. By the time they reach the breeding grounds they are literally skin and bones. It is not unusual for the skin of these old salmon to be frayed, hanging in shreds, or even rubbed off entirely from spots that have been scraped against rocks or logs.

Then, in the shallows over the gravel beds where they began their lives, these salmon migrants spawn. After spawning they turn belly-up and lifeless and are cast up along the shore. Thousands of pink eggs sink into the gravel bed to hatch, in due time, into another generation of salmon which will continue to follow the wordless command of instinct which directs their lives.

There are puzzles in this story, many of which will remain unsolved for years, perhaps centuries. One in particular has baffled marine biologists, its solution appearing at times tantalizingly close but never yet attained. HOW DO SALMON FIND THE STREAM IN WHICH THEY WERE HATCHED AND HOW DO THEY FIND THEIR WAY HOME FROM THE SEA? As late as 1939, a biologist named Scheer summarized all our knowledge of the salmon's homing ability by saying only that "......salmon or trout hatched and raised in a particular region will, upon returning to fresh water, return in the great majority of cases to the same region, even from considerable distances."

There are records of marked fish straying from home streams, but the great body of evidence shows this to be the exception. A convincing experiment was conducted in 1939 by Canadian biologists named Pritchard, Clemens, and Foerster. They marked 469,326 salmon before the oceanward migration, and of these nearly 11,000 survivors returned to their parent stream. None was ever found in other streams.

A few scientists in the past have hinted at the possibility that a sense of smell may aid fish in migration. Not until 1951, however, was the idea proposed that home waters may carry a distinctive odor which serves as a guide to salmon in the search for their original habitat. This theory presents two distinct problems:

- Do streams have characteristic odors to which fish react? If so, what is the nature of the odor?

- Can salmon detect and discriminate between such odors if they exist?

In order to answer the first question, a group of bluntnose minnows, an animal of proven olfactory acuity, was trained to discriminate between the chemical differences of two Wisconsin creeks. (See Arthur D. Hasler and Warren J. Wisby. Discrimination of stream odors by fishes and its relation to parent stream behavior. The American Naturalist 85:223-238 (1951).) The arrangement was such that the fish found food on entering a test zone in their aquarium when water from one creek was being piped in, and received an electric shock if they entered when water from the other was introduced. After a few weeks of training, the fish entered the test zone only after detecting the creek odor associated with food, and avoided the zone when the other odor was perceived.

Proof that the fish were actually smelling the odors was established by destroying the organs of smell of the trained fish, after which they no longer reacted to either test odor. It was also found that these fish could "remember" the differences between the stream odor for long periods of time, and that the odors to which they reacted existed in the volatile organic fraction of the water.

After solution of this initial problem, the next step was to determine if salmon, also, could detect the difference between the two streams. It was found essential to adapt special apparatus for testing salmon. After a short training period it was evident that these fish, too, could detect differences in water from the two creeks. On the basis of the evidence, it appears that substances in the water, probably from the vegetation and soil of the area through which the streams run, impart to each stream a distinctive odor which salmon can smell, remember, and recognize even after long periods of non-exposure.

It seems probable that the odors characteristic of individual streams can seldom be changed even by flood or by pollution. Each stream seems to possess an individual odor which it keeps year after year, enabling salmon to find home streams after long sojourns at sea. This, too, helps to explain the discovery in 1948 that salmon migrants unable to pass Grand Coulee dam yielded spawn that became established in adopted streams, and that eggs from these relocated fish yielded young salmon that "homed" to the adopted stream.

The evidence presented to this point is circumstantial. A mechanism has been outlined whereby it would be possible for salmon to return to their home stream even after a long absence. The theory is now being tested by exposing salmon to an artificial odor through the fingerling stage and then decoying them into a tributary below their home stream when they return from the sea. By conditioning salmon fry in this manner, scientists in the fisheries may be able to train salmon to return to selected waters to spawn, bypassing the streams wherein they would find too many obstacles. In this way, we might conserve one of nature's greatest resources—a source of food protein that takes all its nutrients from the sea.

The number of salmon in one year's catch on the Columbia River alone is sufficient to furnish the protein food needs for one million people for over a year. When this fact is considered, the effort spent trying to save the salmon seems well worth while. Most of the rivers running into the Pacific may eventually be dammed, and conditioning of salmon fry so they will return to adopted streams may help save the U.S. salmon industry.

A New Look for Aircraft Instrumentation

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An historical study of our modern aircraft instrument panel shows that its development was a progressive series of modifications of old ideas apparently stemming from clocks and steam gauges. The first airplanes had only two or three instruments: a tachometer, an oil-pressure gauge, and sometimes an altimeter. As performance improved, however, the requirement for more information for the pilot became a necessity and engineers designed instruments with the characteristics of those which were familiar to them. The resulting instruments, of course, were the conventional round-dial and rotating-needle type. When the increments around the dial became too congested to read, the designers added idler gears and more needles. When the panel itself became too congested to receive more data, instruments were combined to conserve space and reduce scanning. Although the input data and the operating mechanism have changed considerably, the display continued to employ the same dial and pointer. From the primitive instrument panels of 1916 tremendous changes have taken place in instrumentation, but on the other hand there has been a notable lack of change in methods of display.

Although present instruments have made it possible to fly "blind," there are certain facts which indicate rather emphatically that present instrument displays are not adequate to fulfill their design objective. For instance:

- It is well known that present instrument systems require a pilot to engage in extensive initial training as well as continuous refresher training to develop and maintain his proficiency. This training is not only expensive but time consuming.

- We know from both military and commercial records that normal air operations are seriously curtailed during bad weather. Observe any airfield when weather conditions are marginal and this will be quite apparent.

- Newspaper files are literally filled with accounts of aircraft accidents attributed mainly to adverse weather conditions, yet most of the pilots were considered fully qualified to fly under instrument conditions.

- The very fact that instrument cards, or licenses, must be renewed each year is sufficient to indicate that flying "on instruments" is not something which we can learn once and retain indefinitely.

- Also controversy is continuous over standardization of the instrument arrangement itself. There is no universal arrangement of the instruments and there probably won't be until the instruments themselves are adequate enough to become standardized.

The foregoing makes it clear that even thougn we have made tremendous advances in the state of the art of instrumentation, the information presented to the pilot today is a long way from being sufficient to meet his needs. The Navy is engaged in a comprehensive program for the improvement of instrumentation, with the long-range aspect a responsibility of the Office of Naval Research. Because one of the primary missions of the Office of Naval Research is to look 10-20 years in the future, and requirements are fixed accordingly, it was decided to take a fresh look at instrument design.

First a clear, concise statement of the problem was formulated, and then a study was made of flights dating back as far as 1945-46. From them much was learned. Stated simply, information can be obtained from five sources: the air, the aircraft, the earth, the pilot, and other aircraft. It was further established that there are four basic discriminations which must be made by the pilot, which are: direction, altitude, time, and control (mechanical). The analysis also indicated that if the data presented to the pilot are to be adequate they must tell him (1) which control to move, (2) when to move it, (3) which direction, (4) how much to move it, (5) and how long to hold it. In summary, then, our problem is fairly well defined. In order for instrument displays to do the job, they must be capable of answering each of the five questions for each discrimination and for each phase of flight.

In addition it is necessary for the pilot to gain "pilot tranquility," as the English call it. This would come in the form of reassurances on the three questions, "What am I doing?," "What should I do?," and "How am I doing?" Whenever the pilot is considered a link in the man-machine system, he needs that something extra from the presentation of the instruments before him.

The tremendous rate of aircraft development has forced instrument engineers to take care of so many fire drills that they never really have had the time to develop ways for eliminating the cause of the fires. In almost every instance, new instrument development has been carried out through crash programs brought about by the necessity for more data.

It takes a team to produce best results on an engineering problem of this sort, so the engineer and pilot must get together. Logically, the pilot serves to establish information requirements, the human engineer works on display designed to meet these requirements, the feasibility engineer or physicist directs his attention to technical requirements for the display, and the flight surgeon defines the parameters of the pilot's performance capabilities and keeps us constantly reminded that man is the indispensable link in the system.

In work with the pilots, an interrogation system has been used, and the people in charge of the instrumentation program are careful to make sure that they found out what the pilot really needs and not what he thinks he needs. For instance, careful questioning determined that the air-speed indicator—long considered indispensable—was needed only to provide information for navigation or for fuel consumption. If location and fuel-hours remaining can be displayed directly, an air-speed indicator is superfluous. The human engineers concerned themselves with the task of determining how the pilot should receive information in order to assimilate the data and react in the most efficient manner. The operation of tracking was studied, and ways were worked out to indicate error signals which would attract the pilot and cause him to react naturally and efficiently. The other members of the team—mostly engineers and physicists—continued with development work on the system. If a system calls for a gyro, it is not enough for these people to design a gyro; they must go back and seek fundamental values to see if a gyro is the best piece of equipment to do a job such as establishing a true vertical to make a fix in space.

Any long-range program must by its very nature establish an ultimate goal. The program at ONR has been based upon the concept that an ideal all-weather cockpit should provide the pilot with direct answers to any question which might arise and, at the same time, should require an absolute minimum of training. A full-scale mockup of an instrument panel and display system grew out of the team effort. It establishes the principles and is not a position chart of existing equipment; it is a representation of the goal toward which the program is striving. The major instrument to be utilized in the cockpit will consist of a flat-plate transparent television tube now being developed as a part of this program. Upon this tube the right kind of information can be displayed when the pilot wants it, in a form he can use, and without the complication of extraneous information which he does not require to enable him to do the job at hand—be it takeoff, rendezvous, strike, or landing.

Over-riding this entire program is a philosophy which may be described as follows:

For every problem we face there may be only a few or an infinite number of solutions; but out of this few or infinite number there is only one logical, completely adequate, and thoroughly compatible answer. All others are only partial solutions. When men distort or overlook the fundamentals, the result can only be a partial solution. Where the analysis is complete and the basic fundamentals are established, the results will be not only complete, but simple as well. We are looking for—and getting—those right answers.

Flame Propagation

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The advent of jet and rocket propulsion has greatly stimulated the interest in combustion and flame propagation phenomena. Man has utilized flames and combustion since the dawn of civilization, long before many other physical phenomena became useful or even known to him. Yet our knowledge about fundamental aspects of combustion is still surprisingly sketchy. This may be due in part to the fact that through our long practical experience with combustion we have taken for granted things which are really quite complicated or even puzzling; undoubtedly the main reason, however, is that combustion constitutes an intricate tangle of physical and chemical phenomena that defies a clear-cut separation into such special fields as thermodynamics, fluid dynamics, acoustics, and chemical kinetics.

Systematic studies of flame propagation in gases date back to the pioneer work of Bunsen, Gouy, Mallard, and Le Chatelier during the latter part of the ninteenth century. These and many subsequent investigations showed that, in general, the speed with which a flame spreads through a combustible gas mixture varies between wide limits, even in the course of a single experiment, depending greatly on the particular experimental conditions. It is possible only in certain special cases, notably in a stationary flame burning in a laminar gas stream issuing from an orifice (Bunsen flame), to measure a velocity of flame propagation which is determined by the composition and state of the combustible gas mixture only. This speed, defined as the velocity with which the flame front moves normal to its surface and relative to the unburned gas at initial conditions, is generally called the burning velocity. A large part of past and current studies of flame propagation are concerned with experimental determinations of burning velocities for various combustible mixtures, initial pressures and temperatures, mostly by means of the Bunsen burner method.

Many attempts have been made to develop a theory of the burning velocity which would make it possible to predict it accurately for any mixture and initial state, taking into account the simultaneous occurrence of chemical reactions, heat conduction, and diffusion in the flame front. This problem is still far from a satisfactory solution, not only because of mathematical difficulties, but chiefly because too little is yet known about the complicated chain reactions, involving many unstable intermediates ("chain carriers"), which take place within the narrow reaction zone of flames. Considerable progress in this branch of combustion research may be expected when the results of many current investigations of flame reaction mechanisms, employing such varied techniques as emission and absorption spectroscopy and mass spectrography will be available.

It has already been mentioned that flames propagate with the burning velocity only under rather special conditions. In practically all applications of combustion, the "effective" flame speed is much higher than the burning velocity. This is of particular importance in the field of jet and rocket propulsion; in fact it would be quite impossible to burn the necessary amounts of fuel within reasonably short combustion chambers and tail pipes if the burning velocity were not exceeded by a large factor. On the other hand, fluctuations of flame speed may be responsible to a considerable extent for the undesirable phenomenon of "rough burning" and other troublesome instabilities of burning in propulsive devices.

Unfortunately, flame propagation studies performed in the past do not provide sufficient information, either for an understanding of the fundamental phenomena involved or as a basis for predicting flame behavior in practical applications. Little is yet known about what causes the increase of flame speed above the burning velocity apart from the generally accepted view that it is due mainly to an increase of flame surface area, and possibly also to increased heat conduction and diffusion rates, both caused by flow disturbances which are usually called "turbulence."

Recent studies have shown that the level of turbulence already present in the unburned gas is of minor significance for flame speed; the predominant part of flow disturbances responsible for increased flame speed appears to originate in the immediate vicinity of the flame front. This result suggests that the older approach, which regarded the problem merely as one of effect of turbulence on flame speed, should be replaced by one which takes into account the mutual interaction of flame propagation and flow disturbances.

Flame studies now underway at Cornell Aeronautical Laboratory under the sponsorship of Project SQUID have already provided strong support for this view. In one group of experiments, an originally steady Bunsen flame in a laminar gas stream was subjected to periodical disturbances, and the distortion of the flame front was analyzed by means of stroboscopic observation or high-speed photography and cinematography. The effects of such varied disturbances as sound waves, alternating electric fields, and vibrating wires, were found to be surprisingly similar. In all these cases, the distortion of the flame front consisted of waves which travelled upward along the flame cone with the flow velocity of the unburned gas.

A remarkable feature common to all flames investigated was the increase of amplitude during the upward travel of the waves. Inasmuch as it seems obvious that the observed distortion of the flame front must be due to flow disturbances present both in the unburned and burned gases, the phenomenon may be quite analogous to the well-known amplification of periodical disturbances in a laminar boundary layer and may thus be of fundamental importance for an understanding of the generation of turbulence in flames.

This interpretation is necessarily tentative, because the distortion of the flame front does not provide sufficient information for deducing the disturbance velocities, even in its immediate vicinity. In order to explore the flow patterns in disturbed flames further, titanium tetrachloride vapor, which hydrolizes upon contact with the moisture in the air, forming a dense white smoke, was injected into the unburned gas stream in several thin traces. As the fine smoke particles follow the gas motion practically without any inertia effects, the presence and nature of flow disturbances can be deduced from the shape of the traces. At present, work is continuing on a modification of this technique to enable a quantitative evaluation of the flow pattern.

Another group of experiments at Cornell Aeronautical Laboratory is concerned with flame propagation in tubes. Numerous investigations of this subject have been carried out in the past; but while it was recognized the flame speed depends decisively on flame surface area and thus on flame shape, few previous attempts were made to study flame structure in tubes systematically.

In order to separate the various factors which may have an influence on flame shape, all disturbances which may affect it are eliminated as completely as possible in one type of experiment of the present study. This condition is realized best for an almost stationary flame burning near the upper open end in a vertical tube, with the premixed gases entering near the bottom at such low speed that laminar flow in the tube is insured. Contrary to what might be expected, it was found that even under these conditions in certain mixtures the flame front disintegrated into a number of roughly hemispherical cusps of fairly uniform size. These cusps, which were always convex toward the unburned gas and separated by narrow ridges, filled the whole cross section of the tube in a single horizontal layer moving about continuously in irregular fashion.

There can be little doubt that this flame structure is caused by flow disturbances generated by the flame itself. Like the amplification of artificial disturbances in flames described above, the phenomenon has the character of an instability. Unlike the former, however, cell structure was observed only in certain mixtures; it did not appear at all in methane-air mixtures but only in rich mixtures of higher hydrocarbons. Recently it was found that cells appeared in lean mixtures of hydrocarbons, including methane, when small amounts of hydrogen were added. The size of the cells was found to depend markedly on the type of fuel and on pressure and other variables determining composition and state of the gas mixture, but not on tube diameter and gas flow velocity.

In another type of experiment the flame is no longer kept almost stationary, but made to flash down more or less rapidly from the open to the closed end of the tube. It was already known to Mallard and Le Chatelier that under these conditions an initial "uniform" motion of the flame is followed by a "vibratory" motion which generally is accompanied by a marked increase of flame speed and which may assume a violently explosive character. This phenomenon, which is of great practical as well as fundamental importance, has been extensively studied in the past. It has been established that the vibration frequencies correspond to organ-pipe oscillations of the gas column in the tube; however, the cause of their excitation, and of the simultaneous increase of flame speed has never been fully established.

Important clues for a better understanding of vibratory flame motion may be provided by studying the hitherto neglected role of flame structure. Because of the extremely rapid changes of flame shape occurring under these conditions the only possible method of attack consists of high-speed cinematography combined with schlieren or shadowgraph techniques. With a tube of circular cross section this can be done only by means of a parallel beam of light traversing the tube axially and passing through a glass window at the closed end. Cells can be seen to appear and disappear periodically in the rhythm of the oscillation. Thus, flame surface area and therefore heat release of the flame will vary in the same rhythm. As Rayleigh had already shown, periodic heat addition, if applied in proper phase, causes excitation of oscillations of a gas column. It seems most likely that the resulting periodic accelerations of the gas column affect flame-front stability and thus cause the observed periodic changes of flame structure, thereby providing the "feedback" necessary for spontaneous oscillations. Further work is being done, correlating oscillographic records of the pressure oscillations at the closed end of the tube with high-speed motion pictures of flame structure for various mixture compositions, in order to arrive at a more complete understanding of these matters.

It is hoped that the field of jet and rocket propulsion will eventually benefit greatly by these and many other studies of flame propagation now underway. While remarkable progress has been made in this field in recent years, it should not be overlooked that this has been achieved to a large extent by costly and time-consuming trial-and-error methods. It is to be expected that a better understanding of flame propagation will ultimately lead to more straightforward design procedures comparable to those customary in other fields of engineering.

Putting Aerodynamics on the Molecular Beam

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It is reported that a Member of Parliament visited Faraday's laboratory on one occasion. After having been given a demonstration of the newly discovered phenomenon of electromagnetic induction, he asked his host this question: "Now, can you tell me for what purpose this electricity may be useful?" And he received the answer, "Sir, some day you will be able to levy a tax on it."

This story may be true or not, but it illustrates the point that scientific research, begun for reasons completely unrelated to any practical use, will often produce tremendous practical applications for the next generation, and sometimes even for the same one. Not only have taxes amounting to hundreds of millions of dollars per year been levied upon the fruits of Faraday's work, but our whole present civilization would have been unthinkable without his discovery of electromagnetic induction. Many other examples of this kind could be given, and while most of them may not be quite as spectacular, it seems safe to say that fundamental research has repaid its cost many times over.

The recognition of these contributions of basic research to the solution of the problems of the Navy led to the establishment of the Office of Naval Research and its program of projects in the laboratories of industrial, private, and educational institutions throughout the country. One of these projects, carried on at the Carnegie Institute of Technology, is concerned with the prediction of drag and temperature of solids moving through fluids.

The practical problem may be described as follows: Any interaction between a fluid and a solid, in particular friction and heat transfer, is ultimately due to two causes: first, the interaction between the molecules of the fluid and the surface of the solid, and second, the interaction between the individual molecules of the fluid with each other. In the problems commonly arising, the second interaction is by far the predominant one, and the first one can be completely ignored. This makes it possible to calculate friction and heat transfer by the methods developed in the branch of physics known as fluid dynamics.

The situation becomes very different, however, if a moving body is immersed in a gas at very low pressure, or if its speed approaches or exceeds the velocity of sound. Problems of this sort arise in connection with missiles flying at high speeds through the rarefied gases in the upper stratosphere. Under these conditions the first interaction becomes more and more important, and unfortunately not very much is

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known about it. Moreover, calculations about the drag exerted by a rarefied gas on a moving projectile produce very different results if one assumes that the gas molecules hitting the solid surface are reflected like billiard balls than if one assumes that their direction after impact is independent of their direction before impact. It is therefore quite difficult to predict the drag and temperature of a missile flying at high speed through the upper atmosphere.

Investigations to solve this problem can be carried out along two different lines. One approach is to measure the desired quantities through direct experiments in a high-velocity, low-pressure wind tunnel. Another approach is to examine the interaction between gas molecules and solid surfaces and to use the data obtained in this way as a basis for theoretical calculations. Experiments of this kind have just begun at Carnegie Institute of Technology under the sponsorship of the Office of Naval Research. The method employed is the molecular-beam technique which has been developed by Otto Stern and his collaborators during the past 30 years and which has been recognized in its importance by the award of the Nobel Prize to Dr. Stern in 1943.

In principle the method is extremely simple. Gas molecules escaping from a fine slit into a highly evacuated vessel travel along straight lines. By means of a second slit it is possible to select a fine pencil of molecules, all of which travel in approximately the same direction. These molecules, which form a molecular beam, are permitted to impinge upon the solid surface to be investigated and can be located afterwards by a suitable detector. The ultimate problem consists of measuring the directional and velocity distribution of the molecules after the impact; the experimental solution of this problem will provide the data which are necessary for a solution of the practical problems of bodies moving at high speeds in low-pressure gases.

Experiments of this sort have been carried out by the author and others since 1925. They have been mainly restricted to the investigation of the scattering of atoms and molecules by crystal surfaces. The results obtained have proven to be very important in connection with the foundations of modern physics. In particular, they provided the first direct experimental evidence for the theoretical prediction by de Broglie that ordinary atoms and molecules possess certain wave properties. These wave properties of material particles form the basis of quantum mechanics; it is fair to say, therefore, that molecular beams have made an important contribution to our present concepts of physical thought.

The research project at Carnegie Institute of Technology under sponsorship of ONR will be devoted mainly to the interaction of gas molecules with surfaces of all kinds, especially those which may have practical application for high-velocity missiles. The molecular-beam apparatus in use at the present time allows the use of beams of air, oxygen, nitrogen, hydrogen, or helium molecules, and its primary purpose is the improvement of the older methods of molecular beam detection. It is expected to make these devices much more sensitive by utilizing the latest developments of electronic and vacuum techniques. A larger apparatus, now under construction, is designed for the measurement of the intensity distribution of molecular beams reflected from various surfaces, and it will furnish additional data required for the calculation of drag and heat transfer.

History of the Research Reserve

Many scientists took an active part in service in the Navy during World War II. Demobilization released many of these men to inactive duty, and they returned to their laboratories to resume their research where they left off. Being members of the Naval Reserve, they retained the Reserve designation—such as line, medical, aviation, and engineering—they had during the war.

It became clear that the mobilization of Reserve scientists would present a problem. Medical, engineering, and aviation Reserve officers would be urgently needed by the Bureau of Medicine and Surgery, Bureau of Ships, and the Bureau of Aeronautics; yet, there was no provision to assure the utilization of these men in research activity. In addition, the newly organized Office of Naval Research would be faced with a major problem in mobilizing research personnel to satisfy its needs. It was apparent that what was needed was a Reserve program for the Office of Naval Research to provide an adequate, trained force of scientific and technical personnel for assignment to activities under its management control.

The Navy authorized such a program in May 1948 by Naval Reserve Multiple Address Letter 24-48. The program was organized with the following mission: "To have a pool of scientifically trained officers available to the Office of Naval Research in case of general mobilization." (This mission was later expanded to include the requirement to provide scientific and technical personnel for the entire Naval establishment.) Given this authorization, the Office of Naval Research acted to implement all phases of the program under the direction of the first director of Research Reserves, CDR Robert S. Woodbury, USNR.

The first Navy Science Seminar, which began three weeks later (9 June 1948) at the Office of Naval Research in Washington, was attended by 100 officers of the Naval Reserve. From the Army, which had made a survey of scientific Reserve officers in World War II, a list was obtained of World War II Naval scientific Reserve officers. A postcard announcing the first Naval Scientific Reserve Seminar was mailed to each officer on this list. As more than 700 applications for the Seminar were received, it was possible to screen the trainees carefully. The officers were selected from many locations in the United States, from many fields of science and engineering, and from ranks ranging from Ensign to Captain. The Seminar proved to be most successful.

From this nucleus the first requests for activation of units were made. The first unit formed was located in Washington, D. C. The Potomac River Naval Command held the first meeting of Volunteer Research Unit W-1 on 14 July 1948. Sponsored by CAPT W. H. Leahy, USN, then Assistant Chief for Research, Office of Naval Research, the group was under the command of CAPT (then CDR) Frederick C. Wiesner, USNR, a scientist in the ONR Power Branch. CAPT Wiesner is still associated with the program and is now the Battalion Commander of the Washington area. Two units on the West Coast—Volunteer Research Units 12-1 and 12-2—were next activated, on 6 August 1948.

Unit 12-2 was under the command of CDR (then LCDR) Nello Pace, USNR, who is now a member of Naval Reserve Research Company 12-5. By the end of July 1949, fifty-eight units had been activated.

This remarkable growth continued, and at the beginning of the Korean emergency in 1950 there were about 90 units with 3,300 members. During this emergency the Research Reserve program was called upon to make nominations to fill technical and scientific billets not only by ONR, but also by BuAer, BuShips, BuOrd, AFSWP, AEC, and other activities. As a result of the experience gained in furnishing these officers the primary mission of the Research Program of the Naval Reserve was extended in April 1953 to include the entire Naval Establishment.

After a brief decline in membership following the Korean emergency, the Research Reserve again started to expand. Today there are 112 companies and 8 panels with a membership of 2,406 Reservists. (The term "Volunteer Research Unit" was changed to "Naval Reserve Research Company" in 1952.)

In building up its membership, the policy of the Research Reserve has been to emphasize quality as well as quantity. To provide a pool of scientifically trained officers in the event of mobilization has required that the program include men capable of conducting, supervising, coordinating, administering, supplying, analyzing, and evaluating research for the Naval Establishment, and men versed in contract administration and patent law. The qualifications for membership have remained basically the same since the program was begun.

The training program of the Research Reserve has continually expanded. Although local companies have followed established guidelines, they have enjoyed considerable autonomy in the development of their training programs, utilizing the particular scientific or technical skills of their own research personnel. Because of the many fields of science represented in the program, no attempt is made to train each officer in his particular field; the Navy assumes that each officer is qualified in that field. However, the program does propose to keep the Reservists up to date on the research program of the Office of Naval Research and to give them the opportunity to participate in it. This objective is accomplished not only through regular drill meetings and on-the-job training, but also by means of seminars and special projects.

Seminars are the principal means of keeping Reservists up to date in current research. Those that have been conducted by Naval research and training activities, by branch offices of ONR, and by Reserve Research companies, and the year they were first held, are as follows:

1948—Naval Reserve Research, ONR, Washington, D. C.

1949—Nuclear Sciences, Oak Ridge, Tennessee

1952—West Coast Seminar, San Francisco, California

1952—Nuclear Power, Brookhaven National Laboratories, Upton, New York

1952—Special Devices, Port Washington, New York

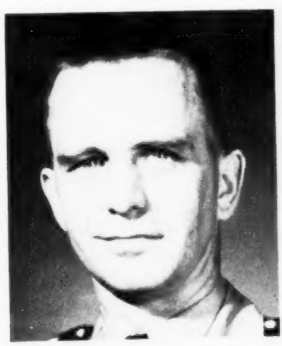

CAPT D. P. Tucker


CDR R. S. Woodbury


CAPT A. B. Cook


CAPT F. L. Edmondson


CAPT T. Blanchard


CDR H. F. Burr

1952—Psychological Warfare, Chapel Hill, North Carolina

1953—Training Seminar, Naval Research Laboratory, Wash., D.C.

1954—Nuclear Sciences, Idaho Falls, Idaho

1955—Research Methods, Columbus, Ohio

1956—Research and Naval Science, Great Lakes, Illinois

1956—Aviation Medicine, Pensacola, Florida

About 400 Research Reserve members are provided active duty for training at seminars at the present time. In 1956 billets were formally made available for allocation to members of other Naval Reserve programs and to members of the other services, although there had been some participation from these sources since the early days of the program.

Another important phase of Reserve training has been the project work, which permits utilization of the Reservist's capability in his particular specialty and provides the Reservist the opportunity to keep up to date on the Navy's research requirements. These projects have delved into many scientific fields; for example, the titles of some of the projects that have been undertaken are "Biological Warfare and Water Supply," "Development of an Aptitude Test for the Selection of Scientific Personnel," "Survey of San Diego Bay to Calculate Probable Effect of an Atomic Bomb on the Waters of the Bay," "Problems of Warfare in the Arctic," and "Automation in the Navy."

The Research Reserve Program did not just "grow up" like Topsy. Able leadership has always been in evidence. CAPT Dundas P. Tucker, USN, who at the start of the program was War Plans Officer at ONR, is called the "father" of the program, although being a bachelor he disclaims the appellation. Following CDR R. S. Woodbury as directors of the Research Reserve were CAPT (then CDR) Albert B. Cook, USNR, 1950-52; CAPT (then CDR) F. L. Edmondson, USNR, 1952-54; CAPT Theodore Blanchard, USNR, 1954-56; and the present Special Assistant for Research Reserve, CDR Horace F. Burr, USNR. The success of the program has been due in large part to the outstanding support given it by the Office of Naval Research on a departmental level and in the field; the branch offices have been particularly influential in building up the program by encouraging and coordinating the formation of new companies and assisting the companies in the development of their training programs.

In the field analysis, however, the growth and success of the program has been due primarily to the Reservists who make up the membership. Their desire to follow their chosen fields, to keep up to date with Navy developments in those fields, and to better prepare themselves for a possible mobilization assignment has resulted in a Reserve program that is of great value not only to the individual Reservist, but also to the Navy.

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BEFORE VANGUARD. . .

For the past several months, this space in Research Reviews has been devoted to a thumbnail progress report on Vanguard. This anniversary issue offers an appropriate occasion for a brief summary of 11 years of upper-atmosphere research with rockets. Out of these years came the specialized experience that has qualified the research team of ONR-NRL to undertake technical direction of the earth-satellite program.

The upper-atmosphere research with rockets began at NRL in December 1945 with the writing of a tentative program and the establishment of a Rocket Sonde Research Section. A suitable vehicle became available, much sooner than anticipated, when Army Ordnance engineers announced they intended to assemble and fire a number of captured German V-2 rockets at White Sands, N. M.

During the 6 years following the first launching in March 1946, NRL conducted 80 experiments in 25 of the 60 V-2's fired. One of the rockets reached an altitude of 102 miles. These investigations required new techniques in instrumentation, telemetering, and tracking, and built up among a small group of naval scientist and engineers an invaluable know-how in the complex art of rocketry.

Before 2 years had gone by, NRL anticipated the time when there would be no more V-2's, and contracted with Glenn L. Martin Co. for another rocket, designed specifically for research. This was the now famous "Viking", first launched May 3, 1949. At the date of this writing, 13 have been fired—one last December in Florida, one several years ago at sea near the equator, and the rest at White Sands. One of them, Viking XI, set an altitude record for single-stage rockets of 158 miles. With Viking-borne research instruments, NRL has conducted 38 upper-air experiments: 3 cosmic radiation, 5 solar-radiation, 8 pressure, 6 temperature, 3 density, 2 composition, 3 ionosphere, 6 photography, and 2 wind-velocity experiments.

The 49-foot Viking, with all its capabilities, was so complicated to manufacture and launch the firings had to be held down to a budget of about two a year. Accordingly, ONR-NRL began using a smaller and less costly vehicle, the "Aerobee," which was already being built for the Navy by Aerojet General Corp. This is a 20-foot single-stage rocket that can carry a 150-pound research load upward to about 70 miles. A more recent version, the "Aerobee-Hi," developed jointly for the Navy and Air Force, has soared to 163 miles. The latter rocket is now carrying the burden of upper-atmosphere research, along with 10-foot "Deacon" and "Cajun" rockets which are carried part way aloft by balloons ("rockoons") or aircraft ("rockairs"). It is planned to fire a large number of Aerobee-Hi's and air-launched rockets from widely separated geographic locations during the International Geophysical Year.

It will be noted that throughout these 11 years of rocket development and high-altitude flights, the prime interest of the ONR-NRL team has been basic scientific research—finding out more and more about the envelope of atmosphere that surrounds the earth. And that is precisely the announced objective of the upper-atmosphere program of the International Geophysical Year, and the reason for Vanguard.

In This Issue

COVER PHOTO: The six chiefs of Naval Research. Left to right, top to bottom - VADM H. G. Bowen (1 Aug. 1946-31 Oct. 1946), RADM P. F. Lee (1 Nov. 1946-30 June 1948), RADM T. A. Solberg (1 July 1948-30 June 1951) RADM C. M. Bolster (1 July 1951 - 30 Dec. 1953), RADM F. R. Furth (30 Dec. 1953-31 Dec. 1955), RADM Rawson Bennett (Jan. 1956-)

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