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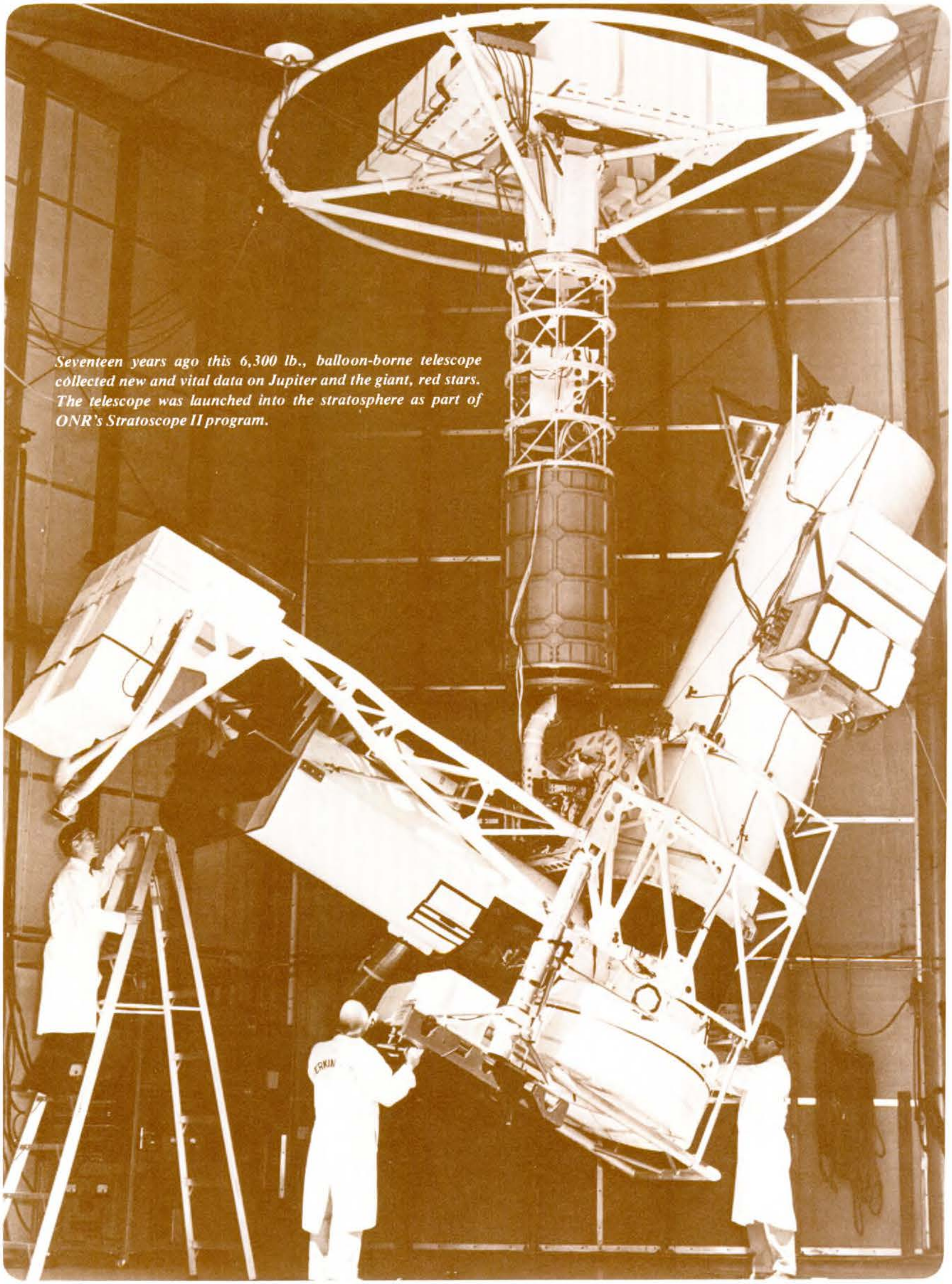
National Academy of Sciences President Speaks On
Future of American Science

See Page 4



Seventeen years ago this 6,300 lb., balloon-borne telescope collected new and vital data on Jupiter and the giant, red stars. The telescope was launched into the stratosphere as part of ONR's Stratoscope II program.

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ARTICLES

DEPARTMENTS

About Our Cover

A P3A Orion antisubmarine patrol plane keeps watch on the USS Pickerel during exercises in the Pacific. Today the Navy is equipping the P3C and P3A aircraft with the latest instrumentation for submarine detection and tracking. See article on page 14.

Naval Research Reviews publishes highlights of research conducted by Navy laboratories and contractors and describes important naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 733, Office of Naval Research, Arlington, Va. 22217. Requests for subscriptions should be directed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. The issuance of this periodical approved in accordance with Department of the Navy publications and printing regulations.

The Future of American Science

Introduction

by

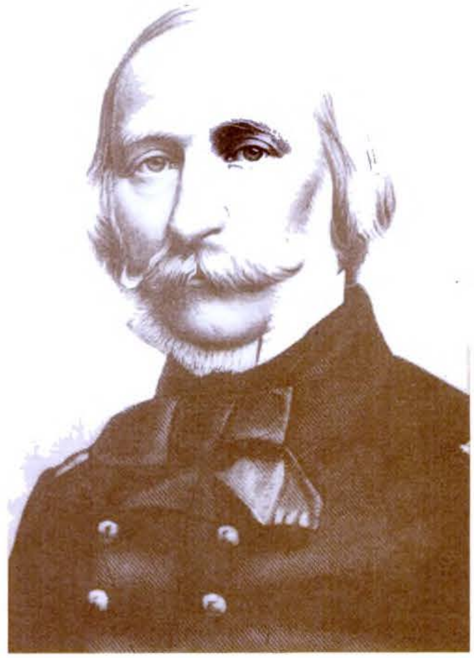
RADM A. J. Baciocco, Jr., USN
Chief of Naval Research

In 1976 the Office of Naval Research celebrated its Thirtieth Anniversary. One of the events commemorating the occasion was a symposium entitled "Science and the Future Navy." A joint effort by ONR and the National Academy of Sciences, the symposium differed in one important respect from previous anniversary celebrations—the papers dealt with where we are going in science rather than where we have been. In other words, through a careful selection of speakers and topics we attempted to illuminate the technical challenges and opportunities facing the Navy and the nation in the years ahead. The reaction to the theme of the symposium and to the individual presentations was so positive that we subsequently initiated discussions with the National Academy of Sciences aimed at identifying some mechanism whereby a similar dialogue between the nation's top scientists and Navy personnel could be continued on a regular basis. These discussions ultimately resulted in the establishment of the Charles H. Davis Lecture Series, jointly supported by the Office of Naval Research and the National Academy of Sciences and at present scheduled to be given twice each year to the students and faculty of the Naval Postgraduate School and the U.S. Naval War College.

The decision to establish the Charles H. Davis Lecture Series is a recognition that the Navy has a vital interest in the health, the innovativeness, and the aggressiveness of American science. It is a recognition that only through the wise and timely utilization of the products and insights of science can the Navy continue to exercise its global responsibilities. It is a recognition that with "wise and timely" utilization comes an ever more complex and technically sophisticated Navy. And, perhaps of greater importance, it is a recognition that not only must the present and future generations of naval officers and enlisted personnel be technically trained, but they must be receptive and enthusiastic in matters of science if we are to realize the operational efficiency and the leverage that science offers and that we must emphasize if we are to maintain our present position relative to the other navies of the world.

It is out of this recognition of the growing need for technically as well as operationally proficient naval personnel that we chose to name the lecture series in honor of Rear Admiral Charles H. Davis. As his friend and colleague, Admiral Samuel F. Du Pont described him: Admiral Davis was "a man of science and a practical officer keeping the love of science subordinate to the regular duties of his profession." Born in Boston, Massachusetts, on January 16, 1807, Davis studied mathematics at Harvard and is listed with the class of 1825. With his appointment as a midshipman in 1823 he began a career that lasted until his death in 1877 as the senior Rear Admiral in the U.S. Navy.

During Admiral Davis' seventeen years at sea he held many important positions and commands. He



RADM Charles H. Davis, USN
(From the collection of the U.S. Naval Observatory)

played a significant role in developing the naval strategy of the Civil War. He participated in the successful operations against Hatteras Inlet and Port Royal Channel and commanded the Mississippi Flotilla, which successfully engaged the Confederate fleet near Fort Pillow and brought about the surrender of Memphis. But, throughout his long career Admiral Davis continued his study of mathematics, astronomy, and hydrology and wrote a number of important papers. He was appointed head of the newly created Department of Navigation in 1862, and in 1865 he became the superintendent of the Naval Observatory—a post he held until his death.

But, Admiral Davis' greatest achievement, and the one that best demonstrates his scientific statesmanship and his long view of the importance of science to the Navy and the nation, was the role he played in the establishment of the National Academy of Sciences under a congressional charter signed by President Lincoln in 1863. Working with colleagues such as Louis Agassiz, Joseph Henry, and Alexander Bache, Admiral Davis played a vital role in the negotiations that led to the creation of an institution charged with fostering the orderly development of science and its use for human welfare and with advising the federal government on matters relating to science and engineering. We believe that Admiral Davis justly deserves the honor we have bestowed on him and that his career symbolizes the objectives of this lecture series.

It was my privilege, first at the Naval Postgraduate School on 6 November 1979 and again at the Naval War College on 14 November, to introduce the first lecturer in the Charles H. Davis Series, Dr Philip Handler, President of the National Academy of Sciences. Dr Handler represents the full sweep of American science and engineering. He is a biochemist by formal training, receiving this doctorate from the University of Illinois in 1939. Much of his distinguished career was spent at the Duke University School of Medicine beginning as an instructor and finally as Chairman of the Department of Biochemistry. In 1969 he became the President of the National Academy of Sciences—a position he still holds. He has authored over 200 technical papers and several books. His honors and awards are impressive and far too numerous to recount here. His very incisive and thought provoking address is reprinted on the following pages.

The Future of American Science

by

Philip Handler
President, National Academy of Sciences

Presented at the
first Admiral Charles H. Davis Lecture

It is a great pleasure to be with you at and to attempt the first Admiral Charles H. Davis Lecture. As you heard from Admiral Baciocco, Admiral Davis was both a most significant figure in the history of the Navy and a founder of the National Academy of Sciences. A splendid portrait of Admiral Davis is incorporated into a superb painting, in the Board Room of the Academy, that depicts President Lincoln signing the charter of the Academy in the company of the founders. You are all invited to enjoy it when next you are in Washington.

It has been quite a year—the 100th anniversaries of Albert Einstein and Clerk Maxwell and the 100th anniversary of the electric light. And it has fallen my lot to participate in special ceremonies commemorating each of those events. The combination of Maxwell and Edison made for one of the most notable transition points in the history of our species—the gift of electrical power and of light to mankind—an event comparable with the beginnings of agriculture, the early refining of metals, and the invention of the printing press. Yesterday's discoveries and inventions are so easily accepted as today's commonplace, and taken for granted, that it is imperative that we seek special occasions to mark the great triumphs of the human spirit. It is that elusive, triumphal quality of the human mind that we term "creativity" that, appearing in especial force in very rare human beings, has blazed the way from the caves of our ancestors—only a moment ago, as geologic time is measured—to the rich fabric of life in the industrialized nations of the world and most particularly in this one.

That is an elitist view of history. To be sure, each human being should be enabled to live life to the fullest of his or her potential. But in a historic sense, only a handful of human beings have been privileged to leave a permanent, positive mark on the course of human events, to have affected in significant degree the quality of life for those who come after. Not all who have done so are known to us. But it would not be difficult to agree on a very small list of those whose legacy has dramatically altered the nature of our own lives: Shakespeare, Galileo, Newton, Darwin, Pasteur, Maxwell, Einstein, Edison, and only a few others. The advent of the electric light and centrally generated electricity constituted what a physicist would term "a change in state" for the entire human race. Nothing could have given more dramatic evidence of that change than the fact that, when Mr. Edison died in 1931, President Hoover contemplated a proclamation that would have turned off all electric power in the United States for two minutes—but then recognized that such an action had become about as unthinkable as asking all American hearts to stop beating for two minutes. But, as others have noted, Edison's greatest gift to us was "the invention of inventions," the gathering and leadership of what we now recognize as the world's first industrial research laboratory, which served as prototype for those that, at General Electric, IBM, Bell Telephone, Du Pont, RCA, Hewlett-Packard, Eli Lilly, Westinghouse, as well as Lawrence Livermore, Los Alamos, NRL (Naval Research Laboratory), and Wright Field, have, in our own time, offered the veritable cornucopia of technology that has totally transformed the nature of daily life and vastly altered the nature of the military endeavor.

The image of Edison that has come down to us was seriously disorted, suggesting a diligent but dreamy putterer who, by trial and error, repeatedly found success. In fact, collectively, the staff of this laboratory was extremely well versed in all of the science that could have been brought to bear on the problems that they chose to address. That trend—the marriage of the most advanced science to the development of new technologies—continues to our time; it is a primary characteristic of this era and nowhere more evident than in the development of military technology.

Only yesterday, the pace of science itself was leisurely and costs were modest. Governments required accurate geological, topographical, and navigational charts and more precise navigational procedures; they were concerned with alloys for coinage, with assays for alcohol (to be sure that the grog wasn't watered or for collection of taxes), with weights and measures for the marketplace, occasionally with agricultural yields, and always with military technology. There were wealthy patrons and even a few governmentally supported institutions for the performance of fundamental research. But there was no thought that the conduct of science, of itself, is a responsibility of a nation-state much less a purpose of society. The First World War altered that view somewhat, and industrialized nations began to develop modest arrangements for the support and the conduct of scientific research.

Modern science arose from the ashes of World War II, which for the first time witnessed in several countries full-scale mobilization of national scientific resources directed to the most critical circumstances of the moment. By integrating fundamental research, applied research, and development, the technological accomplishments were prodigious: not only rocketry, radar, jet engines, the proximity fuse, and nuclear weapons but also penicillin, atabrine, sulfonamides, fractionated blood plasma, treatment of shock burns, and even the beginnings of peripheral nerve surgery.

When the guns were silenced, the demonstration remained alive in the minds of the world's political leadership. Uniquely, North America emerged from the war richer, stronger, and physically unharmed. The report, "Science, The Endless Frontier," produced under the Chairmanship of Vannevar Bush, laid out the United States' credo with respect to science. That report called upon our government to share the faith of scientists that the science and technology that it makes possible are unqualifiedly in the public interest, that scientific knowledge, in its own right, is a good to be cultivated, and legitimately fertilized by public funds. It asserted the deep conviction that applications of that knowledge would make a nation militarily more secure, increase the food supply, improve the public health, expand the economy, and, in diverse ways, enhance the quality of daily life. Recognizing that both the findings and the fruits of science are unpredictable, it averred that the support of science by the very best scientists in all disciplines will, in time, redound to the national interest.

Yet those who planned so well, who seemed—at the time—to be sharing a grand vision, really had a limited sense of the future. To be fair, one should note that when the Bush report was written, 35 years ago, atomic nuclei were thought to contain only neutrons and protons, the transistor was yet to be invented, plate tectonics was unknown, Sputnik was a word unknown outside of the Soviet Union, and the man on the moon was a childish fantasy. Pulsars, quasars, and black holes were yet to enter the consciousness of man. Few of us had heard of ecology; the living cell nucleus was a "black box," and no one had yet spoken of molecular biology. And so, the Bush report looked forward to a happy day when the total support of fundamental and applied research and development by the U.S. Government, including military R&D, might be as much as $50 million annually—by now, an underestimate by almost three orders of magnitude. So much for predicitions!

The principal features of the American system

"There is a tide in the affairs of men,
Which, taken at the flood, leads on to fortune;
Omitted, all the voyage of their life
Is bound in shallows and in miseries.
On such a full sea are we now afloat,
And we must take the current when it serves,
Or lose our ventures . . . "

—Shakespeare

for support of research and development emerged rapidly. Federal agencies developed competitive mechanisms for the award of research grants to individual investigators. The peer review system assured democratic accountability for the quality of the judgments thus made and, *pari passu,* the universitities collectively became the primary locus for basic research. The funds so provided made possible, on campus, much of the science physical plant as well as support for faculty, graduate students, post-docs, instrumentation, supplies, and travel.

A limited number of special laboratories were created with purely scientific missions, usually centered about one or more major pieces of research equipment—an accelerator, a telescope, or oceangoing vessels, for example. In this "big science" category may also be included several of the great industrially sponsored laboratories—the National Institute of Health at Bethesda and a few others. Science rapidly grew more sophisticated and, hence, more expensive, so that, within two decades, federal funds became the principal support of both private and public universities that aspired to front-rank fundamental research.

Applied research and development proceeded somewhat differently. The military services developed powerful in-house laboratories that they operate themselves, as did the AEC, (Atomic Energy Commission) and the Space Agency. But all came to rely on industrial laboratories for major aspects of their programs. The NIH (National Institute of Health) and the USDA (United States Department of Agriculture) also grew powerful in-house capabilities but came to rely on academic laboratories for the bulk of their programs.

Support of fundamental research by the federal government now totals $3.5 billion per year. And that endeavor, in turn, serves as the essential, intellectual substrate for $30 billion of federally funded applied R&D and for an effort of equal magnitude sponsored and conducted by industry in its own laboratories. Surely, I need not enumerate the fruits of that enterprise.

Our culture proved to be highly stimulating and supportive of this endeavor. Our national research enterprise has been spectacularly successful in all disciplines and was never more productive than today. And yet, not all is well with our research enterprise. That immensely productive system carries on—but in some disarray, disorder, even despair. And if we do not turn the circumstances around, the national future might well be compromised.

The fortunes of war gave to the American

"That immensely productive system carries on—but in some disarray, disorder, even despair..."

scientific community almost two decades of a headstart into the modern era; in the 1950's American science was surely three quarters of the world's total. As Japan and the nations of Europe emerged from the debris of World War II, they developed scientific enterprises of their own, each in a pattern reflecting its own cultural history. In almost every country, universities again became significant instrumentalities for the conduct of scientific research. But in Germany, France, Japan, and the East European nations, powerful freestanding institutes are the principal loci for front-rank research.

In fundamental science, much the same problems are engaging the attention of the foremost practitioners of any given discipline regardless of their national homes. But I am uneasy that we are gradually losing touch with the research communities of other countries. They are beginning to develop styles of thought and methods significantly different from ours, and it behooves us to make the effort necessary to remain apprised of their trends and directions. By now, the relative role of American science on the world scene has diminished considerably. We are perhaps one third of the world total, West Europe and Japan together constitute a second third (although Japan spends disproportionately little on basic research), and the East European nations together represent a more or less equivalent third major bloc.

The annual announcement of Nobel Prizes continues to give us chauvinistic national cheer. You should know that the European, Japanese, and Soviet research institutes have been tooling up with remarkable care, skill, and intensity. Their science grows ever more impressive and competitive, their research institutes ever more powerful. I had the privilege of visiting two research institutes in the Soviet Union a few weeks ago: the Kurchatov Institute, which is the site of their experiments with the tokamak, the instrumental arrangement whereby they hope to achieve magnetically confined fusion; and the Shemyakin Institute, devoted to general biochemistry. As a scientist I rejoiced in the remarkable facilities that these two institutes enjoy, their superb instrumentation, the abundance of technical help. Surely, I told myself, knowledge gained anywhere simply adds to the world's stock, and it matters not where it is discovered. But that was wishful thinking. Although much of science is undertaken for its own sake, it is a competitive enterprise; the rewards come to those first to learn, to understand, and to apply.

What gave me pause was the discovery that , for the first time, dozens of graduate students are working in these two institutes, engaged in their thesis research. That is a completely new development for the previously highly directed, hierarchical research institutes of the Soviet Union. They are now blending those aspects of research and education in science that have been so fruitful in our system with the organizational arrangment and facilities that they had developed earlier but that, heretofore, never rivaled ours in performance or productivity.

I had always considered their system to be bureaucracy-ridden, with a very heavy governmental hand imposed upon the management and conduct of their institutes. The reality is that each institute defends its budget request every five years, and an undifferentiated overall appropriation is given to the director and his colleagues, who are then free to utilize the resources thus made available as best they see fit for the next five years—at least, so they tell me. That strikes an American scientist as remarkably like his secret closet fantasies! Much the same approach is utilized for the applied research laboratories of the mission-oriented ministries, while their major expenditures for development are controlled in a manner more like ours. This circumstance is made all the more painful by knowledge of the fact that, while the funds available for science in other countries, particularly the Soviet Union, continue to grow in real terms, the resources available to the average American scientist have declined almost by a factor of two in the last decade. Moreover, governmental bureaucracy is exercising an ever more detailed control of the conduct of fundamental research even in the laboratories of universities, a circumstance that appears to worsen almost daily.

What is sad to note is that the bureaucratic encroachment on our research enterprise and its inadequate financial support reflect not so much an altered view of the importance of science in our national life as they do the erosion of trust, the decline of confidence in all the established institutions of our society.

Nor is that all. In small science, not dependent on major instrumental facilities, West European science is in the doldrums, largely because of the impact of inflation. However, while the political unification of Europe may be proceeding haltingly, the scientific unification of Europe proceeds apace. A decade ago every European scientist found it necessary to spend at least a year in the United States, and there was a flurry of planning of cooperative research between American and European laboratories. But today, driven by the high costs of major scientific instruments, those relationships are being replaced by a network of cooperative endeavors within Western Europe itself. And the pooled resources of Europe are comparable with ours. Increasingly, national barriers cease to confine European science. And as their sense of unity, their common strategic planning waxes, the strength of their scientific relations with this country wanes. That makes particularly ironic the decline in the number of young American scientists who can arrange a meaningful experience in the European laboratory—when the benefits of such experience are now greater than ever.

"Creativity is easily smothered by the niggling red tape in which the American research endeavor is now enmeshed. Scientists work well on their toes—not on their knees."

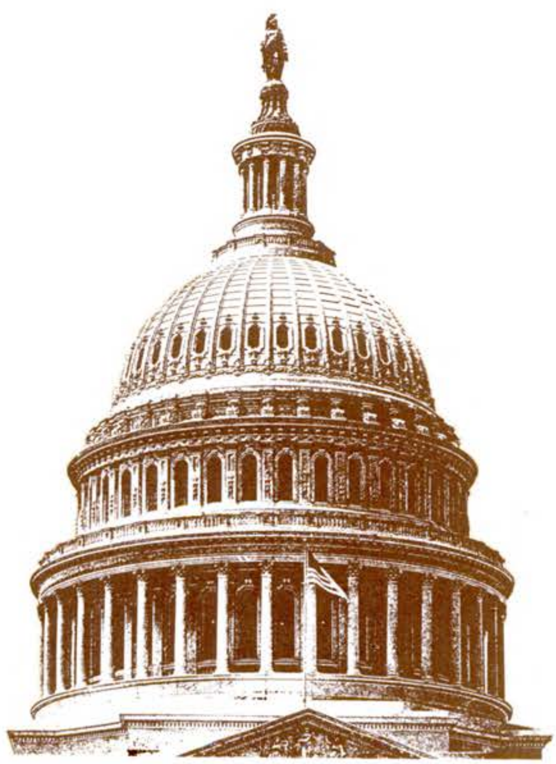
American science is still at the forefront of all disciplines, and it is prodigiously productive—but patently we shall soon have to look to our laurels. As each year we devote an ever-decreasing fraction of our Gross National Product to research while other nations continue to develop their capabilities, I can too easily imagine a scenario in which we congratulate ourselves on our current crop of Nobel Prizes for *yesterday's* research while science elsewhere overtakes and surpasses ours. Much of the creative attention of our investigators has been deflected from science itself to the search for its funding and to diverse, increasingly stringent, and vastly annoying constraints imposed on the use of those funds once they have been obtained. For too many scientists much of the joy has been removed from what they should be doing and that must certainly reduce their productivity. Creativity is easily smothered by the niggling red tape in which the American research endeavor is now enmeshed. Scientists work well on their toes—not on their knees.

Support of scientific research by government meant that, inherently, it was to be subject to a tension that has characterized American society from its beginning—egalitarianism versus elitism, in this case, pressures to assure that funds appropriated in support of research are distributed geographically as widely as possible versus pressures to support only the very best of science wherever it may be. That conflict was inconsequential during the decades of expansion. However, as the fiscal pressures grew ever more severe, that tension takes on ever greater significance. But in science the best is immensely more important than the next best. If our country is to retain its place on the world scene it is imperative that we not take from the best of science to support the second and the third rate in the interest of misguided political egalitarianism.

The knowledge gained by science has been freely shared with billions of persons worldwide who have had some glimpse of the nature of matter, of electricity and electronics, of DNA and genes, of plate tectonics, of photosynthesis and brain hormones, of what we are and where we are and how we have constructed the man-made world. That life experience—faith that what is not now understood will be learned tomorrow—stands in contrast to centuries of mysticism, superstition, and black terror. It is easily worth all that mankind has spent on the scientific enterprise.

It is certainly equally arguable that science-based technology has eased and enriched the personal lives of billion of humans, albeit in varying degree. No end to that process is in sight. It has been the great technological triumphs—television, communication satellites, jet aircraft, computers, better weather forecasting, antibiotics, vitamins, steroids, the pill antihypertensive agents, improved diagnostic and surgical procedures, insecticides, and herbicides—that engendered the large-scale public support of science. Our lives are pain-free and rich in experience beyond the imaginings of the past. That technology has also quickened the pace of history—for good and for ill. And it happens before our eyes.

No aspect of our affairs has been more dramatically affected by technological advance than the military—as you known better than I. But the process has just begun. As a sample, here is a statement that I sent to *SIGNAL* magazine, a few weeks ago, at their request:



The Impact of Electronic and Communications Technology in the Decade of the 1980's

The impact of electronic and communications technology on both military and civilian activities during the decade of the 1980's will be widespread and, in some areas, profound. In my opinion, the most profound impact will be on those functions and services performed by space-based systems and their associated ground terminals (i.e., surveillance, targeting, communications, navigation, earth studies, and environmental monitoring). The driving technologies behind what I see as a significant increase in the role of satellites over the next decade will be the use of scanning electron microscopy or x-ray lithography to produce submicron-scale electronics; thus achieving another plateau in volume reduction and circuit switching speeds. Also, the introduction of charge-coupled devices or magnetic bubbles promises an increase in memory storage capacity that will permit data processing both in the satellite and in the ground terminal. The space shuttle will add some economy and flexibility through the maintenance and recovery of orbiting satellites, as well as a significant increase in some space-based capabilities by permitting the construction of large antennas in space.

The full impact of these new technologies should begin to emerge during the latter half of the 1980's. The increasing use of satellites for tactical purposes and the improvement in coverage, sensitivity, and resolution will greatly enhance the satellite as a peacekeeping tool. However, the effect of this capability on existing military systems and practices is likely to be nothing short of revolutionary. The Global Positioning Satellite will provide navigational accuracy to within a few meters for any platform large enough to mount a terminal. The netting of communication systems will greatly increase the accessibility of data banks. And, the follow-on systems to Seasat-A will greatly increase our understanding of ocean processes and greatly improve global weather predicitions.

The technical problems yet to be solved are largely those of architecture and data management. The growing accessibility of data bases leading to the technical question of privacy for governments, institution, and individuals is likely to be much more difficult to resolve.

As you will know, a set of inhibitory phenomena has begun to afflict industrial research. There is a rising sense of national concern for the decline in innovation in American industry, concern that might not find expression were it not for the extraordinary invasion of the American market by technology designed and produced outside our borders, resulting in a negative balance of payments for technology itself. The origins of that problem are multiple and complex, but I trust that they are not intractable. The facile explanation is "taxation, regulation, and inflation." And therein does lie a considerable measure of truth. The evidence before us are the increased fraction of all American patents registered by non-American citizens, an absolute decline in the number of American patent applications, a sharp decline in the number of publicly funded new technology-based entrepreneurial enterprises, and the negative balance of payments of technology.

The alleged effect of the heavy hand of capital gains tax on entrepreneurial investment needs no recounting here. Inflation has surely driven up the costs of the innovation process to where, in certain industries, innovation has become so expensive and risky that boards of directors find it the better part of wisdom to use available capital in other ways. It is hard to know the extent to which high interest rates have inhibited formation of new, small entrepreneurial ventures. But such ventures are to be cherished and encouraged since they have contributed disproportionately to the overall innovation process. It is both heartening and sad that numbers of our largest industrial corporations have recently begun to invest significantly in such smaller ventures, still controlled by their entrepreneurs. How this new pattern will work out, remains to be seen.

The regulation problem is even more complex. Much of regulation is today concerned with considerations of safety. That pendulum may have swung too far. Too frequently actions have rested on a flimsy scientific base of understanding concerning the magnitude of risks that are to be averted, too frequently the costs to be incurred seem vastly disproportionate to the benefits sought—although none of us knows how to put a dollar value on a statistical human life. What is important in the present context is that the need to attend to the problems created by regulations divert the attention and the resources of a given firm from those more creative endeavors that might have stimulated innovation, increased productivity and profitability, and thereby generated employment while reducing our negative balance of payments.

One almost self-evident aspect of our national circumstance has received remarkably little attention. On one side we confront a potential military adversary whose government controls all aspects of the national life and deliberately invests in military preparation, including R&D, a far larger fraction of its GNP than will our country, in the absence of a military emergency. The challenge to the relevant American scientific community is to assume that we compensate in quality what we are unwilling to do in quantity. That we do so is made possible by the fact that a disproportionate fraction of our most talented physical scientists and engineers are drawn into defense research because of its great intellectual challenges, its exciting technical opportunities, and its relatively generous support. At the same time, those nations that are our most successful competitors in the international marketplace for technology invest and engage in very little military R&D. Their competitive success may rest, at least in some part, on the circumstance that the German and Japanese counterparts of our brightest scientists and engineers, shielded by the American military umbrella, are designing superior consumer products for the American market; no easy solution to that dilemma is evident. As a minimum, we should surely encourage those nations to do more basic research and help fund some of our large science projects.

One great problem within which many of these concerns come into focus is the future of energy supply and use in the United States. The totality of that problem is far too complex to attempt to analyze here. But a few thoughts are relevant:

However, unfair, public disillusionment with revelations of unpredicted but genuine negative impacts of science-based technology has eroded public support for science and technology. Disaffection began with the obscenity of nuclear weapons and of means of biological warfare. Three Mile Island, the DC-10, Love Canal, Torrey Canyon, kepone, vinyl chloride, asbestos, assertion of the carcinogencity of many articles of common commerce, allegations of adverse effects of innumerable pollutants of air, water, and the food supply, have all dampened public ardor for science and technology. Some of our brightest young people now believe that the unanticipated consequences of technology have *already* injected the seeds of inevitable disaster into human affairs. They look askance upon the introduction of any new technology and are fearful, therefore, of further scientific advance.

The obligation of scientists remain clear: To pursue science at its frontiers and to address society's problems including the national defense wherever genuinely constructive opportunity affords. Tomorrow, as yesterday, we shall be judged by our success in meeting both sets of challenges. We would be ill-advised to offer guarantees of success—we can guarantee only that those challenges will certainly not be met if we are not permitted to try.

The intellectual elite in every era has always been pessimistic. But today, concerned that that which can be done will be done, there has arisen an antiscientific, antirationalistic trend that must give us pause. At its ugliest—or most absurd—it finds expression in gurus, tarot cards, and astrology; more importantly, an antiscientific attitude is subtly but perniciously affecting the news media, the intelligentsia, and decision-makers. It must be confronted at every opportunity. I must confess that I fret at the fact that the umbrella of the First Amendment protects publication of astrological charts in newspapers as it does the flood of pseudoscience, faddist approaches to nutrition and unfounded allegations of environmental hazards. I admit that I do not know quite what to do about it. The political safeguard of the First Amendment is too precious knowingly to erode it just because it is abused by those who publish trash for profit. Yet it is just such practices that denied to the Navy the ELF antenna (Project Seafarer) that would have permitted communication with submerged submarines without the need for a trailing antenna. In this instance, "CBS Sixty Minutes" was the principal malfactor, with Dan Rather giving full play to hysterical old ladies in sneakers and to two scientists who have never really worked in this area while falsely accusing of prejudicial bias the committee of distinguished experts, convened by the Academy, that had carefully studied the matter and reported that there is no evidence of adverse biological effects of extremely low-frequency radiation. Moreover, a few weeks ago the *Saturday Review* published a most extraordinarily garbled and erroneous account of this matter, once again deliberately spreading fear by

"It is time to return to the ethics and norms of science so that the political process may proceed with greater confidence."

asserting high risk in the face of a complete absence of evidence to that effect. Why does the humanistically oriented press take renegade scientists to its bosom?

The public image of science and scientists has been distorted by the participation of scientists in public policy formation. Although, beneath the surface, the environmental and the consumer movements may be an expression of anomie, a cry of protest for the sense of powerlessness of the individual educated citizen, a frequent surrogate for that deep-seated complaint is an expression of concern for the safety of some product or technology—such as nuclear energy—based always on an assertion of risk first brought forward by some member of the scientific community. In protesting what they see as excessive risk, some are really urging change in the values of our society, our national life style and form of government. What we must recognize is that, whereas the evaluation of risk is a genuine scientific question, the acceptability of a given level of risk remains a political, not a scientific, question. And when scientists fail to recognize that boundary, unspoken ideological or political beliefs becloud seemingly scientific debate.

It is imperative that those who study technological risk carefully document their conclusions and recommendations. A decade ago it may have been desirable to flag public attention to potential hazards and proceed as if each were a clear and present danger. But that can also set us off in the wrong direction. For example, by so doing, public attention has been fastened on the no more than five percent of all cancer that is caused by the sum of radiation, man-made chemicals, and environmental pollutants, taken together. And it has done so at the expense of resources and talent that might more usefully have been utilized to address the more important mechanisms of carcinogenesis. It is time to return to the ethics and norms of science so that the political process may proceed with greater confidence. The public may wonder at why we do not already know that which appears vital to decision. But science will retain its somewhat diminished place in public esteem only if we steadfastly admit the magnitude of our uncertainities and assert the need for further research. And we shall lose that place if we dissemble or if we argue as if all necessary information and understanding were in hand. Scientists best serve public policy by living within the ethic of science, not that of politics; those who depart from the scientific ethic do disservice to the nation and to public esteem for science and, hence, to science itself. If the scientific community will not unfrock the charlatans, the public will not discern the difference and the nation and science will suffer.

An immense amount of effort has gone into analyzing the nation's energy circumstances and the alternatives that lie before us. It seems as if a major book on the subject appears each week. (The Academy's contribution, a report called *Energy in Transition—1975 to 2010,* has just gone to the printer; it summarizes an analysis in which more than 400 experts from diverse backgrounds have participated.) But the nation is fast running out of time in which to continue the debate. It is not that we know all we need to know—we do not. But it is imperative that we contain the feckless debate concerning the magnitude of the risk of proliferation if we build breeders or engage in reprocessing, the risks involved in burning coal, the economics and feasibility of solar energy, the environmental consequences of a synthetic fuels program, and the myriad other ways that may contribute in various small degrees to the nation's energy supply. Surely this nation is not about to be denied the use of hydrocarbons, coal, and nuclear power for the generation of electricity.

We are certainly agreed as to conservation, even if we have not yet agreed as to the optimal policies whereby conservation may be encouraged. But we already know that conservation itself will not be sufficient, at least not if we wish to maintain a civilization anything like that we have known and enjoyed, not if we hope to continue that economic growth that alone has provided the means for improving the circumstances of those on the bottom of the economic ladder. Nor can we indefinitely remain hostage to a set of foreign powers whose stranglehold on the American economy has deprived us of freedom in the formulation of foreign policy, truly transforming us into a helpless giant. Witness what is now happening in Tehran. It is time to recognize that this country is still blessed with many strings to its energy bow, that we still have many open options, and that we should embark on them posthaste since the penalties of serious energy shortage are far greater than those associated with any available energy technology.

"...the penalties of serious energy shortage are far greater than those associated with any available energy technology."

Harvey Brooks of Harvard University has pointed out that the optimists among scientists continue to see scientific understanding as a worthy goal in itself. We see it as the means for expanding the planet's energy resources base, for converting nonrenewable resources into an infinite resource base, for minimizing human pain and disease, and, in his phrase, as "a means of so managing affairs that the goal of an equitable harmonious world need not be denied to mankind." But the path is perilous. Success demands an endless stream of greater and lesser appropriate decisions with little forgiveness of error. The scope of human choice and freedom widens, at the same time that the possible price of error escalates.

We now live on an overpopulated, competitive, interdependent planet, characterized by a generally similar civilization in the developed world. Yet many another once powerful, prosperious, dominant civilization has disapperared. Please understand that I am concerned for a serious possibility. Few of us gathered here can readily imagine such a fate for America; we cherish the American dream and fancy our country to be exempt from such a fate. Yet to think so is to fly in the face of history. We erode that dream daily by encouragement of children to think of their ethnic cultural backgounds as more precious than their entry into the wondrous American melting pot, by publishers with reckless regard for truth if their publications will sell, by a new-found passion for a risk-free world that can never be and might not be worth having, by living beyond our energy and mineral resource means, and by withholding support from our scientific and technical community. Many nations at the apex of power were inwardly doomed when their willpower began to falter. We should be most careful about retreating from the specific challenges of our age, reluctant to turn away from the frontiers of this epoch.

As James Michener has noted, "each noteworthy civilization has grappled with the great problem of its time." For the ancient Greeks, it was the organization of society. For the Romans, the organization of empire. For the Medievalists, it was establishing their relationship to God. For the Europeans of the fifteenth and sixteeth centuries, mastery of the oceans. For the last two centuries, it has been the scientific understanding of nature and the creation of an industrial society. For tomorrow, the challenge is to continue the latter tasks; to determine how mankind can live in harmony on this globe; establish stable, permanent relationships to its finite shrinking resources as well as with infinite space; and to enable achievement of the individual potentials of human beings as we reduce the ravages of disease. To those ends we shall need all the science we can manage. If, instead, foolishly intent on a risk-free society, we succumb to a national failure of nerve, if we always heed the naysayers, then again Shakespeare will have been proved prescient. Let me remind you of his lines:

"There is a tide in the affairs of men,
Which, taken at the flood, leads on to fortune;
Omitted, all the voyage of their life
Is bound in shallows and in miseries.
On such a full sea are we now afloat,
And we must take the current when it serves,
Or lose our ventures. . . ."

Whatever other policies we follow, we can be unabashedly optimistic concerning the prospects for continuing great discoveries in science. Indeed, a century or two hence, this time may well appear to have been the heroic age of science in most disciplines. And yet, in every discipline the principal questions remain. This extraordinarily successful enterprise repeatedly pierces the veil of ignorance to reveal some elegant, unanticipated structure or arrangement—while making evident a host of additional, more subtle questions, offering ever greater challenges and opportunities.

Our current malaise, then, stems from a few bad experiences and from the time delay in meeting the high hopes and expectations raised in the minds of those who appreciate the great power of science and the force of technology. Those expectations have taken on a new light as science has also revealed the true condition of man on earth. I see no alternative but to address vigorously the principal questions of science itself and to use our ever-widening understanding and increasingly sophisticated technology with grace and charity and wisdom.

For myself, I retain my faith that science, which has revealed the most awesome and profound beauties we have yet beheld, is also the principal tool that our civilization has devloped to mitigate the condition of man. ■

Adaptive Decision Aiding in Tactical Operations: an Application to Airborne Antisubmarine Warfare

By
Amos Freedy, Peter C. Gardiner, and Antonio Leal

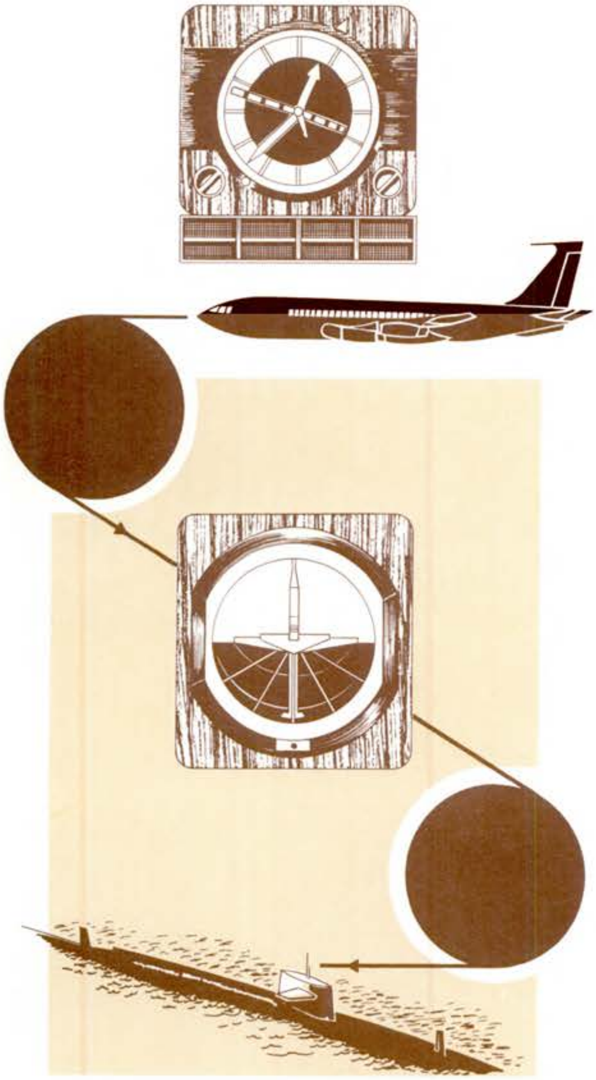
This paper presents the results of a four-year research program on tactical antisubmarine warfare (ASW) operations. The program has been supported by the Defense Advanced Research Projects Agency (DARPA), the Office of Naval Research (ONR), and the Naval Air Development Center (NADC) with the objective of developing a way to aid decision makers faced with making rapid responses in a dynamic environment.[1,2,3] The research program produced adaptive mathematical decision models, operating software and evaluation data, as well as demonstrated an application in the P-3C aircraft for airborne tactical ASW decision-making.[4]

Tactical Antisubmarine Warfare

Tactical operations are becoming increasingly sensitive to the quality of decision-making. Modern technology has made intellectual skills, especially those of judgment and decision-making, the crucial human elements. Large stakes rest on the ability of people to request and process volumes of information, and to make rapid and effective decisions.

Decision-making is the process of converting information into action. Success depends primarily on *what information is chosen and how the conversion is executed.* The difference between a good tactical decision maker and a poor one lies at this point. Every tactical decision maker has available a large number of information sources. Each selects and uses only a small fraction of the available information and, even then, makes incomplete and erratic use of that information. The tactical decision-maker sets the stage for his decision (and its results) by his choice of which information to use and which to ignore. He must then decide how to weigh the information, and how to use it.

The decision tasks involved in tactical antisubmarine warfare are good examples of the type in which evaluation of information is critical. Tactical ASW consists of four major phases: intelligence, detection, localization, and tracking or destruction. Intelligence serves to identify the capabilities of classes of submarines and to locate them within a particular ocean area. Intelligence capabilities include information about the number of submarines in each class, the number and range of missiles (cruise or ballistic), number and type of torpedoes, speed and endurance, noise level, and sonar and



radar capabilities. Tactical intelligence includes information about the number of submarines out of port, the number in each ocean basin, operating tactics, special vulnerabilities, etc.

In the detection phase of ASW, an expanse of ocean is searched to make initial contact with hostile submarines. A wide range of sensors is used to perform this function, including the following: radar and ECM; radio-frequency direction finders; visual sighting systems; magnetic anomaly detectors; passive acoustic methods such as fixed hydrophone arrays, sonobuoy fields, and surface vessel or submarine-mounted passive sonar; active acoustic methods such as active sonar mounted on surface vessels or helicopters; and ocean floor sensors.

Dr. Freedy is Executive Vice President of Perceptronics, Inc., Woodland Hills, California 91367. His work has been directed toward the integration of the concept of artificial intelligence and man-computer inter-reactive systems for continuous decision and control. Dr. Freedy has done extensive work in the development of computer decision aids, publishing numerous articles in this area. He has been acting as Program Director of the research described here and has expanded this concept toward other areas, such as large-scale command and control systems, multi-sensor correlation and information management in advanced aircraft.

* * *

Dr. Leal is a specialist in the areas of artifical intelligence and decision support and decision elicitation systems. In his former position with Perceptronics, he acted as Project Manager in this program. Dr. Leal is currently with ISC, Santa Monica, California.

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Dr. Gardiner is currently an Assistant Professor of Systems Management and Research Associate at the Social Science Research Institute at the University of Southern California, Los Angeles. He acted as a consultant on this project and participated extensively in related applications.

In the localization phase, an object is assumed to have been detected and the objective is to pinpoint its location and identify what it is. The sensors available for this phase are the same as those used for detection, but because the search is much more directed, the patterns of usage will differ. The distinction between tactical intelligence on the one hand, and detection and localization on the other, becomes blurred when a submarine's location can be limited to a particular area.

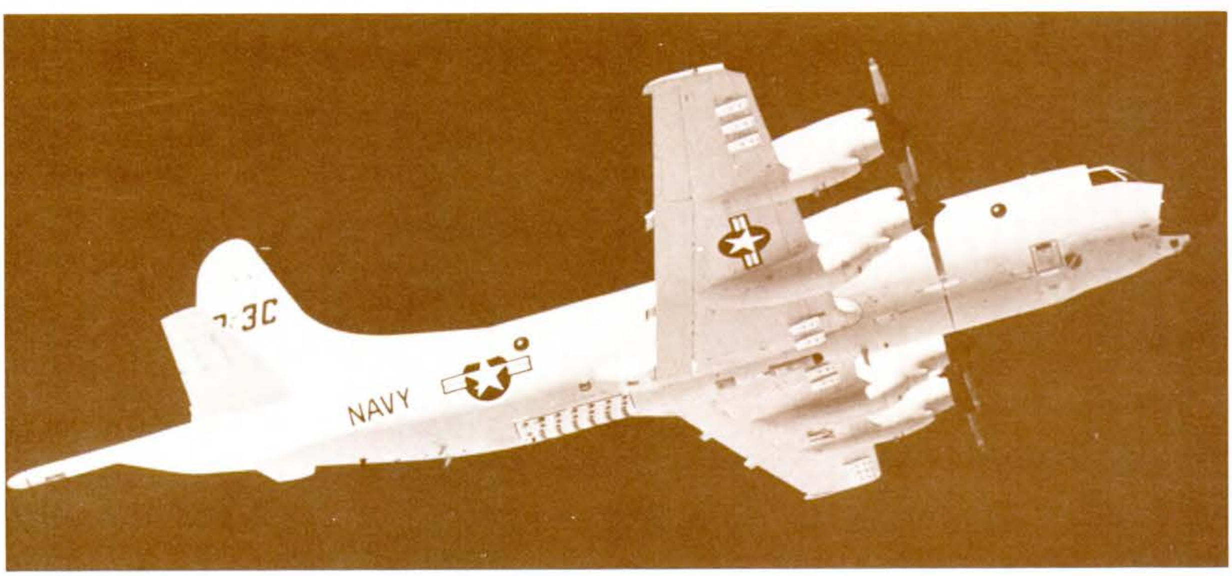
The tracking and destruction functions depend on whether there is a peace-time or war-time situation. In peace-time, it is highly unlikely that a submarine will be destroyed once it has been located and identified. Instead, the submarine will probably be tracked until it no longer constitutes a potential threat. In war-time, however, it is far more likely that an attempt will be made to destroy the submarine.

The P-3C aircraft is a flying platform which performs specific ASW tasks and includes all of the major tactical ASW functions except intelligence. The major function of the P-3C system is to establish ASW sonobuoy patterns and to analyze and evaluate the received data. The command and control section of the P-3C system is composed of two main crew positions: (1) a Tactical Coordination Officer (TACCO), and (2) a number of sensor operators. These crew members control the allocation of sensor resources, the data-processing functions that are being performed on the sensor data, and the data display equipment.

The decision tasks that are associated with the P-3C crew can be categorized into three types: (1) deployment of sensors, (2) data processing, and (3) sensor data evaluation. Sensor deployments involve the allocation of sensor resources (such as sonobuoys) to the specific environment in which the detection, localization, or other ASW tasks that depend on the sensor data are being performed. Deployment decisions by the TACCO are based on the data obtained from previous sensor data evaluations, as well as on sensor allocation procedures, sensor availability, and considerations regarding the achievement of optimal sensor response.

Once the TACCO has deployed a series of sonobuoys, some critical tactical decisions must be made. He must decide what the sensor feedback or lack of it means. Conflicting feedback information can affect decisions. For example, items that influence the noise factor in sensor feedback are bottom bounce, conflicting bearings, loss of contact (the submarine may hide behind undersea mountains, etc), errors in sonobuoy bearings, and submarine course and speed changes. If a contact is lost in the passive search phase, one option is to go active (if permitted by fleet policies). In the localization and tracking phase, the critical factor is the time to make a decision in addition to the "rightness" of the decision. An incorrect or slow decision can cause a contact to be lost.

A typical P-3C scenario would involve the search of a designated area where intelligence data indicates that a target exists. The mission is structured according to a set of general procedures that governs the modes of sensor allocation patterns, sensor types, and the sequence by which various sensors are allocated as information is acquired. In general, the operation begins with the allocation of inexpensive multi-directional sensors that detect the existence of the target within a certain area. Once the existence of the target is established, higher-capability, higher-cost sensors are used. The decision problem of sensor allocation becomes critical as the



sensor resources are depleted, along with fuel supply and mission time, and the decision becomes a tactical decision task. At this stage, careful tactical decisions must be made as each aircraft maneuver is executed. This type of situation is ideal for application of adaptive decision-aiding methodology for the following reasons: (1) the decisions are sequential and repetitive in nature, (2) tradeoffs must be made between the cost and the benefit of available resources, (3) a high proficiency level must be maintained over a long period of time, and (4) the decision environment is highly time-stressed.

The decision environment of the TACCO tends to follow a cycle of tasks. (Figure 1). The cycle begins when the TACCO receives information from the previously deployed sensors. The sensor operator, who filters the raw information coming from the sensing devices, presents the submarine contact information as directed bearings and range circles on the TACCO's main data display screen.

The TACCO evaluates the incoming data and integrates his assessment of the situation by placing "fixes" at the bearing line intersections he believes to be true submarine locations. If he needs more information, he can prompt the sensor operator to obtain more data from any sonobuoy in the water. The decisions he must make at this stage are: (1) which signal is a true submarine signal, (2) which intersection of bearing lines should constitute a fix,

Figure 1. TACCO task cycle.

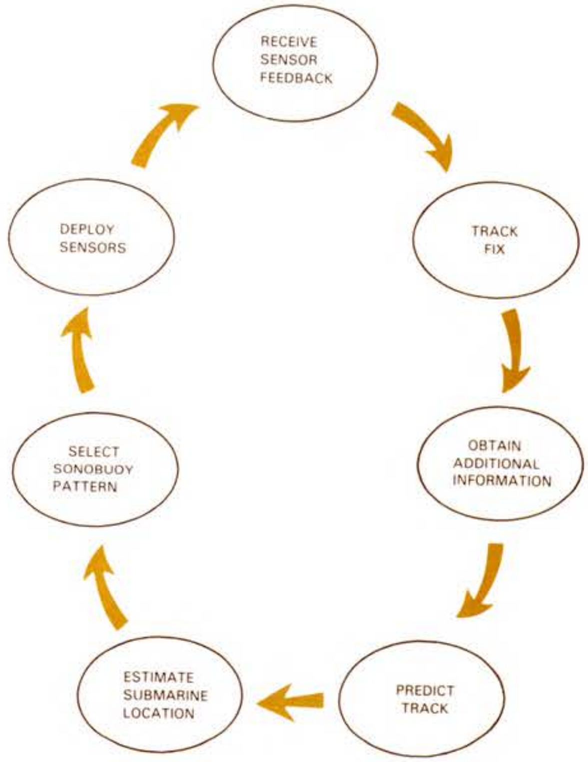


Figure 2. A Tactical Coordination Officer at his work station.

and (3) when to stop asking from more information and to go to the next stage (Figure 2).

He then makes, with the aid of the computer system, the best estimate of the current submarine location. This is given by the system as a probability distribution map which is calculated from the TACCO assessment of the tracks and from *priori* statistical information on submarine behavior. It represents the probability that the submarine will be at various locations at any given time.

The final step of the decision task cycle is the selection of an appropriate sonobuoy pattern and the actual deployment of sensors into the ocean. With the completion of this action, the cycle begins again when new contact information is received. It is this critical step, the selection of a sonobuoy pattern, that has been chosen as the most valuable application of an adaptive decision-aid in ASW operations.

Adaptive Decision-Aiding Concept

Figure 3 illustrates the generalized form of the adaptive decision-aiding system investigated by Perceptronics over the past five years. The upper part of the figure shows the usual control loop of the human decision-maker. He processes decision information, presented on some form of display, and makes choices which both affect the decision environment and alter the information available for the next decision. The lower part of the figure shows the aiding system, resident in a digital computer, that has

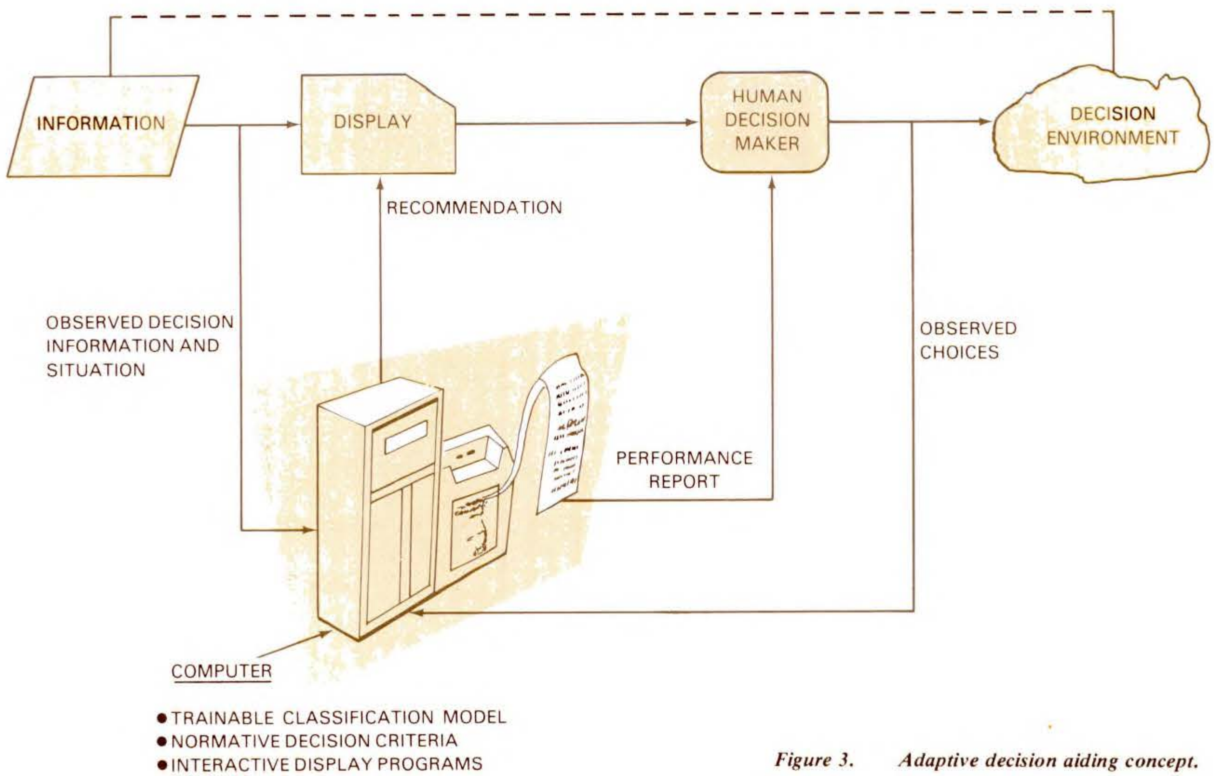


Figure 3. Adaptive decision aiding concept.

as its input the same decision information available to the human operator, as well as the decisions made by the operator on the basis of that information. Using adaptive programs and normative decision criteria, the computer builds a decision model of the decision-maker, and, by means of interactive display programs, provides the operator with on-line recommendations based on *his own preferences* and decision strategy. Later, for evaluation or training purposes, the computer provides a performance report, in which decision-making effectiveness can be separated from the actual, probabilistic consequences of the decision.

The decision aid consists of an adaptive decision model which continuously observes both the decision environment and the decision maker's behavior, learns his decision policy, and makes decision suggestions to him based on the apparent value of the alternatives. Currently, the modeling technique is based on the prediction of decision behavior according to a maximum expected utility (EU) strategy. In simple terms, expected utility is calculated by multiplying the subjective value (utility) of a decision outcome by its probability of occurrence. Previous investigators have shown that the EU model is robust, and adequately represents human decision behavior in a variety of circumstances.[2,5,6]

The adaptiveness of this type of aiding system is realized through the use of a trainable multi-category pattern classifier that is used to estimate a decision-maker's utilities or value structure.[7] As the tactical decision-maker performs his decision task, this on-line pattern classifier observes the choices among the various decision options. The classifier, using event probabilities as inputs, attempts to classify these probability patterns by adjusting utility weights according to an adaptive error-correcting algorithm. In this manner, the pattern classifier tracks an individual's decision-making preferences and learns his utilities.[1] Such an approach has a number of advantages compared to off-line utility estimation. Dynamic estimation observes and models actual behavior rather than responses to hypothetical decisions. It does not interrupt or intrude on the process of decision-making; it responds to ongoing changes in task characteristics and operator needs.

It is evident from the structual description and from the system behavior that the operator-modeling and action-recommendation portions comprise a closed loop, adaptive system. The basic closed loop nature of the utility-modeling program can be seen in the simplified diagram of Figure 3. Closed loop behavior is present since the modeling system compares the feedback of the system output (the model choice) with the desired output (the operator choice) and uses this error as an input to the controller. More important, the system is adaptive to a present function driven by the error signal, but it adjusts its parameters (the utility weights) to minimize succeeding errors. That is, the behavior of the system is modified toward the goal of maximally predicting operator choice behavior.

Aiding the Tactical Coordination Officer (TACCO)

An adaptive decision aid intended to be used by the TACCO aboard the P-3 aircraft has been designed, developed, and integrated into the P-3 training simulators at the Naval Air Developent Center (NADC).[4] The aid makes recommendations to the TACCO concerning the best sensor pattern to deploy. From all of the possible decisions confronting the TACCO in his submarine tracking task, the pattern selection decision has been reduced, through detailed analysis and interviews with experienced TACCOs, to two critical variables:

(1) Sensor pattern type

(2) Number of sensors in the pattern

TACCOs generally do not drop individual sensors into the water except in special cases. The basic unit for sensor placement is a *pattern*. A basic experimental set of patterns has been developed for the decision-aiding prototype system as one of the dimensions of the decision space. The basic pattern types permitted in the decision-aiding model are the following:

(1) Tri-Tac (triangle)

(2) Barrier (straight line)

(3) Wedge (bent line)

(4) Entrapment (circle)

The decision aiding program aids the TACCO in making sensor pattern deployment decisions by displaying relevant information on the TACCO's CRT screen. The aiding takes the form of the following major functions:

(1) Recommendation of the three best sensor pattern configurations and number of sensors to be deployed.

(2) Display of relevant attribute data-values characterizing each recommended pattern.

(3) Indications of the optimal deployment location for the recommended pattern.

The characteristic attributes displayed are descriptors of the patterns that aid the TACCO in making his selection. There are currently four attributes which describe most of the factors taken into consideration in determining the sensor pattern by the TACCO. They are:

(1) Detection Index (DI): A measure of probability of detection of the pattern.

(2) Coverage Area (CA): A relative measure of the projected ocean area covered by each pattern.

(3) Uncertainty Reduction (UR): The amount of reduction of uncertainty on the submarine location provided by the pattern.

(4) Resource Conservation (RC): The effect on aircraft sonobuoy resources of deploying the pattern.

These attribute values are displayed to the TACCO along with the recommendations so that a rational acceptance or rejection of the recommendations can be made. The final aid is a display of the optimal deployment location of the recommended patterns. This display appears on the TACCO video screen as a location point with an orientation mark. This information also aids the TACCO in selecting a sensor pattern to deploy.

Figure 4 shows the TACCO display screen with decision-aiding information near the bottom. The two arrows are possible submarine tracks computed from the sensor information received from operating sonobuoys in the water. The decision information in the table recommends a barrier of 8 sonobuoys (BAR8) as the optimal choice for the TACCO to make in order to keep the submarine in track. The circles "R" in Figure 4 represents the optimal location for this pattern. Second and third choices

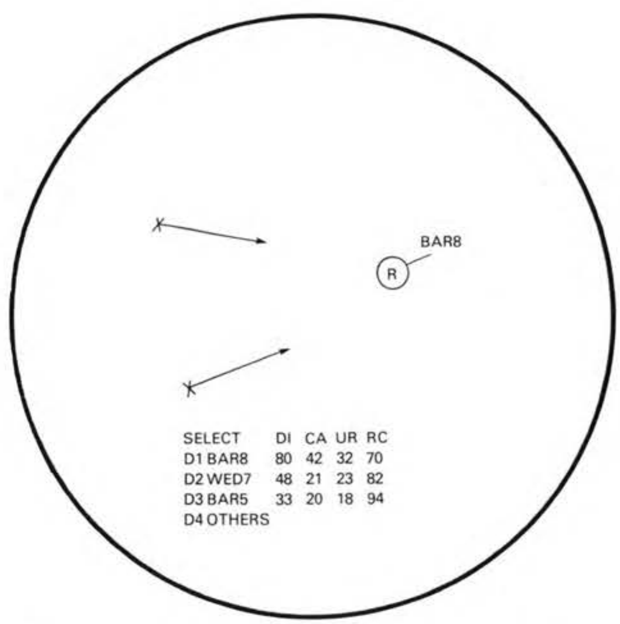


Figure 4. Sensor pattern and placement recommendations.

are a wedge of 7 buoys (WED7) and a barrier of 5 buoys (BAR5) respectively. Each of the attribute values are displayed as feedback for pattern selection. In order to choose a pattern, the TACCO need only press one of the four standard decision buttons on his control panel: D1, D2, D3, or D4. The D4 choice indicates that the TACCO wishes to select a pattern not among the recommendations.

Once the TACCO has accepted or rejected the pattern recommendations, the adaptive aiding system modifies its internal utilities so that they reflect the TACCO's preferences for the four major attributes. In this way, a new recommendation can be made on the next cycle which is closer to the TACCO's current deployment strategy. After a short time, the model will successfully "capture" the TACCO's strategies and aid him accordingly.

Decision Aid Demonstration

The installation and preliminary testing of the adaptive decision aid in the P-3 aircraft simulators have demonstrated its application to TACCO decision-making tasks. Moreover, implementation feasibility within the current computational and task constraints of the system has been demonstrated. With respect to general application, the P-3C development has shown that adaptive decision methodology fits the task domain of general tactical decision-making. It also has demonstrated that such a model can effectively describe the ASW tactical environment and can "capture" pattern selection strategies. The critical factor which has been shown is the compatibility with existing tactical environments. This operational decision aid has been incorporated into the TACCO structure with no detectable interference with the TACCO or with team operations.

With respect to implementation feasibility, it has been shown that feasible hardware/software interfaces can be developed and that the computation functions of adaptive decision aids can be interfaced efficiently into the existing software and hardware computer systems. In particular, the information display and required data input can be accomplished using already existing TACCO multi-purpose data displays and control panels. With respect to actual tactical operations, it has been demonstrated that given an operational computer, adaptive decision aids are able to provide satisfactory response time to operator requests for aiding.

This prototype system thus provides the first step of a transition from basic research to operational systems technology. The current system can already be used as a practical demonstration and evaluation tool of decision-aiding in airborne operations and could easily be expanded to other types of aircraft. Also, implementation of the aid appears feasible on any high-performance aircraft or shipboard operation which involves large amounts of data and repetitive action selection under stress (such as radar intercept operations, etc). Since the aid is operational in a real command and control setting, one of the main questions that can now be studied is the procedure and criteria for evaluating operational crew acceptance of decision aids and evaluating the training requirements necessary to introduce such systems into tactical fleet operations. ■

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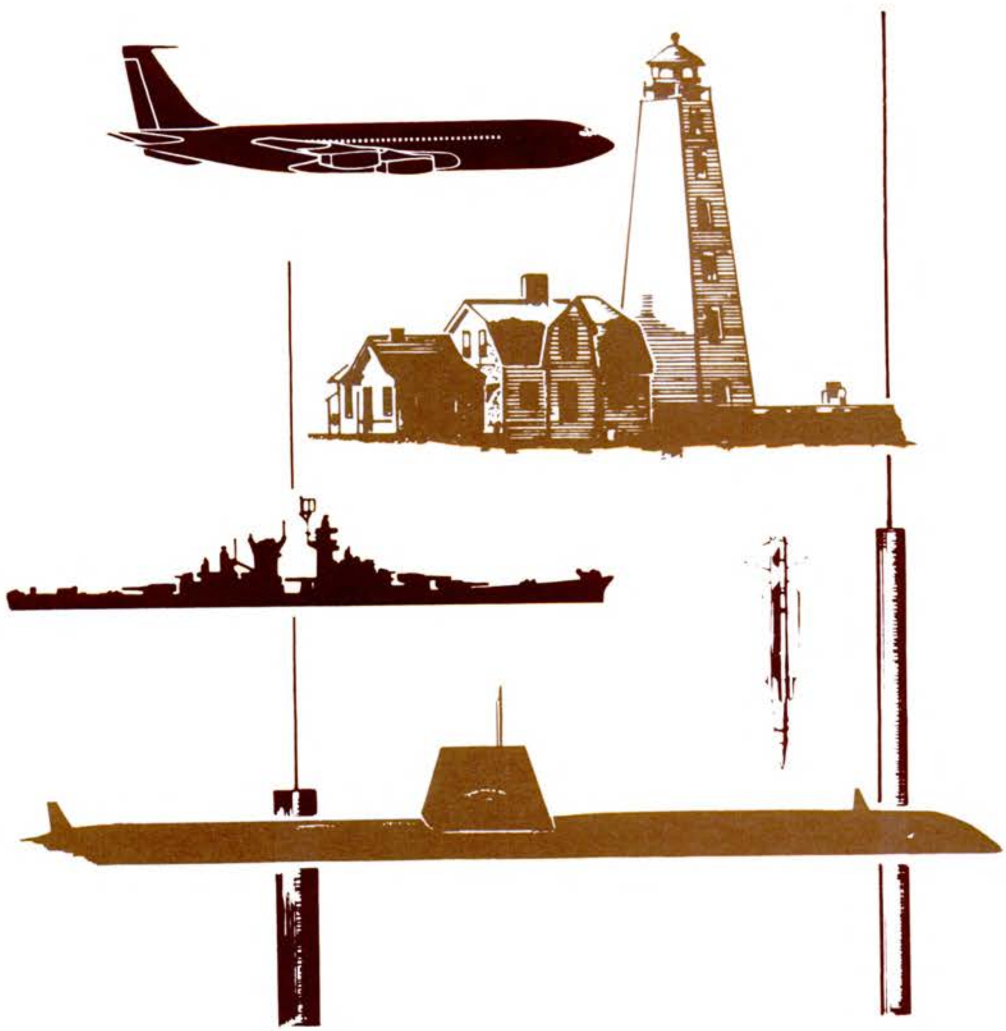
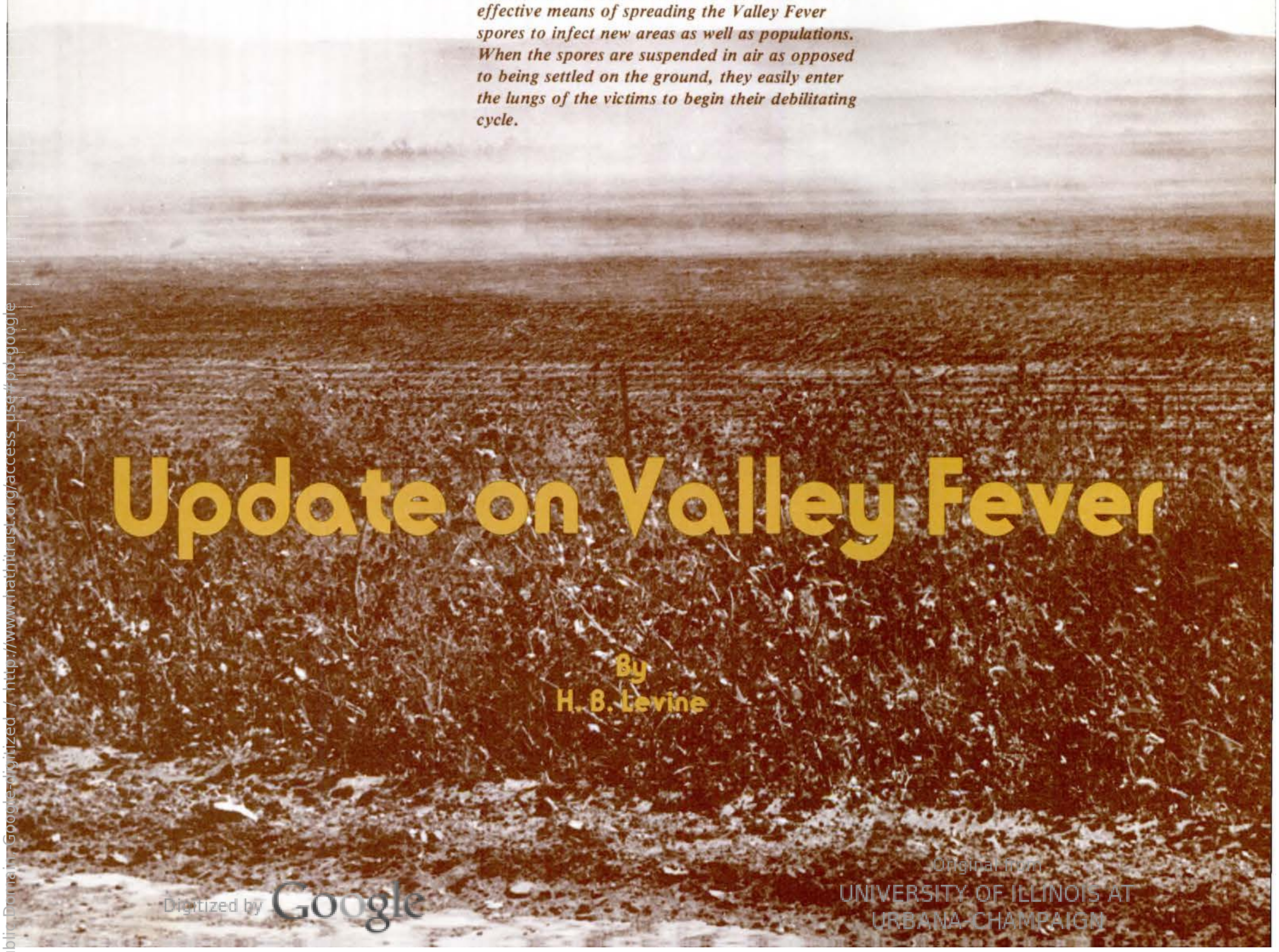


The Armed Forces became intimately aware of Valley Fever during World War II when illness arose among airmen at Mintner Field (Bakersfield, California) and at Basic Flying Training fields in California's San Joaquin Valley: It was then that Dr. C.E. Smith, with the collaboration of the Western Flying Command (later called the West Coast Training Center), began epidemiologic studies that have led to military support of Valley Fever research to this day. The Navy's interest focuses largely on Lemoore Naval Air Station, located south of Fresno, California, in a region endemic for the fungus which causes Valley Fever.

During the last two years there have been 44 serious Valley Fever infections originating at Lemoore, including one which terminated fatally. The cost in man-hours lost is high. In several instances personnel have been hospitalized for longer than six months; inability to perform duties for up to three months is not uncommon in severe infections. The cost in human suffering is incalculable; weakness and proloned debilitation are features that always occur in serious infections. And for each serious infection there are approximately five others that are symptomatic but are not diagnosed or do not come to medical attention.

There was no time to attack the Valley Fever problem academically during World War II. Personnel, needed urgently in a desperate struggle, were becoming incapacitated on the training fields of California and Arizona. Smith did all that was possible at the time. He knew that the offending fungus (called *Coccidioides immitis*) grew in the soil of the endemic regions and that dust, raised by aircraft or sports, or even the most gentle of winds, dislodged the fungal spores (called chlamydospores or arthorospores) into the air. If these then found their way into the lungs, coccidioidomycosis, the

Figure 1. ***In the South West of the United States where Valley Fever is prevalent, dust storms are the most effective means of spreading the Valley Fever spores to infect new areas as well as populations. When the spores are suspended in air as opposed to being settled on the ground, they easily enter the lungs of the victims to begin their debilitating cycle.***



Update on Valley Fever

By
H. B. Levine

scientific name for Valley Fever, could result. Accordingly, Smith convinced base commanders to saturate all ground areas accessible to personnel with heavy oil. Conventional sports were banned (but swimming pools were constructed where money and topography permitted). The numbers of infections then declined markedly (Figure 1).

But the problem remains, and has now even touched America's allies. For example, some personnel leaving Lemoore developed their Valley Fever symptoms after arrival in Asia or Europe. In one such instance that was particularly tragic, the infection, which became apparent in Japan, caused the loss of an eye. Cases originating in the United States have now been reported from Britain, France and Germany. Also, German Luftwaffe personnel training in the United States have reported infections caused by the Valley Fever fungus. The problems this poses in foreign lands are magnified because Valley Fever does not occur outside of the three Americas and hence foreign physicians are not trained to recognize the illness or to treat it. Indeed even in the United States, physicians in nonendemic areas (Figure 2) often encounter diagnostic difficulties.

It should be emphasized that the actual numbers of severe infections are low compared to the total numbers of people exposed as well as to the numbers who experience infection in a mild or asymptomatic form. An estimated 35,000 debilitating infections occur annually in the entire country. There are additionally about 55,000 coccidioidal infections where the symptoms are minor or of short duration. The immediate cause is almost invariably the same in all infections—the patient breathed air contaminated with Valley Fever spores. During the warm, dry months of the year, the spores are discharged into the air and reported illnesses mount in May and June and continue through September to November. To be sure, there are sporadic cases of infection contracted from soil-contaminated wounds and scratches, but the primacy of the respiratory route of infection is clear.

All segments of the population in regions where the fungus is prevalent are at risk, but those in agricultural pursuits, who have close contact with the soil, and people undergoing military field-training, often show a particularly high incidence of disease. Medical officers have reported that at Williams Air Force Base, near Phoenix, the cost of Valley Fever, in terms of man-days of hospitalization, greatly exceeded the combined corresponding costs of the three most frequent acute illnesses—tonsilitis, upper

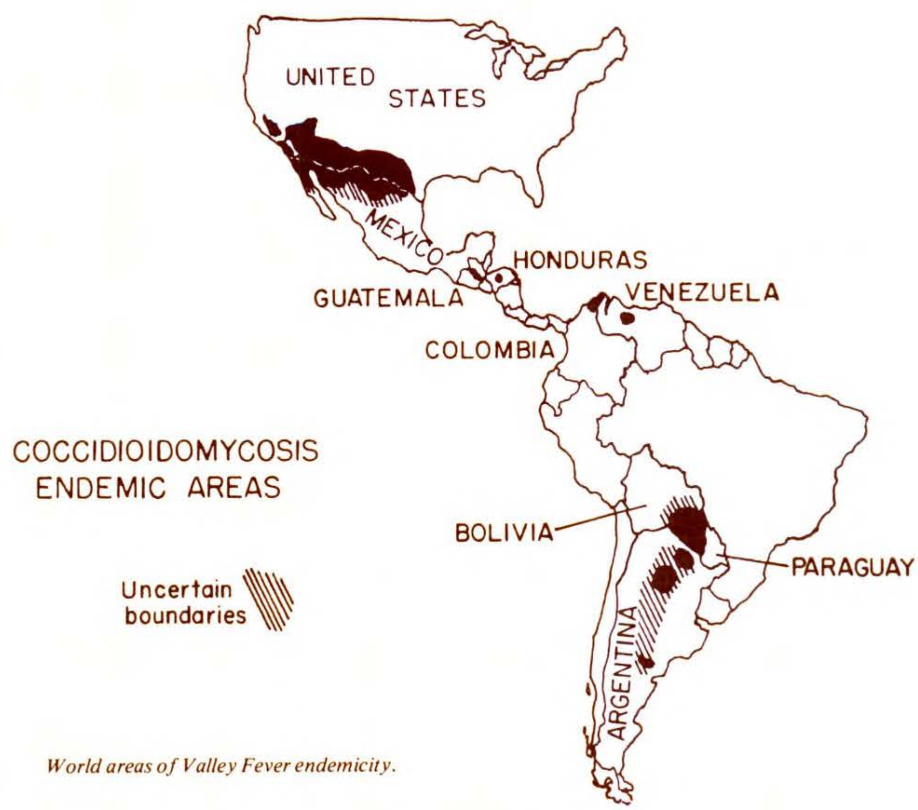


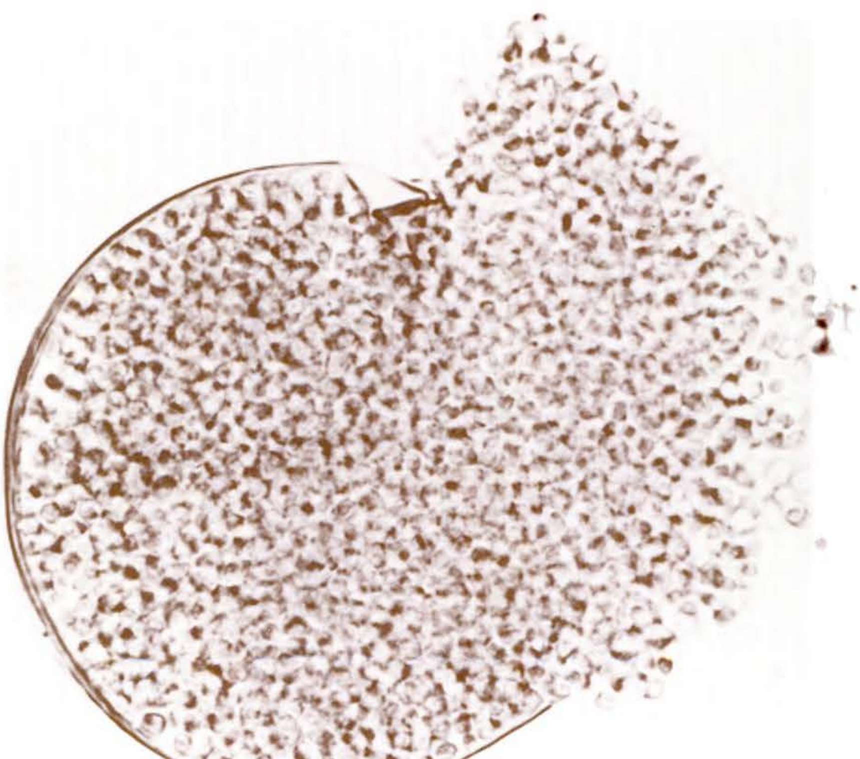
Figure 2. *World areas of Valley Fever endemicity.*

respiratory infections and gastroenteritis—plus all traumatic injuries.

The striking public health importance of Valley Fever becomes clear when it is appreciated that vast populations are exposed; between 60% and 80% of residents in the areas of Bakersfield, Phoenix and El Paso give a postive skin test with spherulin which indicates they had been exposed to the Valley Fever fungus.

The Naval Biosciences Laboratory has been concerned with Valley Fever for more than three decades, and the laboratory has been recognized as a center of excellence in this area of study. Its contributions fall into three categories relevant to military and civilian health: improved diagnosis by means of a new skin-testing preparation, treatment by means of newly developed drugs and prevention by a recently perfected vaccine.

Dr. Levine is Chairman of the Medical-Microbiology Department of the Naval Biological Laboratory, Oakland, California 94625. Through his many publications, Dr. Levine has become an authority on mycotic infections, particularly coccidioidomycosis.



COURTESY OF DR. LUCILLE K. GEORG

Figure 3. ***Rupturing spherule of Coccidioides immitis. Within lesions, coccidioidal spherules can rupture and release endospores which can spread the infection from one location to another.***

Spherulin

The Valley Fever fungus has two forms, one that occurs in the soil and a second that the fungus assumes when it is causing disease. The latter is called the spherule form because the thread-like structure of *Coccidioides* enlarges to a sphere when it invades the body (Figures 3 and 4).

Navy scientists were able to produce the sphere form in test-tube nutrients. It was identical to the sphere form ordinarily seen in lesions. And from these fungal spheres they extracted a substance they called spherulin, which had interesting properties. When a few millionths of a gram of spherulin were injected into the skin, it distinguished between people who had experienced a Valley Fever infection and those that had not. If the individual had been infected, spherulin produced a bump on the skin that lasted for several days. This did not occur if there had not been an infection. Obviously this property aided diagnosis.

There had been a similar material, called coccidioidin, used for this purpose for many years. However, coccidioidin "missed" about 35% of the Valley Fever cases. This was shown dramatically by Dr. David A. Stevens in a well-controlled study at Standford University. His results are summarized in Figure 5. Spherulin is now used widely throughout this country and overseas.

New Drugs

A life-saving drug for Valley Fever was introduced in the mid-fifties by E. R. Squibb & Sons of New York. It was called amphotericin B. As the use of amphotericin B became widespread, however, an alarming side effect was seen. In some patients on prolonged treatment, damage occurred to the kidneys. If the treatment were continued long enough, as was often necessary to save life, the damage became irreversible in many cases.

As a result, physicians generally opted not to use amphotericin B unless the patient was in imminent danger of death or of developing a severe case of Valley Fever. And in such patients, the chance for successful treatment is less hopeful than in early disease.

Clearly, the search for less toxic drugs was of major health importance. Scientists at the Naval Biosciences Laboratory recognized that such a search had to be preceded by the development of an animal model system which would show whether infected animals responded to new drugs or not. The chance of testing unknown drugs in human beings could not be taken without first determining their usefulness in animals.

Credit should be given here to Dr. Lorraine Friedman and Dr. Demosthenes Pappagianis of the University of California at Davis who perfected a mouse model for evaluating the efficacy of drugs in Valley Fever treatment. The Naval Biosciences Laboratory then entered into studies to evaluate drugs that pharmaceutical companies were developing. Three such drugs were found applicable and their influences in animals are outlined below.

Miconazole (Monistat iv, Ortho Pharmaceutical Corporation, Raritan, New Jersey) prevented death in 100% of mice infected with Valley Fever chlamydospores. Other groups of animals, infected at the same time with the same dose of spores, but which received no miconazole treatment, all died. Miconazole prevented the spores from growing extensively in the lungs or other parts of the body and it was this feature that allowed the animals to live. But miconazole did not wipe out the infection. The animals harbored the fungus in low numbers, insufficient to do extensive damage, for months. During this period the natural immunity of the animals further controlled the fungal invasion. So the drug, while not perfect, had the capacity to "buy time" to allow natural defenses to become mobilized. The drug has very few side effects and is now marketed for use in human beings.

Ketoconazole (Janssen Pharmaceutica, Beerse, Belgium) has not yet been investigated in human Valley Fever. But it is 100% effective in saving life in the mouse model for the disease. Most interestingly, in contrast to miconazole, which must be injected three times a day, ketoconazole is taken by mouth. Also, unlike miconazole, ketoconazole eradicates the fungus from all organs of 50% of the animals. Human trials are scheduled to begin in the near future.

Ambruticin (Warner-Lambert, Morris Plains, New Jersey), is an experimental antibiotic still untried in man. It is also administered by mouth and is fully life-saving. Further, at appropriate doses, for prolonged periods, it eradicates the fungus in all animals. It is well-tolerated and produces no serious side effects. A trial in human beings is not yet scheduled. The drug is expensive to manufacture and current efforts are directed at developing manufacturing skills to lower the cost.

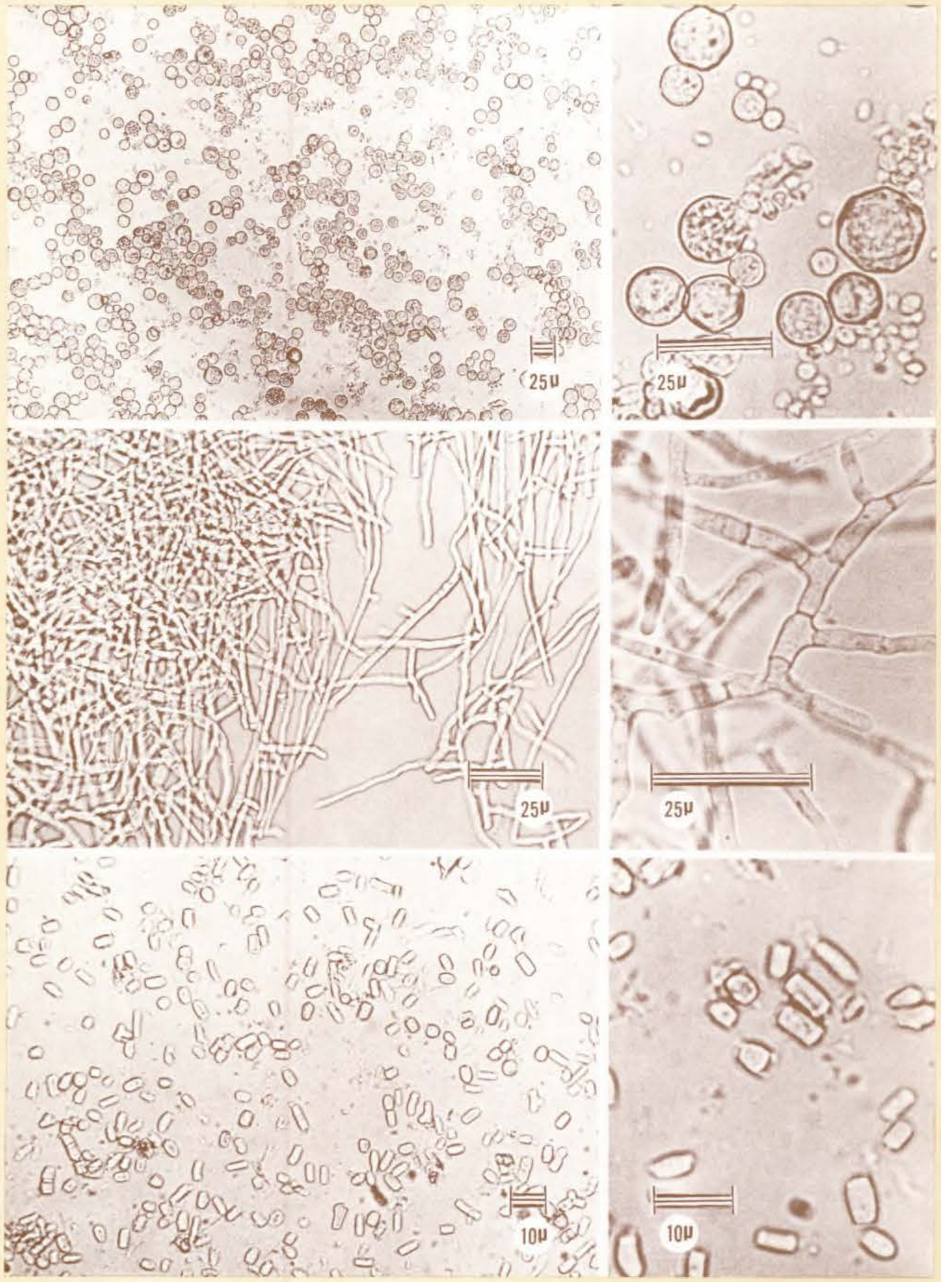


Figure 4. *The growth phases of Coccidioides immitis. In the soil, the organism produces thread-like structures (center). In dry weather, the structures may disarticulate to release spores (bottom) that may become wind-borne. If the spores initiate an infection in the lungs, they change into the spherule phase (top) which is the main form appearing in lesions.*

The Spherule Vaccine

During World War II, Dr. Smith supervised the task of minimizing the extent of Valley Fever in military establishments by oiling the fields. This expediency, of course, could not be applied to the San Joaquin endemic areas as a whole, which is one of the most important agricultural regions of the country. Smith surveyed the frequency and intensity of Valley Fever in different regions of the southwest by skin testing and blood analysis. He made literally hundreds of trips to endemic regions to complete the task. Little wonder his old Ford was nicknamed: "The Flying Chlamydospore!"

Later, Smith and his colleagues, reflecting on their very extensive clinical experience with Valley Fever, inferred that induced immunity played a decisive role in the control of symptoms. Patients rarely experienced symptomatic reinfection after recovery from an initial infection. Even when the first Valley Fever episode was asymptomatic, recognized only by the development of a positive skin test, it was unlikely that a second episode, attributable to reinfection, would occur.

Evidence obtained at the Naval Biosciences Laboratory with experimental animals is in accord with observations pointing to the importance of induced immunity. Mice vaccinated with killed spherules were protected against death from 1,000 spores, compared to 50 spores which were lethal to nonvaccinated animals. Recently an improved lot of the vaccine protected more than 70% of mice against a challenging dose that was in excess of 10,000 spores. In mice, and also in monkeys, vaccination did not prevent infaction; it sufficed only to protect life, to minimize spread of the offending fungus from the lungs to other organs and to enable the animals to restrict extensive multiplication of the fungus in the lungs and throughout the body.

In short, if these properties of the vaccine apply also in human beings, then much of the battle with Valley Fever would be under good control. But one can not be sure that the animal experience foretells the human response. Thus far, more than 80 volunteers have been tested with the vaccine and its safety has been ascertained. Now a trial of the vaccine at Lemoore Naval Air Station is underway to determine the vaccine's efficacy.

The question to be answered during the trial over the next three years stated simply is: Will the vaccine work as well in man as it does in animals? Our hopes are obvious, but, if they don't materialize, other approaches to the problem will be initiated. This is in keeping with the mission of the laboratory.

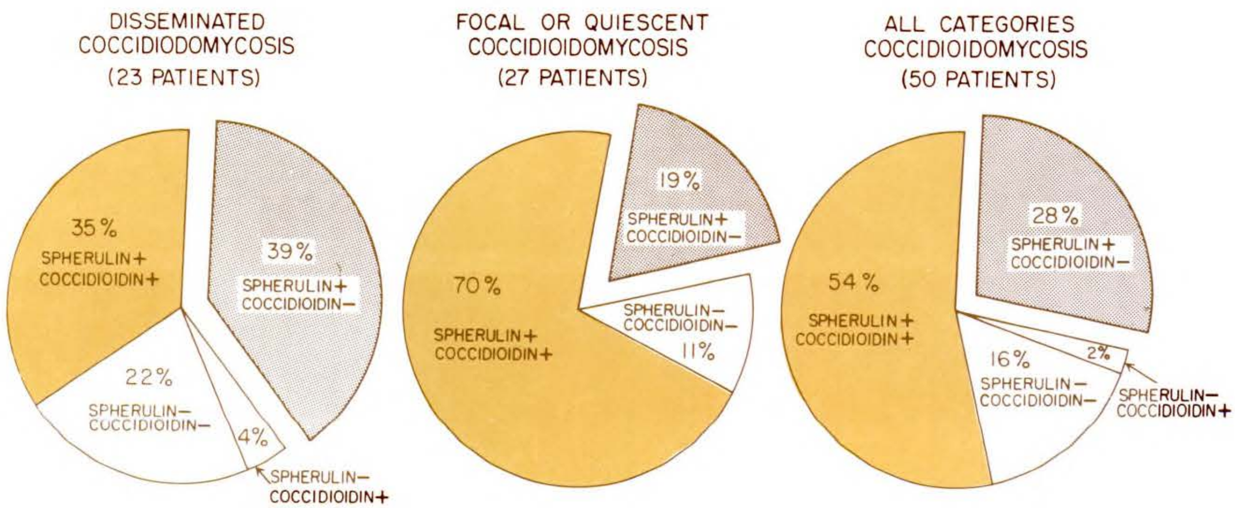
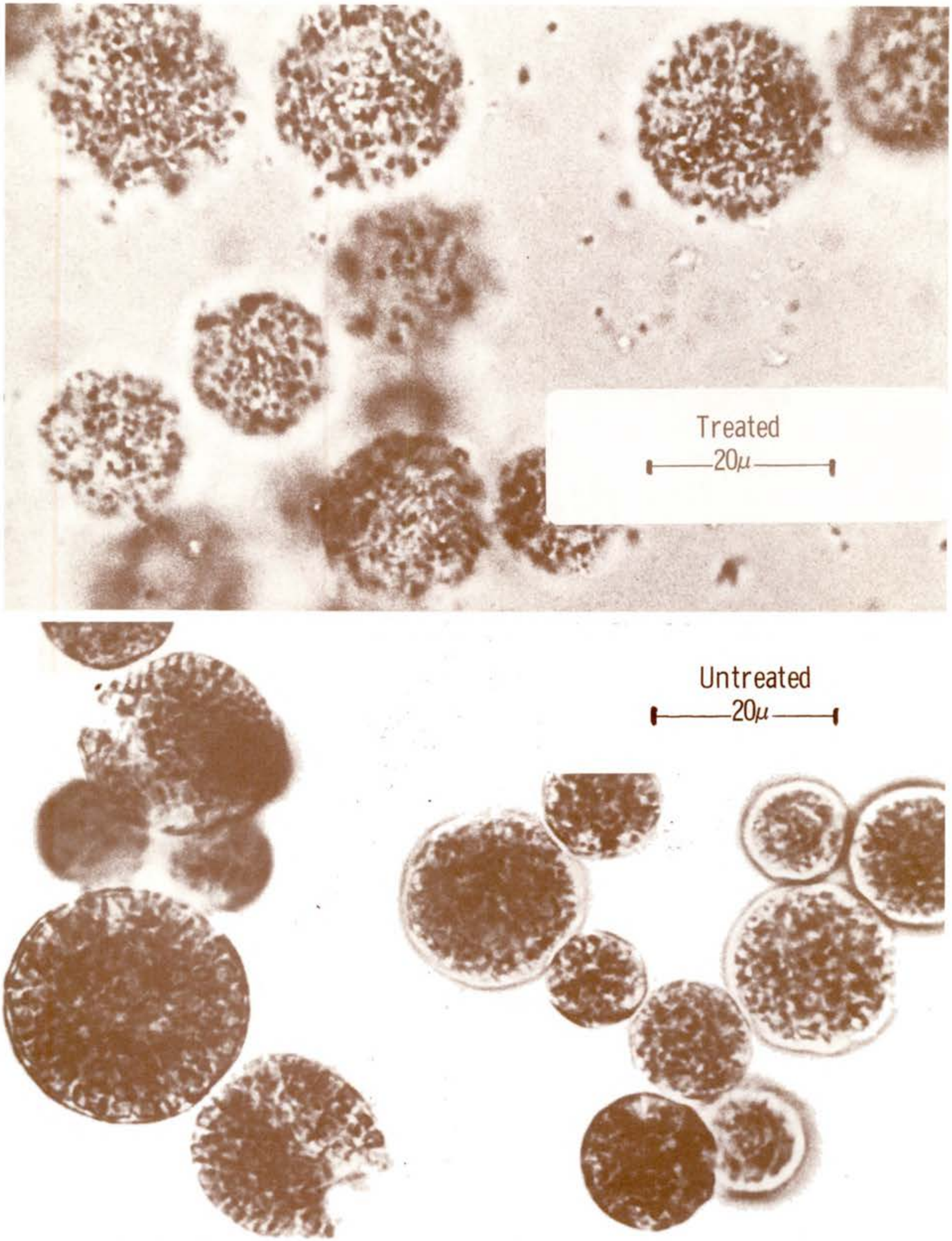


Figure 5. Spherulin and coccidioidin reactions in Valley Fever syndromes.



Scientists at the Naval Biosciences Laboratory succeeded in removing the walls of spherules (top frame). The organisms then lost their capacity to induce immunity. Intact organisms (bottom frame) retained this immunity-inducing property. The immunogens were thus shown to be located in the spherules walls.

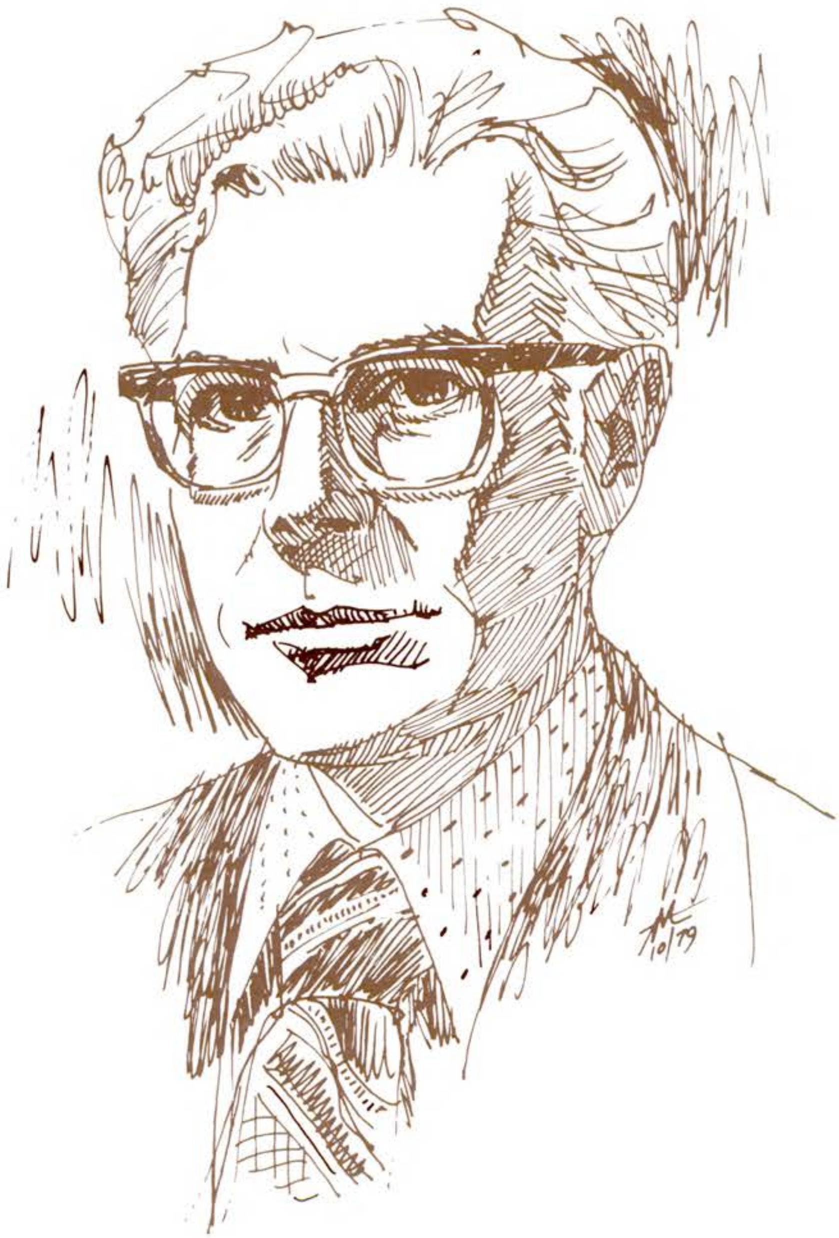
Profiles in Science

Dr. David Turnbull, who is the Gordon McKay Professor of Applied Physics at Harvard, is well known for his outstanding contributions to physical chemistry. His research has been primarily in the fields of crystals, diffusion in solids and liquids, solid state reactions, nature of the glassy state, and thermionic emission.

Professor Turnbull is recognized internationally for his lectures on the nature of the amorphous state and the behavior of amorphous materials. Research by Professor Turnbull and his students has clarified the atomic scale structure of amorphous solids, electroplating, vapor deposition, and irradiation. His early measurements of viscosity with temperature contributed greatly to a better understanding of the mechanism of deformation and associated mechanical properties. Currently he is in the forefront of the research which relates transformation by phase separation and crystallization to atomic transport behavior.

Before joining the Harvard faculty, Professor Turnbull was a scientist at the General Electric Research Laboratory and on the faculty of Case Institute of Technology. The Office of Naval Research has supported his research for many years.

One hundred eighty-two publications as well as the von Hippel Prize of the Materials Research Society and the Acta Metallurgica Gold Medal acclaim his accomplishments. He is a member of the National Academy of Sciences and a fellow of the American Academy of Arts and Sciences.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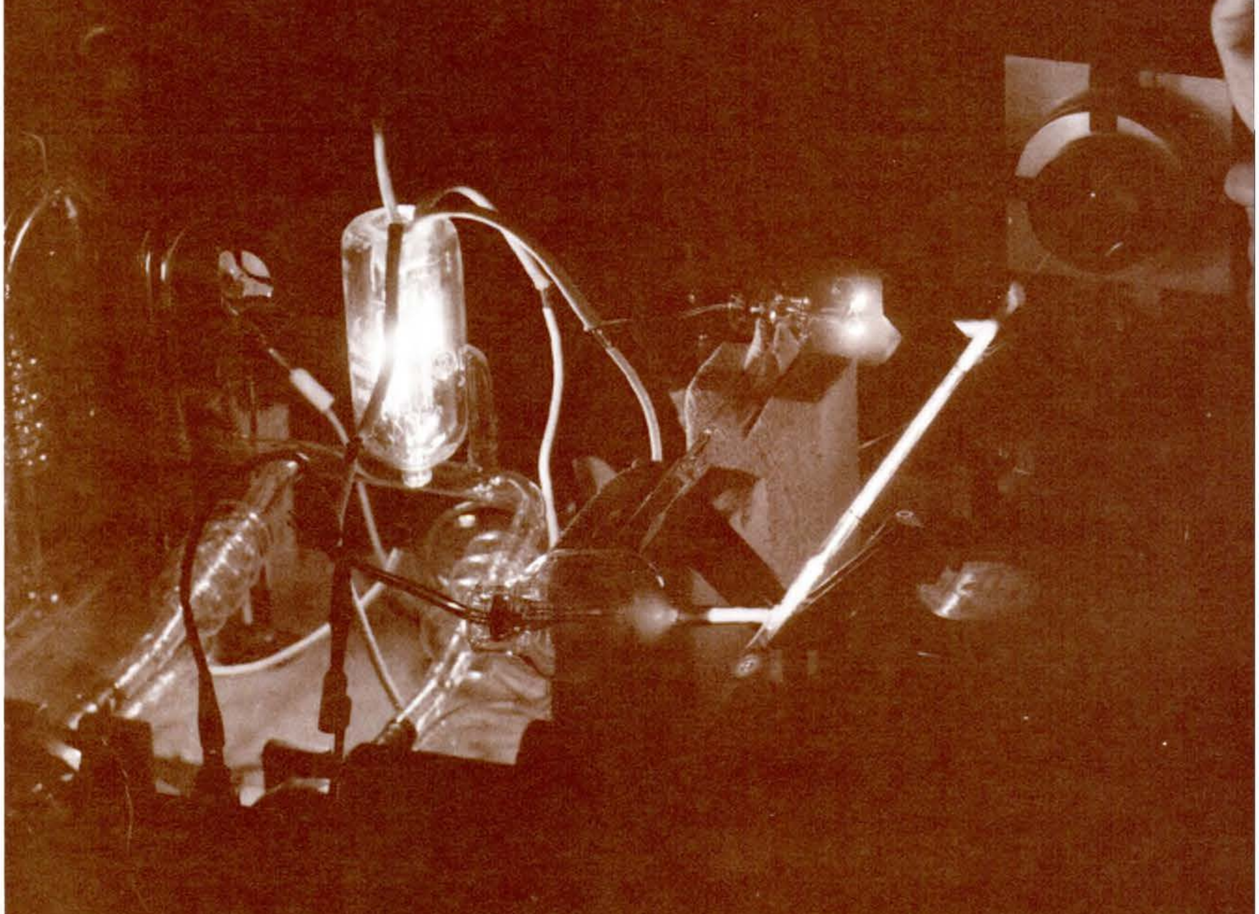
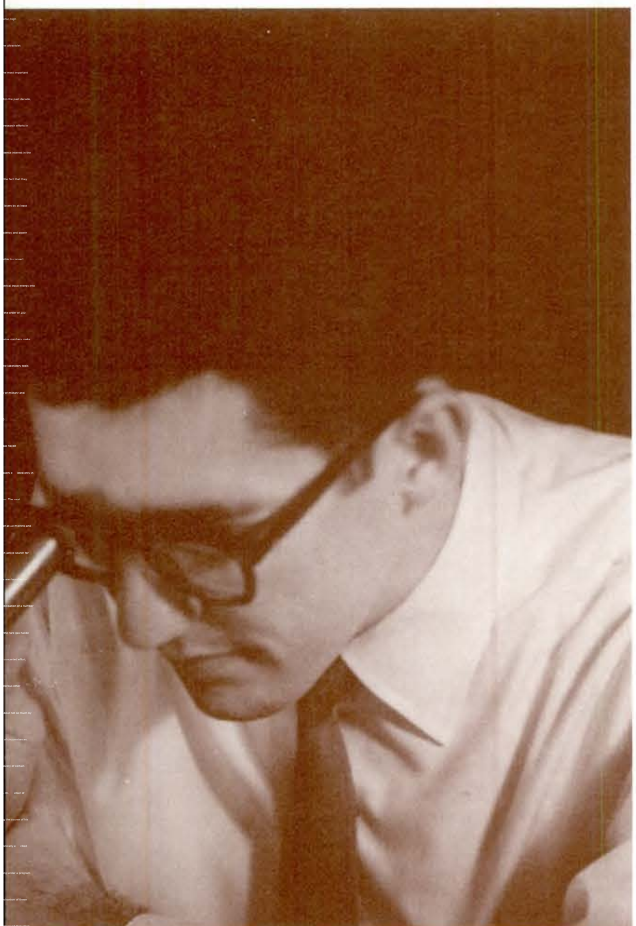
Rare Gas Halides: The Lasers of the 70's

By
N. Djeu





Dr. Djeu heads the Advanced Laser Concepts Section in the Laser Physics Branch at the Naval Research Laboratory, Washington, D.C. 20375. In the past several years, he has been engaged in the research and development of the rare gas halide lasers. For his contributions to that field, he was given the E. O. Hulburt Science Award in 1978.

The rare gas halide lasers are powerful, high pressure gas lasers operating in the ultraviolet region of the spectrum. Possibly the most important class of new lasers discovered within the past decade, they command one of the largest research efforts in quantum electronics today. The intense interest in the rare gas halide lasers stems from the fact that they out-perform the earlier ultraviolet lasers by at least an order of magnitude in both efficiency and power output. With these lasers it is possible to convert approximately 10% of the electrical input energy into light output at a specific power of the order of 100 megawatts per liter. These impressive numbers make them immediately attractive as new laboratory tools and potentially useful for a variety of military and industrial applications (Figure 1).

Prior to the discovery of the rare gas halide lasers, truly efficient high power lasers existed only in the infrared portion of the spectrum. The most notable of these were the CO_2 laser at 10 microns and the HF laser at 3 microns. An active search for efficient shorter wavelength lasers was launched in the early 1970's primarily in anticipation of a number of projected tactical needs. While the rare gas halide lasers are a direct product of that concerted effort, their realization—like that of numerous other technological advances—came about not so much by design as by a happy coincidence of circumstances. In this case, it was the timely discovery of certain chemical reactions by Professor D. W. Setser of Kansas State University during the course of his studies of the quenching of electronically excited metastable rare gas atoms. Working under a program to better understand the basic mechanism of these processes, he and his colleagues observed that when certain halogen-bearing compounds were used as the quenching gas, collisions with the metastable rare gas atoms resulted in chemiluminescent reactions with extraordinarily high photon yields. The laser community quickly grasped the significance of these findings, and it was not long before the first rare gas halide laser was demonstrated.

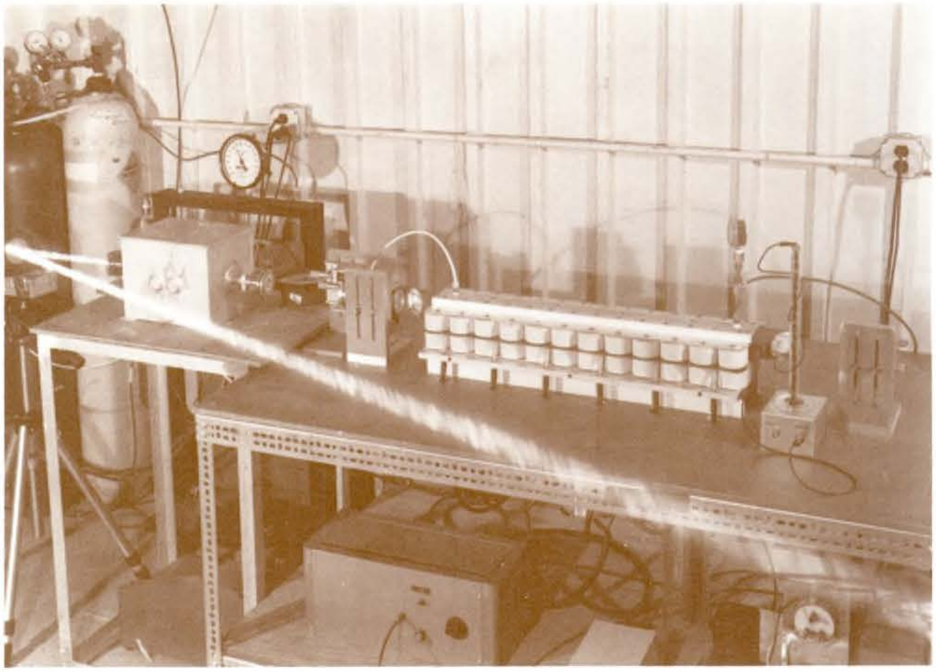


Figure 1. ***The ultraviolet output from the discharge pumped rare gas halide laser on the right is converted into the blue-green region of the spectrum through stimulated Raman scattering in the lead vapor cell at the left. This particular approach is at present one of the leading blue-green sources for an underwater communication system.***

Laser physicists at the Naval Research Laboratory have played a central role in the development of the rare gas halide lasers. They were the first to prove the feasibility of this class of lasers, and then went on to build the prototype of the model now most widely used in research laboratories. More recently, they have dramatically improved the efficiency of a number of these lasers through diluent gas optimization and demonstrated for the first time a proton-beam-pumped rare gas halid laser. In related work, NRL scientists have also carried out measurements of radiative and deactivation rates which are crucial in the numerical modeling of the lasers.

Laser Mechanism

The rare gas halide lasers belong to a broader class generally known as excimer lasers. These are molecular lasers whose lower states are either purely dissociative or only weakly bound. Excimer molecules are ideal laser candidates since their vanishingly-small lower state density virtually assures the requisite population inversion for optical gain. If the unstable lower level should be the ground molecular state, one enjoys the additional benefit of being able to utilize the entire excitation energy of the upper molecular state. This is in contrast to most other lasers, which tend to terminate in states with substantial residual energy and therefore are intrinsically inefficient.

For the rare gas halide lasers, the strongly bound upper state correlates with the ionic species of the separated atoms while the unstable lower state is paired with the neutral ground atomic states, as illustrated in Figure 2. There, the symbols Rg and X stand for the rare gas atom and the halogen atom, respectively. The depth of the ground state potential well varies from nearly zero to a few hundred wavenumbers for the longest wavelength systems. Correspondingly, the emission spectrum can be a continuum with virtually no discernible structure or a quasi-discrete one showing undulations of varying degrees of complexity. When these emission profiles are combined with radiative lifetimes for the laser transition of the order of 10 nanoseconds, stimulated emission cross sections of 10^{-16} - $10^{-15} cm^2$ are obtained.

Pumping of the upper rare gas halide laser level is supplied mainly by two sets of reactions. In the first excitation sequence, positive rare gas ions and negative halogen ions are formed through electron impact ionization and dissociative attachment, respectively. They then come together to produce the upper laser level through a three body recombination reaction. In symbols, this can be expressed as follows:

$$e + Rg \rightarrow Rg^{+} + 2e$$
$$e + XR \rightarrow X^{-} + R$$
$$Rg^{+} + X^{-} + M \rightarrow RgX^{*} + M$$

Here, R stands for the radical which binds the halogen atom, and M for a third body which is typically a diluent, light, rare gas atom. By carrying away some of the excess energy of relative motion, the third body makes possible the trapping of the ion pair in the excited state potential well in the recombination process. Since the rare gas halide lasers are generally run at pressures of several atmospheres, three body collision rates are sufficiently high to make ion recombination an important channel for excited state formation.

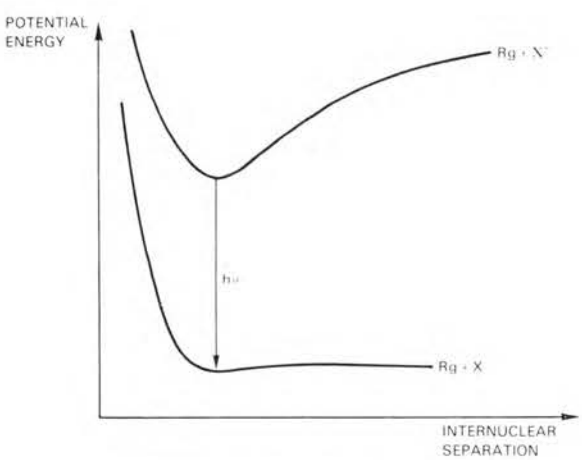


Figure 2. ***Representative potential energy curves for rare gas halide excimer laser transition***

A second mechanism for excited state production is the process first observed to yield intense rare gas halide excimer emission, namely, the bimolecular reaction between metastable rare gas atoms and the halogen-bearing molecule. While the overall reaction can be written as

$$Rg^{*} + XR \rightarrow RgX^{*} + R$$

the detailed steps are believed to be the following:

$$Rg^{*} + XR \rightarrow Rg^{+} + X^{-}R$$
$$Rg^{+} + X^{-}R \rightarrow Rg^{+} \cdot X^{-}R$$
$$Rg^{+} \cdot X^{-}R \rightarrow RgX^{*} + R$$

In other words, there is first a transfer of the outermost electron from the excited rare gas atom to the halogen atom in XR. The ensuing coulomb force then draws the pair together to form a short-lived species which can be viewed as a collision complex comprised of Rg^{+}, X^{-}, and R. Since the attraction between Rg^{+} and X^{-} is the strongest, the complex breaks into an excited rare gas halide molecule and a free radical. The long-range nature of the electron jump step results in an extremely large cross-section for this process. This so-called neutral excitation channel is especially important in discharge, as opposed to e-beam (electron-beam), excited rare gas halide lasers.

The best halogen donors for the rare gas halide lasers tend to be small molecules with weak bonds such as F_2. The halogen donor gas is typically used in fractions of less than one percent of the total gas pressure, since it not only quenches the upper laser level but also may absorb at the laser wavelength. Similarly, the pertinent heavy rare gas generally constitutes no more than 10% of the laser gas mixture in order to avoid excessive quenching through processes such as

$$RgX^{*} + Rg + M \rightarrow Rg_2X^{*} + M$$

which, at elevated pressures, becomes a major loss channel for excited rare gas halides.

In the ultraviolet region where the rare gas halide lasers operate, absorption at the laser wavelength can be quite severe during excitation by transient species such as Rg^*, X^-, and dimeric diluent rare gas ions. While the absorption by species derived from the active gases is, by and large, beyond control, the proper choice of the diluent light rare gas can minimize absorption due to ionic or excited dimers. A most dramatic example is found in the more than order of magnitude improvement in the performance of the XeCl laser when Ne is substituted for Ar as the diluent gas. Calculated absorption profiles show an Ar_2^+ peak almost exactly at the XeCl laser wavelength and a Ne_2^+ peak shifted considerably to lower wavelength.

Table I lists the emission wavelengths of all the rare gas halides which have been made to lase to date. With the exception of XeF which exhibits two clusters of "discrete lines" centered at 351 nm and 353 nm and XeCl which emits mainly in two bands of about 0.1 nm width near 308 nm, the remaining lasers either are or should be tunable over bandwidths of 1-2 nm. Some possibility still exists that laser oscillation may be obtained in NeF, KrBr, and XeI. However, the rest of the rare gas halides are not expected to produce lasers because of the anticipated strong predissociation of their upper states.

	Ar	Kr	Xe
F	193	248	351-3
Cl	170	222	308
Br	—	—	282

Table I. ***Output wavelengths in nm of rare gas halide lasers.***

Excitation Methods

The methods of excitation for the rare gas halide lasers are basically the same as those developed in the last decade for other high pressure lasers such as the CO_2 laser. They are e-beam pumping, UV-preionized discharge pumping, and e-beam controlled discharge pumping. However, gas mixtures containing the heavier rare gases and halogen-bearing molecules tend to have poorer current-voltage characteristics. As a result, discharge instability in rare gas halide lasers has posed a greater problem than previously encountered with other lasers.

In the e-beam device, a swarm of relativistic electrons is generated in an evacuated chamber. They are then deposited in the laser gas after passage through a thin metal foil which separates the active medium from the gun chamber. Current stability is not an issue here, since there is no discharge in the laser medium in the conventional sense of the term. The relativistic electrons generate secondary electrons through ionization collisions

$$e^r + M \rightarrow M^+ + e + e^r$$

where the superscript r denotes relativistic. (Clearly, e^r on the right hand side, while much more energetic than e, is less so than e^r on the left hand side.) This process is repeated many times before the electron is slowed to a stop. For example, if the initial energy of the electron were 200 keV, it would be able to make on the average 10^4 ion pairs when M is Ne. Generally M would be a diluent light rare gas atom, Rg_D, which is needed in order to absorb an appreciable fraction of the e-beam energy for a typical lateral dimension of a few centimeters. The diluent ions can lead to the formation of molecules in the upper laser level in a number of ways. Two of these are

$$Rg_D^+ + X^- + M \rightarrow Rg_DX^* + M$$
$$Rg_DX^* + Rg \rightarrow RgX^* + Rg_D$$

and

$$Rg_D^{\ +} + Rg \rightarrow Rg_D + Rg^+$$
$$Rg^+ + X^- + M \rightarrow RgX^* + M$$

With e-beam pumping, the efficiency for converting the energy deposited in the laser gas to laser output has been shown to be as high as 10% for KrF and in excess of 5% for XeCl and XeF. The maximum pulse energy of 300J and pulse duration of 3 μsec obtained to date are still far from what are permitted by state-of-the-art technology. One serious drawback of the e-beam excitation technique is the limitation placed on pulse repetition rate by foil heating considerations.

The UV-preionized discharge excitation method provides a simple device for applications requiring high repetition rates, but not necessarily long pulse duration. A variety of circuits have been used successfully to make the discharge rare gas halide laser. But they all have in common a fast rising discharge current pulse preceded by the preionization pulse. The preionizing UV radiation is generally supplied by a series of sparks located in close proximity to the main electrodes. The UV radiation thus produced generates a small, but nevertheless orders of magnitude larger than ambient, number of electrons through the photoionization process

$$h\nu + M \rightarrow M^+ + e$$

These seed electrons are then avalanched to give a high current when the voltage for the main discharge is switched on. The uniformity of the discharge depends very sensitively on the delay between the preionization pulse and the main current pulse, for reasons that are not yet completely understood. The duration of a discharge-excited rare gas halide laser pulse is typically 20 nanoseconds. Maximum repetition rates of 1 kHz and single-pulse energy of 1 J have so far been achieved (on separate devices). An overall efficiency of between 0.5 - 1.5% is possible for the KrF, XeF, ArF, and XeCl systems with discharge pumping. The development of this kind of rare gas halide lasers is already advanced enough for a number of companies to offer them as standard products now. It is not unreasonable to expect the commercial availability of models capable of delivering several hundred watts average power within the next few years.

High pressure discharges may be stablized by the simultaneous use of an electron beam. In this approach, the e-beam acts as an ionizing source, generating large quantities of electrons which could in turn be energized by the applied field. For the high pressure CO_2 laser, for instance, stable discharges can be run with the e-beam supplying only about 1% of the total energy deposited in the gas. A large discharge enhancement ratio would clearly reduce by the same factor the amount of thermal loading on the e-beam foil, thereby enabling the laser to be run at much higher repetition rates. This e-beam controlled discharge excitation technique has also been applied successfully to the rare gas halide lasers. However, the propensity for electron multiplication in gas mixtures containing large metastable rare gas densities has so far limited the discharge enhancement ratio to factors of only about two. The ultimate utility of this mode of excitation for the rare gas halides still remains to be explored.

Recently NRL scientists have discovered yet another excitation source for the rare gas halide lasers in the form of a proton beam. Since protons are stopped much more readily than electrons, it would be possible to use He instead of the heavier Ar or Ne as the diluent. A lighter diluent should facilitate the attainment of optical homogeneity in the laser medium. The use of He-diluted laser mixtures may also permit larger discharge enhancement ratios. As this represents the first instance of any laser pumped by a proton beam, a full assessment of its potential must await further detailed investigations.

Applications and Future Directions

The most immediate Navy application for the rare gas halide lasers is likely to be in the area of blue-green light sources for underwater communication systems. The rare gas halide lasers are certainly efficient enough to be considered for that purpose. However, since all of them have output in the ultraviolet, practical means of downconverting into the blue-green must first be found. One of the schemes NRL scientists are working on is conversion through stimulated Raman scattering in metal vapors. They have already demonstrated that the output of the XeF laser can be shifted into the orange region with almost unit photon efficiency when Ba vapor is used as the Raman medium. At present, they are investigating the efficacy of a number of similar schemes which would yield Raman output in the blue-green.

At least two roles for the rare gas halide lasers are discernable in the energy sector. The first one is as ultraviolet sources in the two-step photochemical separation of uranium. In the envisioned process, a narrow band infrared laser would be used first to pump $^{235}UF_6$ into a vibrationally excited level. This isotope selective step would then be followed by photodissociation of the molecule with radiation from one of the rare gas halide lasers. For this application, the discharge-pumped rare gas halide laser would be the device of choice. Another important area of application for which these lasers are being seriously considered is that of laser fusion. Although the rare gas halides in themselves are not suitable for the extraction of the very short optical pulses required for inertial confinement fusion, their output can be compressed in time through either optical pumping of media more amenable to energy storage or nonlinear techniques such as backward Raman amplification. These ideas are being actively pursued at a number of laboratories around the country.

Not to be left out of the list of applications is the adoption of the rare gas halide lasers as valuable tools in basic research. These lasers render truly powerful coherent radiation in the ultraviolet accessible for the first time to a vast community of research scientists. The molecular spectroscopists and photochemists would benefit especially since most electronic absorption bands lie in precisely the wavelength region covered by the rare gas halide lasers. Thus, these lasers are certain to gain an increasingly prominent position in the arsenal of research tools in years to come.

While great strides have been made in the development of the rare gas halide lasers since their initial discovery, additional breakthroughs with a qualitative difference can still be expected. One example would be their operation in a true continuous wave fashion. Since the excimer systems, almost by definition, guarantee population inversion on a CW basis, the rationale for such a laser certainly exists in principle. Indeed, the microseconds-long laser pulses obtained from e-beam excited devices illustrate precisely this point. It is most likely that a CW rare gas halide laser would have a rather small active volume because of the enormous specific power requirements. Nevertheless, its output could be orders of magnitude larger than that of any existing CW ultraviolet laser. The realization of such a device would mark the start of yet another chapter in the annals of lasers. ■

research notes

Accurate Typhoon Forecast Model

A computer model that can predict the movement of typhoons (tropical cyclones in the Pacific Ocean) with greater accuracy than current operational models was developed by Dr. Rao Madala at the Naval Research Laboratory.

Preliminary comparisons of model forecasts with observational data at the Naval Environmental Prediction Research Facility, Monterey, California, indicate the mean and standard deviations of the forecast error for the NRL model are about 30% smaller than those for the Navy's official forecasts.

The size of the area over which the typhoon warnings are issued is generally determined by the mean and standard deviation of the forecast errors. The Navy's current 48-hour forecasts have a mean error about two to three times larger than that required by the Seventh Fleet for efficient operations.

Dr. Madala says that lack of improvement in the accuracy of the official forecasts during the last few years, coupled with the success of numerical models in providing better forecasts on a global scale, encouraged the Navy to develop the present model. Novel numerical techniques developed by Dr. Madala reduced the computing time on a Cyber 175 computer for 48-hour forecasts to 36 minutes, which is about 3 to 4 times faster than equivalent numerical models using conventional methods. It is anticipated that the model will be available for operational use in about a year, with even greater accuracy.

A reduction in the magnitude of the forecast errors by using sophisticated numerical models similar to the one developed at NRL not only would lead to significant savings by reducing the movement of men and equipment around the Pacific from potentially dangerous typhoons, but could also help increase the effectiveness of the Navy operation in the Pacific Ocean. ■

(Rao Madala, NRL)

Steel-crushing stormy seas can take their toll among ships, resulting in costs both in time and money, as depicted by this shot of the guided missile destroyer USS Barney (DDG-6). Such problems may be lessened by use of a new typhoon forecast model developed at the Naval Research Laboratory. The model improves forecast error about 30 percent over present weather prediction methods.

New Electrical Brushes Developed on Navy Contract

Professor Doris Wilsdorf and colleagues at the University of Virginia, in a research project funded by the Office of Naval Research, have developed a new technique for making electrical brushes out of metal fibers.

Electrical brushes are those electrical conductors that make contact between the moving and stationary parts of a generator or motor and are usually made of graphite or graphite-metal substances.

The technique developed at the University of Virginia involves the use of metal "velvets" which consist of hundreds of metal whiskers thinner than a human hair, separated by similar small distances and embedded in a metal backing.

The study was instigated in response to a perceived need for greatly improved brushes capable of working well at higher speeds and current loads. In present graphite brushes, voltage loss and heating occur as current passes through the brushes. The higher the current, the greater the voltage loss and the more the heating.

Power loss is due to friction between the brushes and the rotor. This is particularly true at high speed where the brushes must press with proportionately greater force to maintain contact with the rotor.

Until recently this voltage loss and resulting heating was of little concern because of the small percentage of power loss relative to the total output. However, in several high technology developments, the lack of suitable brushes can be a severe handicap, for example advanced motors and generators that operate at high speeds and pack great horsepower in a small volume.

Another example is the superconducting motor in which the systems must be cooled to extremely low temperatures approaching absolute zero. Any source of heat would be detrimental to its operation.

Laboratory tests of the metal velvets show that they have extremely low voltage loss at very high rotor speeds, maintain excellent contact with the rotating part of the motor and are very "quiet," producing negligible radio noise or static.

The flexible metal fibers allow the brushes to maintain thorough contact with the surface of the rotor with a minimum of pressure and friction. A patent for the new metal velvets has been applied for. ■

(Ralph Burton, ONR)

Amorphous Corrosion-Resistant Alloys

For the past two years, the Office of Naval Research has funded research which has been directed toward understanding and utilizing the corrosion-resistant properties of amorphous alloys based on the composition Fe-Ni-Cr-P-B. The research, which was conducted by R. B. Diegle and D. M. Lineman of Battelle, Columbus, Ohio had two objectives: (a) separating initiation from propagation stages of localized corrosion phenomena and characterizing the tendency for each; and (b) developing a sputtering technique as a means for preparing these alloys. Propagation of localized corrosion was studied in prepared crevices, which circumvented the need for initiation at structural heterogeneities at alloy surfaces. A series of amorphous alloys with chromium contents ranging from 0 to 16 atomic percent was investigated. Classical anodic polarization experiments in acidified chloride electrolytes indicated that the chromium-containing alloys were extremely passive, pitting occurring only above about 1 V (standard colomel electrode) in 1 M NaCl at pH 1. The existence of classical active-passive polarization behavior suggested that the susceptibility of these alloys to crevice corrosion would be considerably less than that of crystalline stainless alloys. Experiments in the crevice cells indicated that the amorphous alloys do crevice-corrode, but only at very noble potentials comparable to those required for pitting.

The sputtering research resulted in a procedure for depositing amorphous alloys with corrosion resistance almost as good as that conferred by liquid quenching. The deposits were free of porosity, extremely adherent to the copper substrates, and easily handled. The sputtered alloys corroded at rates that ranged from about 1 to 10 times faster than those of melt spun alloys under conditions of open circuit exposure and anodic polarization; but they retain the excellent resistance to pitting exhibited by their melt-spun counterparts. ■

(B. A. MacDonald, ONR)

Milestone in Superconductivity Research

Scientists at the Naval Research Laboratory report the first observation of an intrinsic temperature width—termed the critical region—at a superconducting phase transition. The experiments were performed on a unique class of inhomogeneous materials called 2-D (dimensional granular superconductors).

In general, inhomogeneous superconductors consist of regions of lower dimensional superconducting materials (O-D granular, 1-D filamentary, 2-D layer) surrounded by a nonsuperconducting matrix. The specific material investigated was a 2-D array of small metallic niobium nitride particles separated by insulating niobium oxide.

These systems exhibit a variety of interesting characteristics which are dependent on 1) the material and dimensionality of the superconducting regions, 2) the electrical properties as well as the dimensionality of the matrix, and 3) the regularity of the overall structure.

From a fundamental standpoint such superconductors allow one to investigate those interactions which are dimensionally and spatially dependent, while from a practical standpoint, they offer a possible wide range of applications from flexible, high temperature superconducting wires (strongly coupled regions) to superconducting high frequency sources and detectors (weakly coupled superconducting regions). ■

(Donald U. Gubser, NRL)

New Instrument Heralds Large-Scale Probing of Ocean Depths

The first expendable ocean temperature and velocity profiler (XTVP) has been developed at the Woods Hole Oceanographic Institution with funding from the Naval Ocean Research and Development Activity (NORDA) based in Bay St. Louis, Mississippi. The inexpensive, disposable, but sophisticated instrument represents a major breakthrough in oceanographic instrumentation by making large-scale probing of the ocean depths practical. The new instrument will be particularly used to collect data on the movement, direction, size, and shape of undersea currents, internal waves, and large mid-ocean eddies not observable from the surface.

The instrumentation was conceived and developed over 10 years' time by Dr. Thomas Sanford and Robert Drever of Woods Hole. Research is under initial funding from the Office of Naval Research Ocean Science and Technology Division and more recently under sponsorship of NORDA's Ocean Programs Office.

The XTVP has already been tested at sea on W.H.O.I. ships and about 100 probes were used in the Russian-American POLYMODE experiment on eddies in the Atlantic. The instrument's first operational use in a Navy experiment took place last summer in the Atlantic when about 150 probes were used in a Navy Project.

The movement of mid-ocean eddies is of special concern to the Navy. These drifting circular eddies have temperatures different from the surrounding ocean. The change in temperature as an eddy moves through an area influences the transmission of underwater sound and therefore affects undersea surveillance systems and anti-submarine warfare operations. The velocity of undersea currents and eddies can also affect submarine navigation.

More knowledge is needed about eddies and currents to develop computerized models that can forecast them. Obtaining measurements has been difficult since the depths of these water masses vary considerably, and some are completely beneath the surface so that they cannot be sensed by satellites. What has been needed is the capability to make numerous measurements in real-time of velocity and temperature at a number of levels between the sea surface and the bottom over a wide area. The XTVP can now provide such data.

There are numerous uses for the XTVP in such oceanographic studies as those on ocean fronts, surface and bottom mixed layers, internal waves, air-sea interaction, and Gulf Stream structure. Measurements of the motion of large volumes of the ocean are vitally needed in advancing the understanding of ocean structure and dynamics.

Among possible commercial applications is the determination of flow during critical marine operations such as pipe laying and drilling. Routing of vessels may also be influenced by real-time detection of favorable currents.

Future applications of the instrument may include aiding fisheries researchers to predict location of fishing grounds based on a better understanding of the effects of undersea currents, eddies, and convergence zones on fish migration.

The large profilers presently used require special handling equipment and are expensive to operate in terms of ship time, support personnel, and the instrumentation itself. As a result, velocity profiles have been made in only a few areas for brief periods of time.

The XTVP is some two feet long and two inches in diameter, about one-tenth the size of previous velocity profilers. It can readily be dropped into the sea by means of the standard launcher for the expendable bathythermograph (XBT), which has been used for years to make simple measurements of temperature. ■

(CDR R.G. Kirk, USN, ONR)

Satellite Experiments Pave Way For New Solar Cell Technology

Fourteen solar cell experiments aboard NRL's Navigation Technology Satellite Number Two (NTS-2), launched in June 1977 as a technology prototype for the NAVSTAR Global Positioning System, continue to receive telemetered data. These data could lead to improved spacecraft solar cell power systems.

NTS-2 is in a circular orbit 10,900 nautical miles high, passing through the Van Allen radiation belts where the experimental array of solar cells is exposed to intense radiation. This gives an insight into how quickly the cells will degrade in a hostile environment.

The major goal in the research is to obtain data that will lead to improvement in the efficiency and radiation resistance of solar cells through a better understanding of silicon technology (silicon is widely used as the major material in solar cells), better coverslip materials and bonding techniques, and an evaluation of the long and short-term effects of ultraviolet-rejection filters versus no filters at all.

The NRL scientists are "highly pleased" with the results of gallium-aluminum-arsenide solar cells, flown in space for the first time. These new cells are showing a minimum of degradation, indicating they may be superior to cells in use today.

A new application of a fluoropolymer as an adhesive used on the solar cells has shown very little degradation after two years in space; and that, coupled with the gallium-alluminum-arsenide cells, could set a new trend in solar cell technology.

The NTS-2 experiment is, in addition, providing some useful information concerning radiation fluxes in space that will be important to spacecraft design engineers in determining the life expectancy of semiconductor devices in a hostile radiation environment. ■

(Bruce Faraday, NRL)

New Method Enhances Faint Photo Images

A scientist at the Naval Research Laboratory has been granted a patent on a technique to enhance the contrast of faint photographic images through a process involving the photofission of low-energy uranium isotopes. Kenneth M. Murray developed the technique to assist in defense photo reconnaissance and intelligence activities.

It also could be useful in other graphic applications, including x-ray work at medical institutions. If this technique was used in medical institutions, the low level radiation that a medical patient receives during x-ray exposure might be reduced by as much as 50%.

The new method calls for toning the negative for a photograph with a harmless photo-fissionable isotope, irradiating it with energetic x-rays, and etching it to bring out extremely faint images impressed on the film.

The isotope used is uranium 238 which has a very low spontaneous fission rate, but can be made to fission on demand by irradiating it with high energy x-rays. ■

(Kenneth Murray, NRL)

Current Sediment Loads in Deep Ocean

Sediment clouds caused by storm-like processes in the ocean and carried by bottom current have been measured for the first time in the deep ocean.

Doctor Edward P. Laine, University of Rhode Island marine geologist, explains that the measurements were made as part of an experiment studying sediment transport by bottom currents in the northwest Atlantic. Dr. Laine discussed the study findings at a recent American Geophysical Union meeting.

"We recorded an increase in sediment carried by bottom currents from 100 to 250 micrograms per liter when currents intensified from 2 to 17 centimeters per second. We also were able to trace the path of the sediments as they were eroded from a point 60 kilometers away from our instruments and moved by the records," Laine said.

The experiment was conducted during the summer of 1978 at a site 4400 meters deep on the north Bermuda rise. In this region it is believed that the strong westward flowing currents have broken off from the Gulf Stream further north and are returning to it. The experiment results appear to support this theory.

Measurements of the current sediment loads were made by coupling current meters with a recording nephelometer, which gauges the amount of sediment in the water. Background data on the site was collected through earlier geologic and seismic surveys.

Laine's experiment is part of a larger project called the High Energy Benthic Boundary Layer Experiment (HEBBLE) funded by the Office of Naval Research. Other participants included Lamont Doherty Geological Observatory, Scripps Institution and Oceanography, and Woods Hole Oceanographic Institution. ■

(Thomas Pyle, ONR)

Investigating Defect States In Amorphous Semiconductors

The versatility of crystalline semiconductors as solid state electronic devices depends critically upon the ability to change dramatically the electrical conduction properties of these solids with the addition of small amounts of impurities. This process, which is called doping, results when impurities incorporated into the host semiconductor cannot satisfy all of their normal bonding requirements so that there exist electrons which can be either donated to, or accepted from, the host.

A successful understanding of the doping process has far-reaching consequences for the use of amorphous semiconductors in electronic devices, such as amorphous silicon solar cells, because these materials are less expensive to produce than their crystalline counterparts, particularly for devices which require large areas.

In order to understand the details of the doping processes in amorphous semiconductors, Dr. P. Craig Taylor of the Naval Research Laboratory and Dr. Gustav Pfester, Xerox Webster Research Center, have been studying the interplay of impurities with intrinsic defects and the effects of intrinsic defects on the doping process. Of great interest are the semiconducting chalcogenide glasses which contain at least one of the group VI chalcogen elements, sulfur, selenium or tellurium. Spectroscopic measurements performed at NRL, such as electron spin resonance (ESR), photoluminescence (PL) and optical absorption, provide detailed local probes of the intrinsic defects.

Using both the PL and ESR techniques, it has been determined that some of the intrinsic defects — those which are metastable in a paramagnetic configuration — are holes localized on a chalcogen atom. Transient hole transport measurements performed at the Xerox Webster Research Center are very sensitive to those particular defects which provide traps in the transport process. Doping with elements such as thallium or copper increases the number of traps by as much as three orders of magnitude. On the other hand, doping with indium or gallium has the opposite effect of reducing the numbers of traps.

Theoretical models have suggested that the intrinsic defects produced by spectroscopic techniques (ESR and PL) are identical with the traps which affect the electrical transport properties and that doping should dramatically alter the number of these defects.

But recent spectroscopic results indicate that for many impurities, there is no change in either the number or character of these intrinsic defects, even though the drift mobility for holes, hence, the number of transport traps may be varied over several orders of magnitude. The impurities which have been studied include such chemically diverse elements as sodium or potassium (alkali metals), thallium and lead (heavy metals), iron and copper (transition metals) and chlorine and iodine (halogens).

The results demonstrate conclusively that the traps controlling the electronic transport are distinct from the defects probed by the ESR and PL techniques. This conclusion means that the existing models for defect states in many amorphous semiconductors must be modified or abandoned.

Although the gross properties (such as densities) of the intrinsic defects studied by ESR and PL techniques in the chalcogenide glasses do not change with the addition of impurities, there are subtle changes (such as the stabilities of the metastable paramagnetic states with temperature) which do reflect the presence of impurity atoms. ■

(Craig Taylor, NRL)

Laser Method Corrects Faulty Photovoltaic Detectors

A novel laser annealing technique for improving the performance characteristics of individual elements of high-density, photovoltaic detector array systems has been developed at NRL. The technique does not replace the standard annealing and fabrication methods used during assembly or formation of such arrays, but is designed to correct faults brought about during fabrication.

When an element of a detector array is found faulty during testing, it can be annealed on the spot by laser to correct the fault. The short laser pulse is shaped to meet a particular situation and is of such a limited intensity and duration that adjacent and other near-by elements are not affected.

Currently there are no other known techniques capable of improving the performance of substandard detector elements in assembly-line-completed high-density photovoltaic arrays, without degrading good elements. Cost savings in materials and manufacturing processes can be achieved since faulty arrays can be reclaimed and made usable. ■

(Filbert J. Bartoli, NRL)

Device Improves Submarine Localization

An electronic filter developed by NORDA for use with the Magnetic Anomaly Detection (MAD) system can achieve substantial improvement in pinpointing the location or localization of submarines from the air. As a result of recent sea tests of the filter, the Navy's Seventh Fleet has recommended that several filters be procured for long-term evaluation under realistic operating conditions.

The airborne MAD system exploits the principle that a submarine in the ocean depths can be identified by its magnetic signal or signature. One problem with the MAD system is that a submarine's magnetic signal is often masked by the natural magnetic background noise produced by underwater geological formations. This noise is particularly high in shallow water areas. While more sensitive MAD equipment increases the detection capability, it also results in greater background noise.

The logical answer to the problem was to develop an environmental filter specifically designed to suppress geological magnetic noise. Based on magnetic surveys conducted by the Naval Oceanographic Office, a family of electronic filters applicable to the magnetic characteristics of operating areas off the East and West Coasts was designed several years ago for the ASQ-10 MAD system. Based on this work, a NORDA team, headed by Kuno Smits (who led the earlier work), and funded by the Navy Science Assistance Program, recently adapted these filters to operate with the new, more sensitivie ASQ-81 MAD system.

A fleet exercise in the western Pacific last August afforded the first opportunity to test the filter at sea with the new system. The test was undertaken even though the available experimental filters had not been designed from the specific area of the ocean, which is known to have unusually high background noise.

The NORDA device in a 7.5 by 6.6-inch package was installed on an aircraft, and the tests were conducted. It was found that the NORDA filter greatly improved the suppression of geological noise and was able to produce a very recognizable signal on every pass over the target.

One of the advantages of the NORDA filter is that identifying the signal requires very little experience by the MAD operator. It was also found that the higher the geological noise, the more effective the NORDA environmental filter is, relative to the current fleet filter, in target detection. It is estimated that filters of the NORDA type could be produced in quantity for approximately $550 per unit. ■

(Clifford Crandall, NORDA)