# Naval Research Reviews

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Summer 1980
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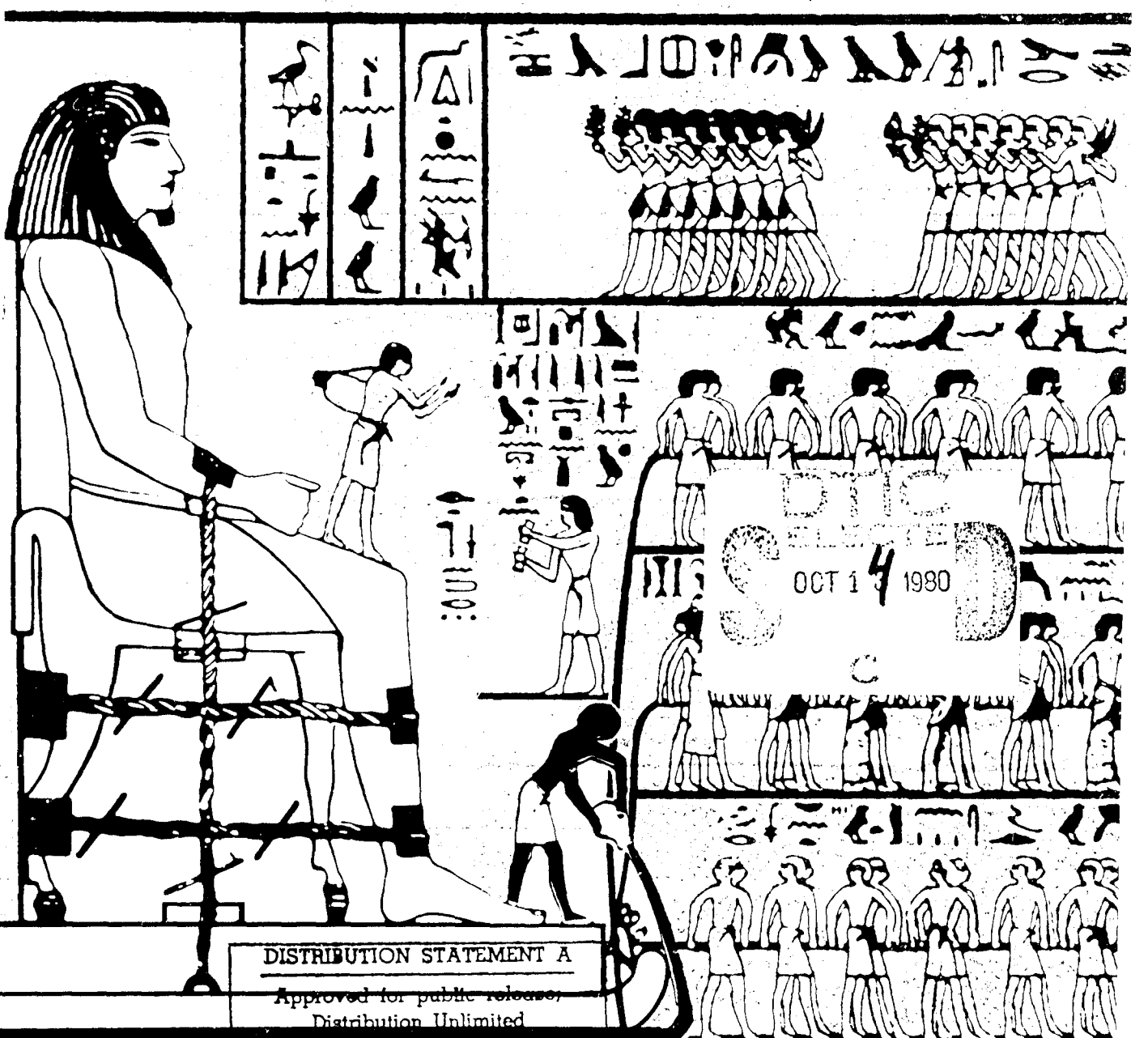
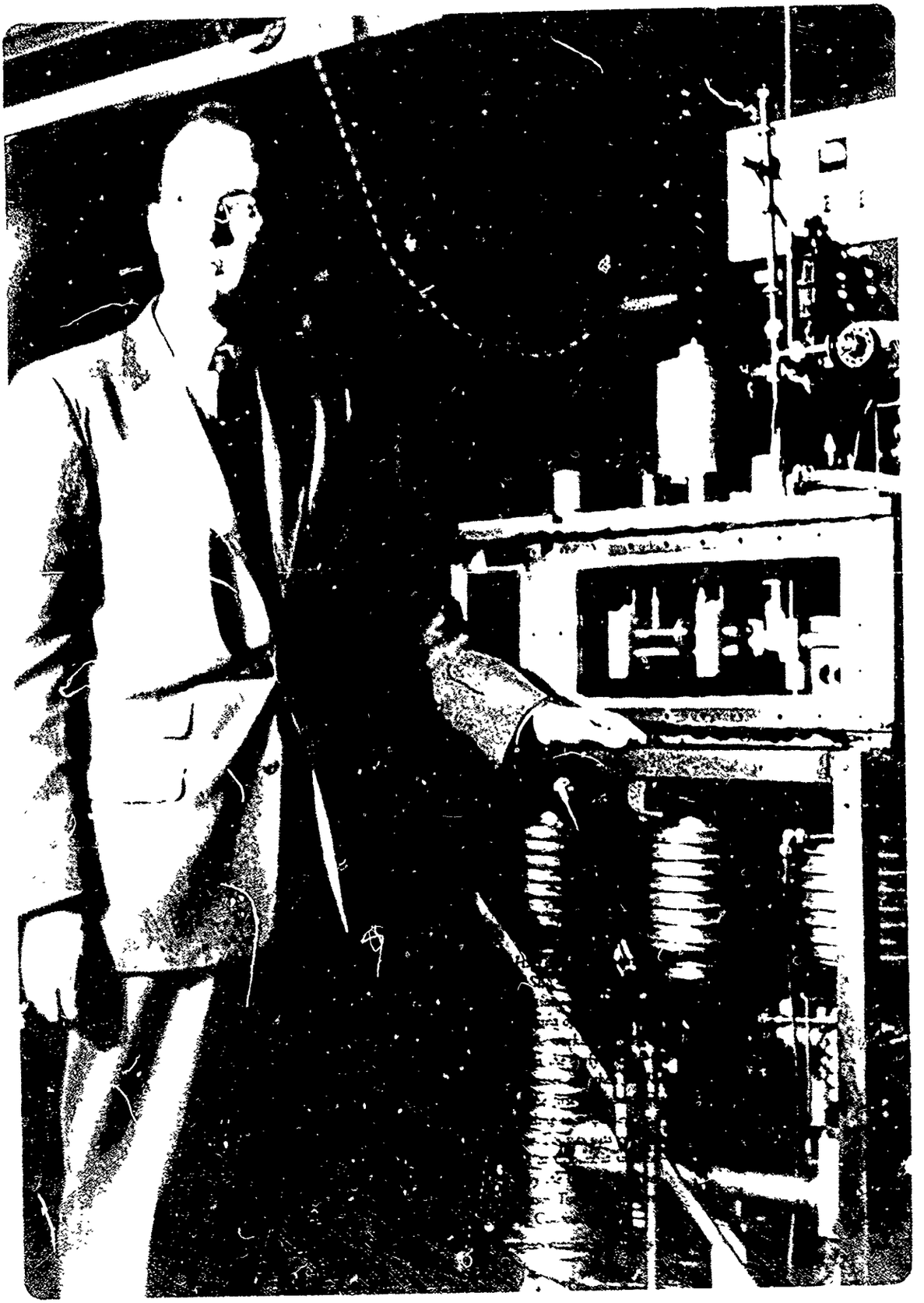








Tribology, 1980's



(10) Edward I. Salkovitz

# Naval Research Reviews

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## ARTICLES Partial CONTENTS:



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## DEPARTMENTS





### About Our Cover

*Tribology, the science that deals with the design, friction, wear, and lubrication of interacting surfaces in relative motion, is liberally depicted in this drawing in a grotto at El Bersheh. An early "tribologist" pours a lubricant in front of the skid on which he stands to lessen friction during the transport of an Egyptian Colossas about 1880 B.C. See Page 4.*

*Naval Research Reviews publishes highlights of research conducted by Naval 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.*

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# Editor's Note

*The following is an overview of the Office of Naval Research as it exists today. Much of this note was excerpted from a statement presented by the Chief of Naval Research, RADM Albert J. Baciocco Jr., USN, before the Subcommittee on Science, Research and Technology, on 13 September 1979.*

Edward I. Salkovitz



The Navy has a continuing requirement for basic research to provide the scientific foundation that underlies the techniques and information required for future systems and operations.

The mission of the Office of Naval Research is to obtain the best scientific research possible for the taxpayer's dollar and to make the most effective use of this research in the interest of the Navy and the Nation. ONR, established by Congress in 1946, is the oldest scientific research contract agency in the Federal Government. Through its contract program, ONR has always been able to attract distinguished members of the civilian scientific community to participate in a program of basic research aimed at providing the base for future technology. This has been done by funding university research facilities and equipment as well as providing compensation for university research scientists. Of more lasting importance, ONR evolved policies and procedures which pointed the way to increased participation by the Federal Government in a comprehensive program of scientific research throughout the country.

Today the ONR mission has not changed; it continues to encompass the pursuit of scientific study and experimentation directed toward increasing knowledge and understanding in those fields of physical, engineering, environmental, biological-medical, and behavioral-social sciences related to long-term Navy and national security needs. ONR seeks to encourage the acquisition of fundamental knowledge needed to solve future military problems, providing part of the base for subsequent exploratory and advanced developments in defense-related technologies and new or improved military functional capabilities in areas such as communications, surveillance, targetting, propulsion, mobility, guidance and control, navigation, energy conversion, materials and structures and personnel support.

By today's standards, ONR is not a large organization, representing but a relatively small segment of total Navy Research, Development, Test and Evaluation activity. While it may be viewed as being embedded in this larger effort which includes the Naval Material Command and its Systems Commands and R&D Centers, ONR is an independent organization reporting directly to the Assistant Secretary of the Navy for Research, Engineering and Systems (ASN (R, E&S)). This organization structure tends to ensure that basic research funds remain somewhat isolated from the pressure of resource requirements in the Navy's near term development programs. On the other hand, an awareness of applied development problems, which frequently indicate need for basic research investment, is maintained through a close and continuous interaction with the Chief of Naval Material (CNM), his Systems Commands and laboratories.

The Chief of Naval Research oversees two major Navy laboratories, the Naval Research Laboratory (NRL) in Washington, D.C. and the Naval Ocean Research and Development Activity (NORDA), Bay St. Louis, Mississippi. NRL, established in 1923, is the Navy's corporate research laboratory and performs basic and applied research and development across the full spectrum of science and technology. NORDA, established in 1975, is rapidly becoming the Navy center for ocean science and technology.

The combination of basic research and developmental effort at NRL and NORDA is viewed as a valuable Navy asset, adding the reality of application to the basic research program while providing the standards of scholarly excellence to exploratory development efforts.

Several levels of the ONR organization are involved in planning the basic research program. The planning of laboratory programs is influenced by existing facilities and the interests and capabilities of their personnel. On the other hand, planning the contract research program involves more flexibility. Briefly, planning the balance between fields and subfields of science or engineering is based upon a systematic process involving many levels of scientific and naval expertise and responsibility. Factors that influence one area over another include the relationship to a Navy need, the activity of other government agencies in funding similar or related research, and the judgment of scientific personnel. The selection of major thrusts evolves more from relevance and opportunity, while decisions on individual program proposals are associated more with quality.

There exists a spectrum of relevance as it relates to mission research. At one end is research, often of a fundamental nature, associated with a specific problem area in which results will be implemented almost directly. Certain work in electronics has this character, where results are quickly picked up and used by industry for application to Navy equipment. At the other end of the spectrum is research, almost always of a basic nature, which can contribute to one or more areas of importance to the Navy. For example, basic research in atomic and molecular physics has this character. While this work relates to clearly defined problem areas of lasers for weapons and communication and for advanced detectors, it has only a tenuous relationship to any specific military hardware. In a slightly different dimension, there are projects which, if successful, will have clear potential for military applications, often specifically defined, but which have high scientific risk.

In planning ONR's basic research programs, the following investment strategy is used. Approximately 70% to 75% of ONR's total basic research resources are applied across the broad spectrum of science and engineering disciplines in areas of interest to the Navy. The objective of these funds is to maintain evolutionary basic research programs at the frontier of scientific knowledge. In addition, within this category, as much as 10% to 15% may be invested in truly high-risk and revolutionary research efforts. Such efforts should be revolutionary either in a scientific or a military sense. The remaining 25% to 30% of resources are applied to programs which specifically address identified Navy needs. The objective of this funding is to stimulate the timely progress of such programs from basic research into the early stages of exploratory development, i.e., to accelerate the transition of our research from general concepts to more specific applications.

Another factor in the ONR investment decision process is the ability to lever available internal resources. Selective investment by ONR often attracts additional research dollars from within the Department of Defense (DOD), as well as from other government agencies. ONR tries to play a role in getting research started in critical fields without having to carry the total support burden. The multitude of joint programs with the Defense Advanced Research Project Agency (DARPA), the Air Force, the Army, other parts of the Navy, as well as with other government agenices, is testimony of the importance of this factor in ONR management.

The other aspect of ONR that contributes significantly to its way of doing business is the manner in which programs are executed or implemented. Fundamental to this is the quality of the scientific officers employed. They can be described as having many years of experience as scientists or engineers, frequently as university faculty, before being hired by ONR. The typical scientific program manager, civilian or military, at ONR is expected to be cognizant of Navy needs, aware of emerging scientific and engineering research areas, and effective in communicating Navy research interests to the community of reseachers. For this they require a high level of scientific stature and experience. To augment the talents of the permanent core of program managers, ONR arranges for temporary assignments of personnel from other naval establishments and utilizes provisions of the Intergovernment Personnel Act to bring university professors to its Headquarters and Branch Offices to assist in managing specific programs. Clearly, a great deal of attention is paid to the selection of scientific officers and temporary personnel.

The selection of the tasks which make up a broad program begins with the decisions of the scientific manager. In establishing new programs or tasks, care is taken to solicit the views of other researchers in the field, elements of the Navy research laboratory community, and, when appropriate, acquisition personnel associated with Navy development projects.

The criteria employed in evaluating specific proposals are:

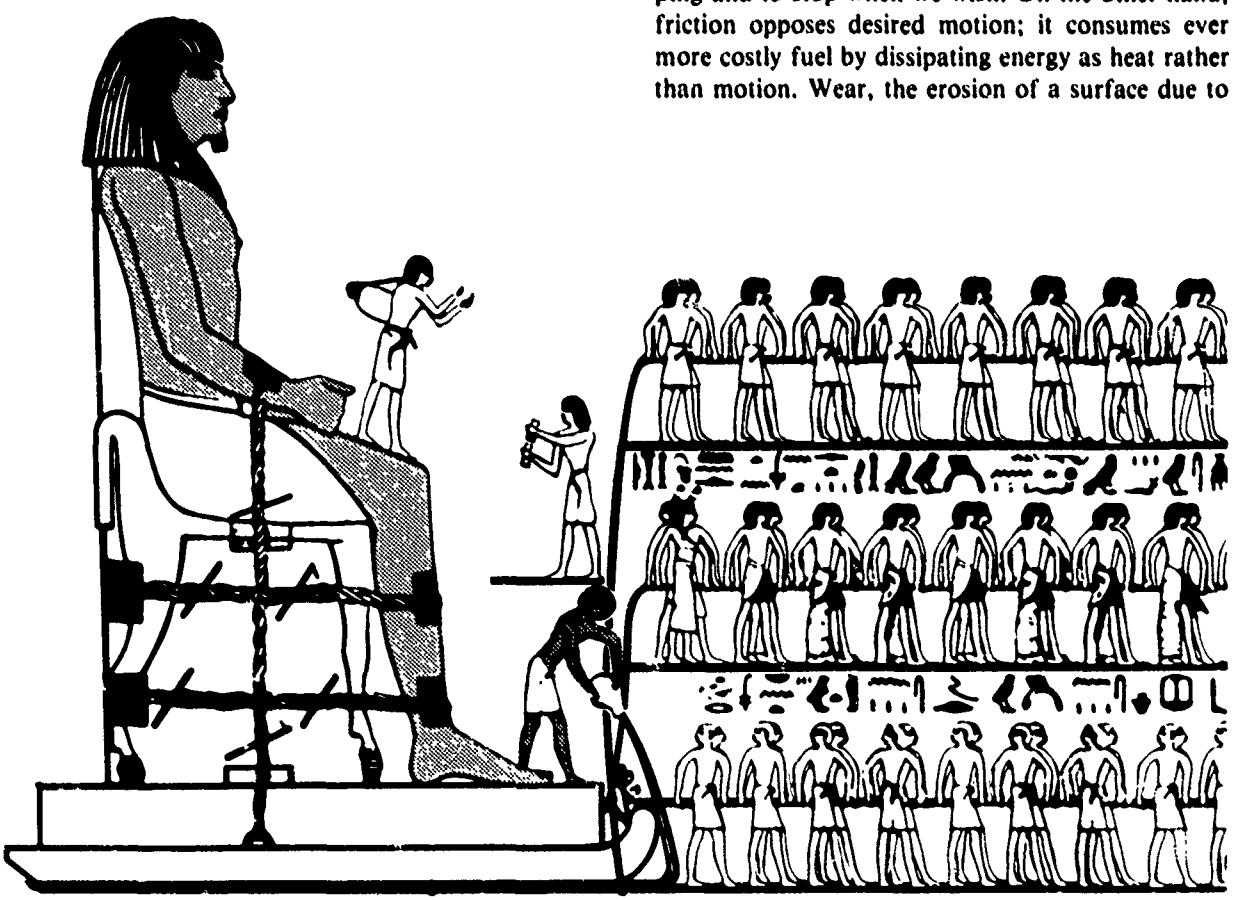
*(continued on page 40)*

# New Opportunities in Tribology

by

**Irvin L. Singer, James S. Murday, Harold Ravner, James K. Hirvonen and N. L. Jarvis**
**Naval Research Laboratory**

Tribology is another one of those newly coined Greek words whose meaning is obscure to the average layman and to a surprisingly large proportion of scientists. The prefix "tribo" is derived from the Greek "tribos" meaning to rub; thus, the science of tribology can be simply defined as the study of interactions between "rubbing" surfaces. In more familiar terms, tribology includes the study of several phenomena—friction, wear and lubrication. We can relate to these in terms of a contrivance we all know, love and hate—the automobile. Friction is both a boon and a bane. It allows us to move without slipping and to stop when we wish. On the other hand, friction opposes desired motion; it consumes ever more costly fuel by dissipating energy as heat rather than motion. Wear, the erosion of a surface due to



moving mechanical contact, is nearly always an undesirable feature. Brakes literally "wear" out; bearings become sloppy or seize; seals start to leak. Anyone with an old car knows the signs of wear all too well. The lubrication process reduces friction and wear by interposing a beneficial material, such as an oil or grease, between the contacting bodies.

More recently, it has been estimated that the comparable present cost to the U.S. economy is about $60 billion annually, of which the DOD component is about $7 billion. The Navy's share of the DOD bill runs into hundreds of millions of dollars annually, due to wear costs alone. Dollar figures for maintaining or replacing bearings range from $10K to $100K per vehicle; for example, maintenance

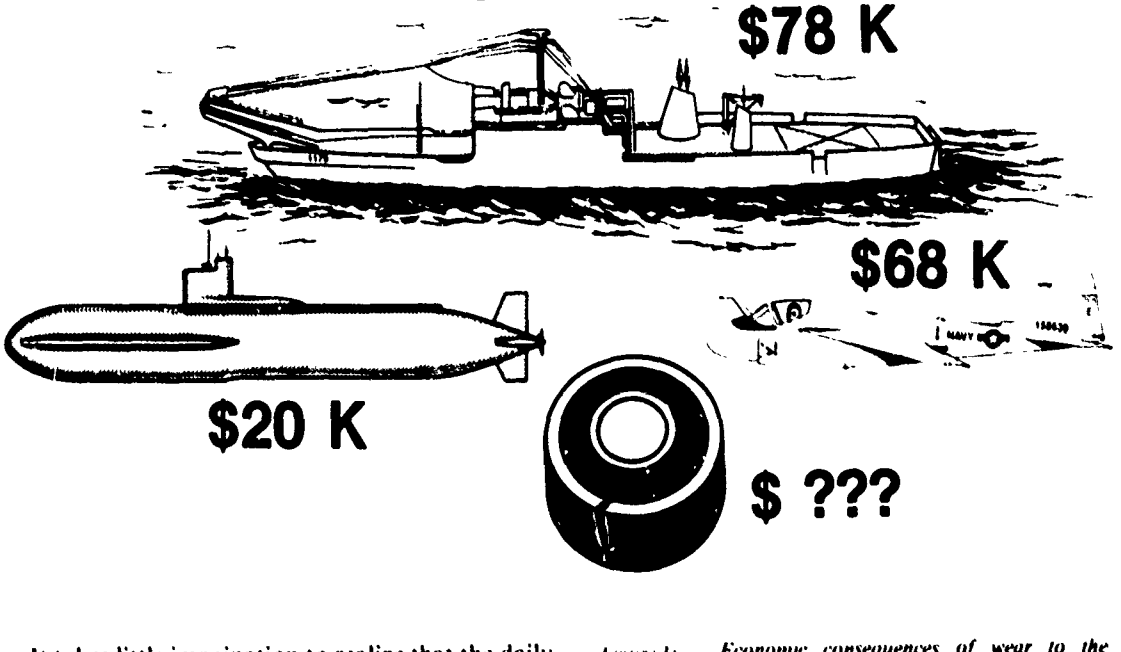



*Figure 1: Economic consequences of wear to the Fleet. Annual maintenance costs for LSTs, A-6E aircraft, and quiet bearings in submarines. Strategic costs, due to failure of critical bearings, e.g., gyro bearings in guidance systems, cannot be assessed.*

It takes little imagination to realize that the daily expenses and problems we all face with friction, wear, and lubrication are compounded when one surveys Naval requirements. Not only are there bigger and more powerful drive systems, such as those used for ship propulsion, but there are also delicate, tiny bearings such as those used in guidance system gyroscopes. Studies of the economics of the wear process indicate that it exerts a major drain on national resources. The historic 1966 Jost report, which for the first time laid out the economic and scientific rationales for the support of tribological research, estimated that the potential annual savings to U.K. industry, if controllable wear could be eliminated, were of the order of 500 million pounds sterling (approximately $1.4 billion at 1966 currency rates). charges, attributed to wear[1], ran $68K in A-6E aircraft and $78K in LST-1179 class ships, and replacement costs for "quiet bearings" averaged $20K per submarine[1]. If the results of the NAVAIR maintenance survey[2] are typical of fleet operations, then control of wear is almost as expensive to the Navy as procurement of fuel. While such dollar costs for wear are high and certainly warrant efforts to reduce them, there are factors which, though less tangible, are perhaps more important and whose effects cannot be directly measured in dollars (Figure

*Dr. Irwin L. Singer received a Ph.D in solid state physics from Indiana University in 1976. After a one-year NRC postdoctoral associateship at NRL, he joined its tribology program. He has been active in research on new methods for modifying bearing surfaces and on the use of surface analysis to relate friction/wear behavior to surface composition.*

*Dr. James S. Murday received a Ph.D in experimental solid state physics from Cornell University in 1970. He joined the Naval Research Laboratory to work in nuclear magnetic resonance. In 1974, he became active in surface physics and served as Head of the Surface Analysis Section from 1975-1979. He is presently leading research in carbon fiber and graphite chemistry. He is retained as a consultant to the Surface Physics Program at the Office of Naval Research.*

***Harold Ravner** is a native New Yorker, who received the BS degree in Chemistry from the City College of New York. His 40-year professional career has been with the Naval Research Laboratory where he is presently Head of the Tribology Section. He has authored more than 35 papers and holds 9 patents. His professional affiliations include the American Chemical Society, the Research Society of America, the American Association for the Advancement of Science and the American Society of Lubrication Engineers.*

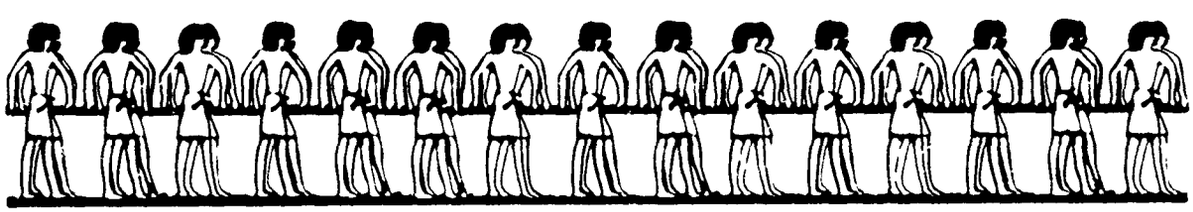
*Dr. James K. Hirvonen obtained a Ph.D degree in physics (1971) under a joint Rutgers University/Bell Laboratories graduate research program. He then joined the Naval Research Laboratory. His research interests and publications have been in the area of applying high-energy ion beams for near-surface materials analysis and for surface-property materials modification. He is Head of the Ion Implantation Section of the Radiation Technology Division at NRL. He has edited a book of nonsemiconductor applications of ion implantation and served as the Navy liaison representative to a National Materials Advisory Board committee which evaluated the potential of ion implantation for DoD applications. He is a member of the Bohmische Physical Society.*

*Dr. N. L. Jarvis received a BS degree in Chemistry from Brigham Young University in 1952 and a Ph.D from Kansas State University in 1957. In 1957, he was awarded a National Research Council Postdoctoral Associateship in Surface Chemistry at the Naval Research Laboratory. He joined the staff of NRL in 1960 and in 1970 became Head, Surface Chemistry Branch. As Branch Head, he directs research in surface analysis, tribology, carbon chemistry and theoretical chemistry.*

1). What, for example, might be the strategic cost of aborting an important mission due to a malfunction of a critical bearing caused by wear?

If tribological phenomena are so important, they should have attracted considerable attention. And, indeed, they have—for thousands of years. When moving stones became a drag, Egyptians practiced and may have originated the art of lubrication; an ancient drawing in the grotto at El Bersheh (See the cover) depicts a slave pouring liquid in front of a skid transporting a colossus. Not only in antiquity but throughout the ages, lubrication to reduce friction and wear has been intimately involved with the empirical development of machinery. Tribology is therefore basically a "catch- up" science trying to explain physical phenomena which, until recently, have been examined only phenomenologically[4].

In recent years, new understanding of



tribological phenomena has been spurred by advances in engineering and science. Systems engineering provides to tribology a formalism to relate stress and strain in complex geometries so that appropriate materials and better designs can be chosen. Materials science and metallurgy have given us improved materials and a better understanding of their properties. Chemistry is producing an abundance of new compounds from which to develop new materials. Tribological problems continue to plague us, however, because they are dependent on surface as well as bulk properties.

When two materials are placed close enough together to be considered as touching, their actual contact involves their high points (asperities), which constitute only a fraction of the total surface area. The adhesion, deformation, and fracture of these contacts lead to the macroscopic properties of friction and wear. The composition and structure of the asperities, in turn, determine the forces and material responses which lead to adhesion and deformation properties. A "delamination theory of wear," developed by Nam Suh and his coworkers at the Massachusettts Institute of Technology with Office of Naval Research support, provides a good example of a modern study which relates subsurface material properties to tribological phenomena[1].

There have been two surface-related scientific developments in the past ten years which will have a major impact on tribology. The first is the development of surface-sensitive analytical tools which can identify the elemental composition of surfaces and also provide considerable chemical and structural identification. These tools can provide the atomistic information which will give the tribologist a more detailed picture of what is happening on a surface. They are not a panacea for tribology; however, as with any new development, they have their limitations. This article addresses their possibilities and presents some recent applications to tribological studies. The second major factor, fueled by the progress in surface science and semiconductor electronics, is the development of new processes for the modification of surface properties. One such process, ion implantation, provides a new way to tailor the surface while retaining desirable bulk properties. Ion implantation and other new opportunities for surface modification will also be examined.

The concurrent development of surface analytical and surface processing techniques is itself a new oportunity for tribology. Modified surfaces can be analyzed at the same time the processing techniques are being tested and developed. The analytical findings can both guide the development of improved tribological properties and suggest the mechanisms responsible for them. And, while this article stresses the value of these new opportunities in the context of tribology, it should be noted that they can also affect other surface-related areas, including corrosion and adhesion. Parallel efforts in these various fields should have beneficial synergistic effects.

## New Techniques for Analyzing Surfaces

A complete chemical description of an engineering surface requires a tremendous amount of information, particularly if the surface has been in contact with chemicals or other solids. It is necessary to identify the elements present, establish their stoichiometry, map out valence electron distributions, and define the atomic geometries. In addition to establishing the chemical identity of the surface species, it is also necessary to locate these species relative to the surface topography in a three dimensional picture. Metallic bearing components, for example, usually have complex oxide films on their surfaces. Moreover, rubbing contact of these surfaces in the presence of lubricants and ambient gases generates wear scars, i.e., microscopic hills and valleys of disturbed metal and film coating. Clearly, the composition of these surfaces is very complicated, and no single analytical tool can provide all the details.

An example of a multi-analytical approach to the study of lubricated steel bearings was reported in 1974 by Coy and Quinn[4]. They used several techniques to examine wear surfaces: electron probe microanalysis (EPMA) for elemental identification and stoichiometry; scanning electron microscopy (SEM) to locate these species; and glancing angle X-ray diffraction to probe the atomic geometries, at least for crystalline forms. The diffraction and elec-

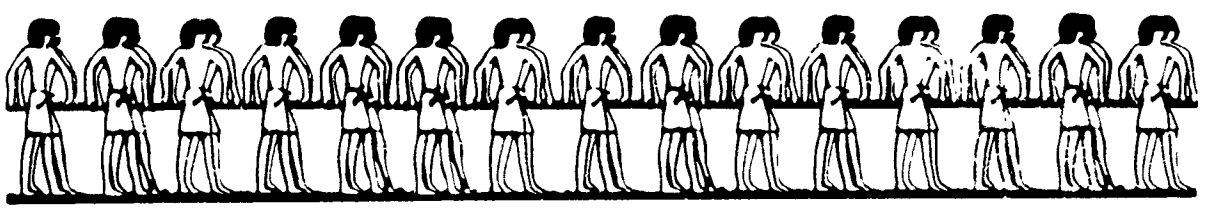


*Table I:*
*Comparison of AES, XPS and EPMA Capabilities*

| Features | Techniques | | |
|---|---|---|---|
| | AES | XPS | EPMA + |
| Elemental identification (Atomic No. Z) | Z > 3 | Z > 2 | Z > 4a; Z > 10b |
| sensitivity (Atomic %) | 0.1 | 1 | 0 1 |
| chemical information | possible | yes | very difficult |
| lateral resolution | 0.2 μm | 1 mm | 0.5 μm |
| depth resolution | 0.5-3 nm | 0.5-3 nm | 0 5-3 μm |

+ X-ray emission spectroscopy (XES); often available with a scanning electron microscope (SEM).

a Wavelength dispersive analyzer

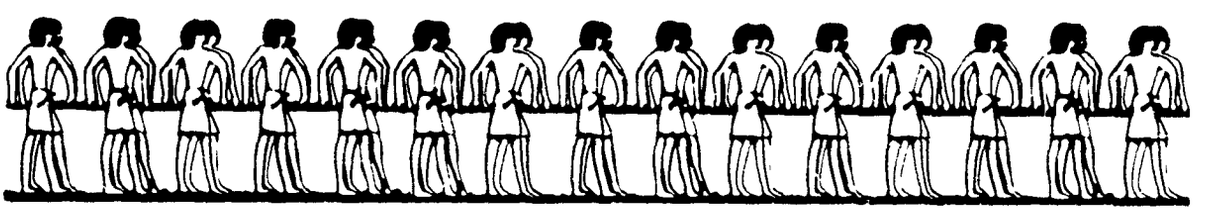
b Energy dispersive analyzer

tron probe analyses both sampled depths on the order of a micron. Chemical species within this layer had to be inferred from stoichiometry and crystal structure since the valence electron distribution could not be examined directly.

In contrast to these techniques, the more recently developed techniques, Auger electron spectroscopy (AES) and X-ray photoelectron spectroscopy (XPS) are more surface-sensitive and give direct chemical information about surface species. Some of the features of AES, XPS, and EPMA are listed in Table I. AES and XPS typically probe several nanometers. AES is sensitive to all elements except hydrogen, helium, and lithium; XPS to all but hydrogen and helium. XPS is a bit easier to quantify than AES and is, therefore, more useful for establishing stoichiometry. XPS, however, requires a fairly large area ($\sim$1 mm$^2$) for analysis and cannot examine features on as fine a scale as AES.

Auger spectroscopy is the surface-sensitive analog of electron-probe microanalysis. It can give elemental images with a lateral spatial resolution of 0.2 microns, which is slightly better than EPMA resolution. AES has an added advantage over EPMA; while the two are roughly equally sensitive to heavier elements, EPMA loses sensitivity for such key lighter elements as carbon, nitrogen, and oxygen. Both EPMA and AES can be used to form images of elemental distribution. Used in this mode, Auger is frequently referred to as scanning Auger microscopy (SAM).

Besides elemental information, XPS and AES can provide chemical information. Unlike (commercially available) EPMS, XPS and AES examine

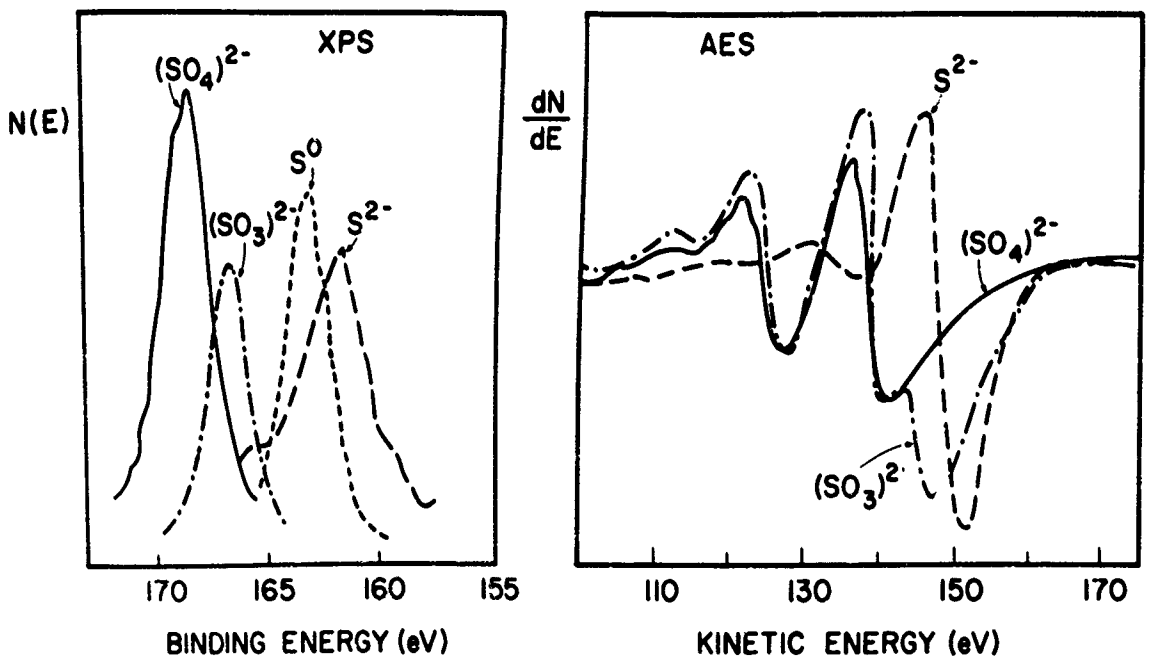


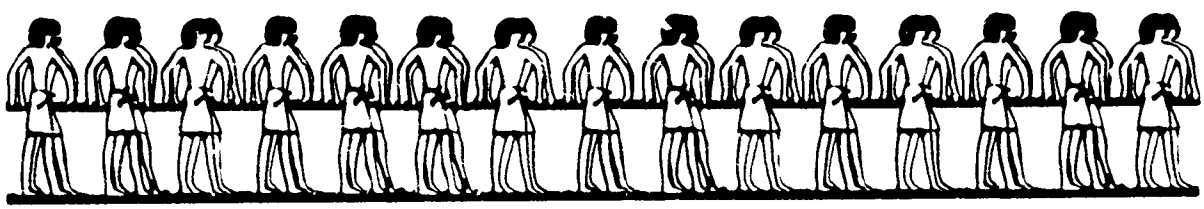
the electronic energy levels of atoms with sufficiently high resolution to distinguish chemical species; and, unlike X-ray diffraction, the two techniques do not require a crystalline surface. With XPS, the valence state of an element is revealed directly by the binding energies of photo-excited electrons. Auger spectra are considerably more complicated; they reflect the binding energies of each of three electrons involved in an Auger de-excitation process. With AES, presently, chemical species are identified or "fingerprinted" by their Auger lineshapes.

XPS is therefore considered more convenient for identifying chemical species. For examining small areas such as wear scars, however, AES would have to be relied on. Fortunately, many elements of interest to tribologists have Auger lineshapes which reflect their chemical states. Most notable are those elements found in lubricants and/or their additives (e.g., carbon, chlorine, phosphorous, sulfur, zinc and boron). An example of the chemical information obtainable by XPS and AES for one of these elements, sulfur, is illustrated in Figure 2, which shows the XPS and AES lineshapes of sulfur for several sulfur compounds.

The surface sensitivity of XPS and AES, coupled with the ability to etch away surface layers by ion beam sputtering, allows one to form a three dimensional picture of surface composition. Heterogeneous surfaces, such as severely worn areas on ball bearings, can be scrutinized in detail with SAM. The wear scar highlighted in Figure 3 has been lightly sputtered, mainly to remove the ever-present carbon overlayer. The optical micrograph clearly shows the rough topography of the wear scar, while the secondary electron micrograph indicates a variation in thickness or in composition of the outermost layer. The four scanning Auger micrographs show the variation in composition quite precisely. Oxygen, iron, carbon and even chlorine are distributed on the hills or in the valleys of the scar; their presence is indicated by bright images in the micrographs. Some areas have been etched through to metallic iron while other areas are still covered by an oxide. An XPS

*Figure 2: Sulfur lineshapes of several sulfur-oxygen compounds obtained by XPS and AES. Note the expanded energy scale of the XPS spectra vis-a-vis that of the AES spectra.*



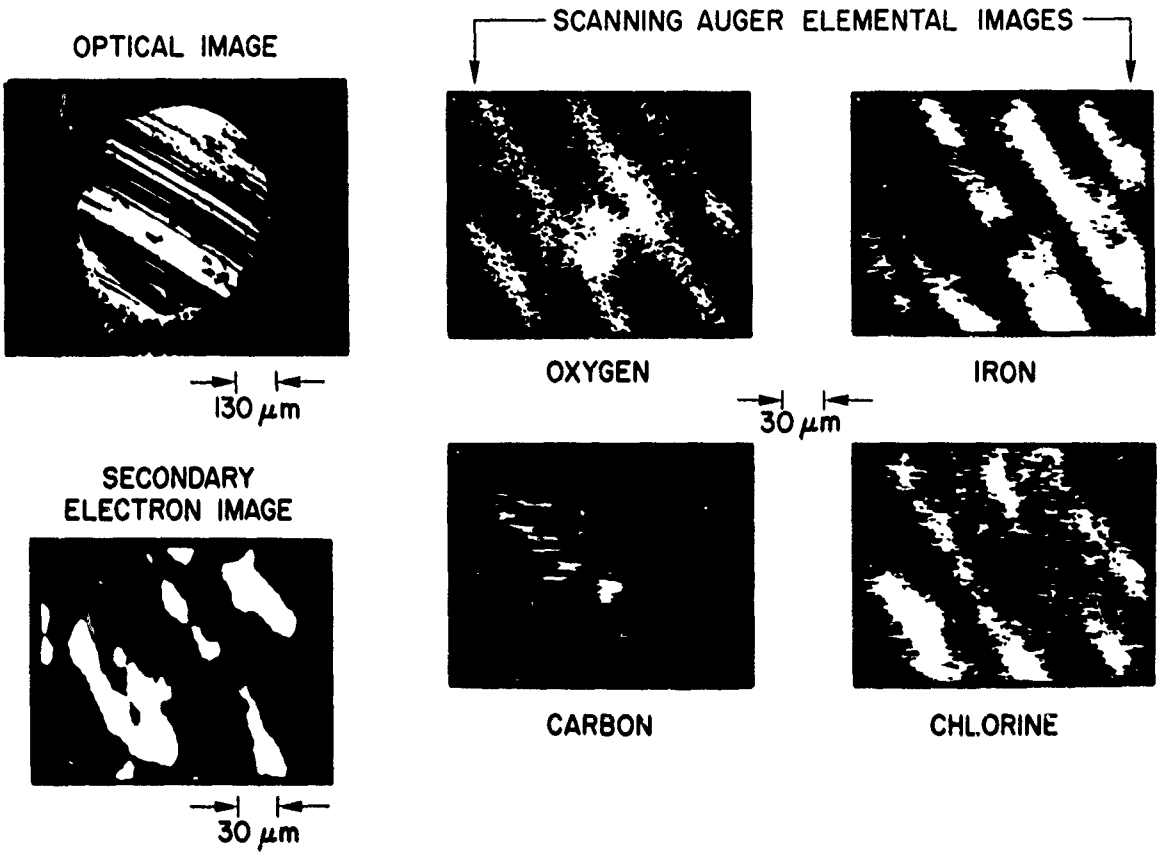
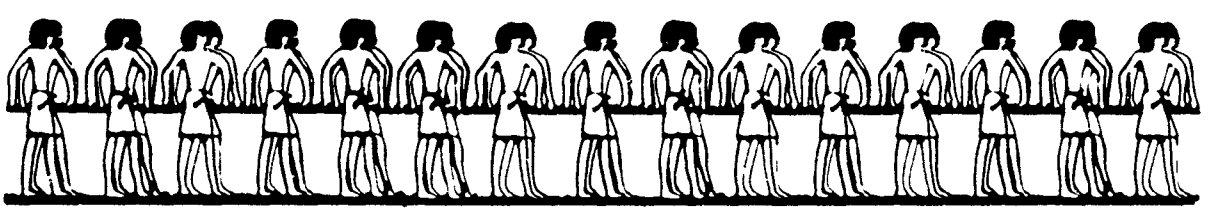



*Figure 3:* *Optical, secondary electron and Auger election images of a sputter-etched surface in a severe wear area. Striations in the optical image depict the physical contours of the wear scar. Patches of white on dark in the secondary electron image indicate that the wear scar is covered by a film non-uniform in composition or thickness. (The optical image is rotated slightly with respect to electron images.)*

study of this surface would show a composition averaged over both areas and would mask the heterogeneity. The heterogeneity depicted by .he SAM images is believed to be characteristic of the surface composition in the sample shown in Figure 4; however, shadowing of the incident ion beam by rough surfaces, or angular dependent etch rates, might also have led to apparent compositional variations.

There are other concerns with ion beam etching, especially if one hopes to extract chemical information from the sputtered surface. Ion bombardment, for example, can alter the chemical bonds of surface species. To date, there is little understanding of the mechanisms responsible for ion beam degradation of materials, and only empirical findings have been reported.[7,8] Nonetheless, ion beams are routinely used in conjunction with AES and XPS to obtain composition vs. depth profiles of materials. And, if one is willing to settle for the more gross chemical features of surfaces, it is possible to construct composition profiles such as that shown in Figure 4 for an iron chromium alloy steel[9]. Several recent texts review these and other techniques used to characterize solid surfaces.[10-13]



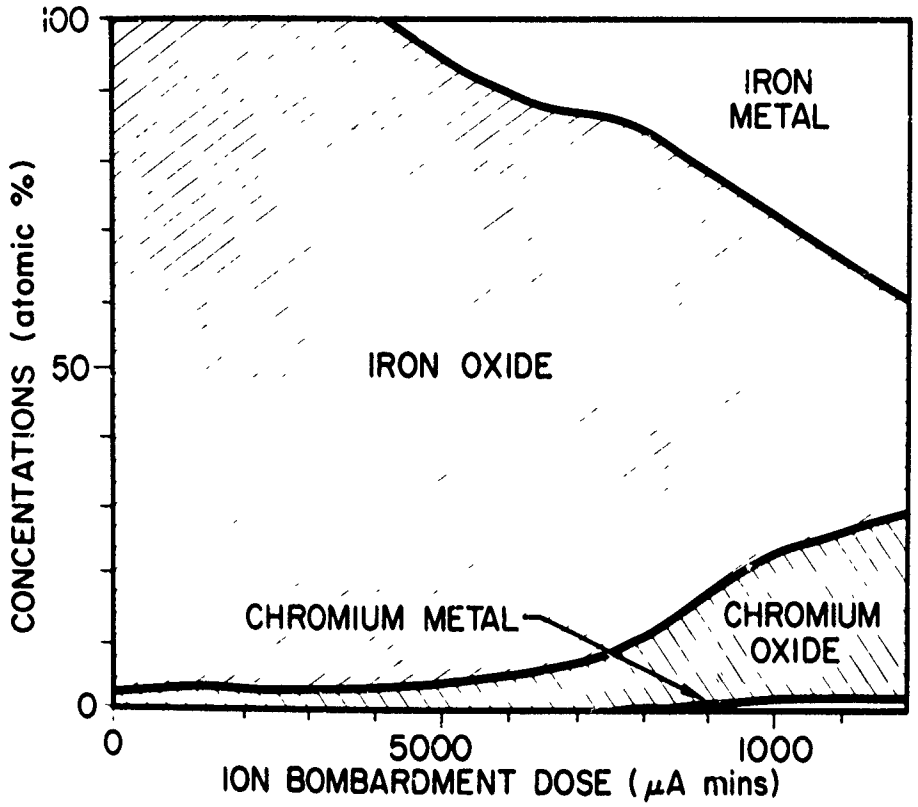
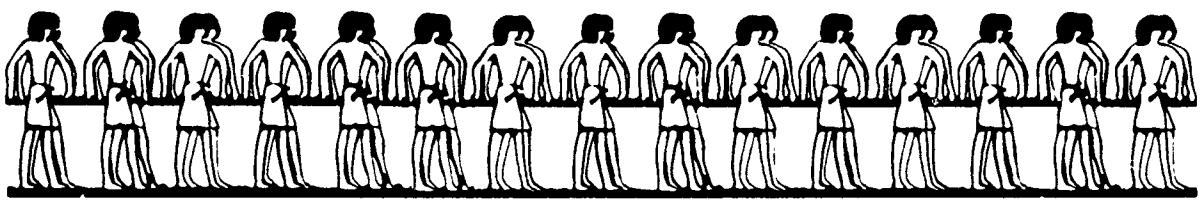



*Figure 4: Composition profile of an iron-chromium steel surface obtained by XPS in conjunction with ion beam sputtering.*

## Applications of AES and XPS in Tribology

Science progresses by taking advantage of opportunities, and the vacuum requirements of the new spectroscopies provide such an opportunity for tribologists. Virtually all surfaces involved in tribological systems are vulnerable to interactions with their environment which can significantly affect their properties and performance. Oxygen might be called the "best lubricant" available because it reduces the friction coefficients of clean metals from complete seizure to values less than 1. Additional lubrication can usually reduce friction by only an order of magnitude. Studies in an ultra-high vacuum system, where the exposure of a surface can be carefully controlled, provide a means to examine the role of an ambient gas on friction and wear.

Examples of such studies are provided by the work of Buckley[14]. In one set of experiments, he examined the interaction of sulfur and oxygen with clean iron surfaces during sliding. Sulfur, one of the most widely used elements in extreme pressure (EP) lubricant additives, has been thought by some to form an easily sheared FeS layer on surfaces while others believed it promoted the growth of an iron oxide layer. Buckley found that exposure to $H_2S$ or methyl mercaptan produced sulfur layers only outside of the wear track. By contrast, an oxygen exposure produced oxide layers inside as well as outside of the wear track. Moreover, oxygen was capable of displacing sulfur layers, but not vice versa. In another set of experiments, Buckley examined the effects of loading on the friction behavior of a surface "lubricated" by adsorbed vinylchlorides. He found



that, with increasing load, the friction coefficient initially dropped and then rose appreciably. Auger spectroscopy showed that the greatest surface coverage of chlorine coincided with the load at which minimum friction was observed.

Adsorption is not the only process that can alter the composition of surface layers and affect the tribological properties of solids. Surface segregation can cause substantial differences in surface composition in alloys and in elemental metals with low levels of impurities. For instance, Buckley reported a five-fold increase in copper-to-gold adhesion with the addition of aluminum (as little as one atomic percent) to the copper. Further, he found that higher aluminum concentrations had no additional affect and that the adhesion data for copper with one atomic percent aluminum were approximately the same as for pure aluminum. Examination of the copper alloy surface by AES showed that the outermost layer was, in fact, aluminum atoms.

In order to relate such fundamental surface interactions to practical situations, it is necessary to determine what chemical and physical modifications take place in bearing materials under realistic wear conditions. Metal alloy bearings are coated with predominantly oxide films which can incorporate other species as well. They are surrounded by lubricants, additives, and ambient gases that can react with bearing surfaces. The result is formation of very complex films which buffer the interaction between two opposing surfaces. The chemical properties of such films can also be probed by the surface-sensitive analytical tools; and while the information thus obtained may be difficult to fully interpret, it can provide valuable insight into the role these films play in friction and wear. The initial application of surface analysis to study the complex composition and tribological roles of these films is more likely to be profitable when the film composition plays a major role. This leads one naturally to

*Dr. Singer, one of the authors, is shown wrapped up in a Scanning Auger microprobe used to study the composition of implanted bearing steels. With Auger analysis and ion-milling, the relative abundance of most elements above helium can be determined to a depth of several thousand Angstroms.*

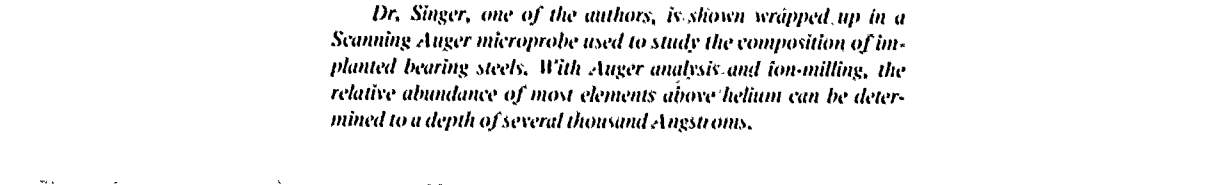


*Table II:*
*Reported XPS/AES Studies*
*Involving Antiwear Additives*

| Source | XPS | AES | SAM | Sputter Etching |
|---|---|---|---|---|
| Baldwin (a) | ● | | | |
| Bird and Galvin (b) | ● | | | ● |
| Wheeler (c) | ● | | | ● |
| Phillips et al. (d) | | ● | | ● |
| McCarroll et al. (e) | | ● | | ● |
| Shafrin and Murday (f) | | ● | ● | ● |

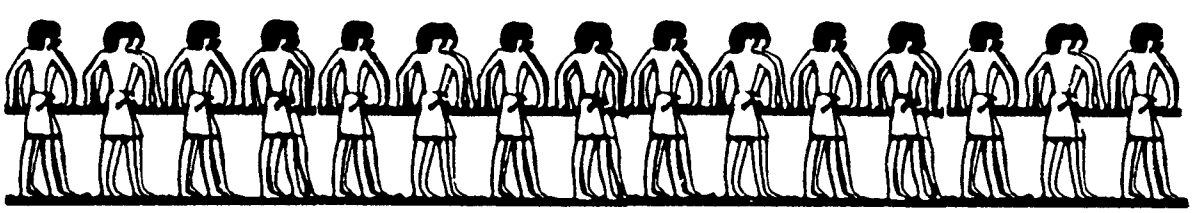
a. B. A. Baldwin, ASLE Trans. 19 (1976) 335-344; B. A. Baldwin, Wear 45 (1976) 345-353.
b. R. J. Bird and G. D. Galvin, Wear 37 (1976) 143-167.
c. D. R. Wheeler, Wear 47 (1978) 243-254.
d. M. R. Phillips, M. Dewey, D. D. Hall, T. F. J. Quinn and H. N. Southworth, Vacuum 26 (1976) 451-458.
e. J. J. McCarroll, R. W. Mould, H. B. Silver and M. L. Sims, Nature 266 (1977), 518-519; Proc. 7th Int. Vac. Congr. (Vienna, 1977), 2301.
f. E. G. Shafrin and J. S. Murday, J. Vac. Sci Technol. 14 (1977) 246-253; E. G. Shafrin and J. S. Murday, ASLE Trans. 21 (1978) 329-336.

boundary lubrication as an initial tribological subject for surface analytical study.

Boundary lubrication conditions, where the bearing surfaces are separated by a film no more than a few monomolecular layers thick, occur most often when bearings are run at high load or low speed. Certain reactive compounds containing sulfur, phosphorous or chlorine are known to reduce wear under such conditions. These compounds are often called either antiwear (AW) or extreme pressure (EP) additives. Although their effectiveness has been thoroughly demonstrated over the past 50 years, little could be learned about how these additives modify the bearing surfaces until the advent of analytical tools capable of examining the structure and composition of surfaces on a fine scale (less than microns).

There have been only a handful of boundary lubrication studies in which the XPS and AES were utilized[15]. This work is summarized in Table II; it should be noted that a comprehensive multi-analytical study has not yet been tried. Of the two techniques, XPS has provided the more definitive data on the chemical make-up of additive-promoted films whereas AES has been more useful at distinguishing variations in the composition of the wear scar. Both techniques have been used in conjunction with ion sputter etching to provide composition vs. depth profiles of surface films. Most of the work has focused on the role of sulfur compounds, with boron, phosphorous and chlorine being examined to a lesser degree. The main conclusion to date is that the lubricant-additive-surface interaction results in a limited number of detectable surface species. In several studies, the surface concentration of these additive-promoted species could also be correlated with the amount of wear.

In future studies of wear surfaces, we anticipate more use of the multi-analytical approach; in particular, SAM is called for on wear-scarred surfaces. More careful analysis is also needed to etablish the relationships of XPS and AES lineshapes to the



chemical compounds of interest and to account for the damage inflicted on the surface during ion sputter etching. Proper application of these techniques should provide an accurate three-dimensional picture of additive-promoted films that will be important in understanding the film's role in resisting wear.

## Tailored Surfaces

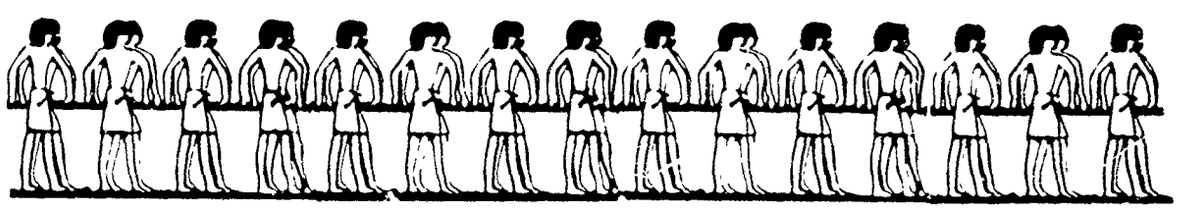
The bulk properties required of materials to be used in bearings or other tribological applications are usually determined by design requirements such as mechanical strength, thermal stability or machinability. The surface properties desired for appropriate friction and wear behavior are often quite different from the bulk requirements For instance, machinability suggests a reasonably soft material while a low wear requirement would argue for hardness. One solution for these dual requirements has been to produce a surface layer with the desired friction/wear properties while leaving the bulk intact to play its own role.

The desired surface may be a coating produced by one of a variety of techniques such as electroplating, spray coating, vacuum evaporation, sputter deposition, chemical vapor deposition or ion plating. We will briefly highlight the ion plating process here because it is often confused with ion implantation, the new opportunity to be addressed later in this section. Ion plating is a technique whereby gas phase atoms are ionized into a plasma and accelerated towards the surface. Although the accelerating voltages may be several keV, the mean energy of particles arriving at the surface is more on the order of 100 eV, permitting them to penetrate no more than several atomic layers. Coatings, in general, tend to be weak at the interface, leading to peeling under mechanical stress or to interfacial corrosion. Ion plated films, however, suffer less from these problems, perhaps because the sputtering and redeposition which accompany the ion/surface collisions result in a mixing of original and deposited material at the interface.

An alternative to coatings, with their interfacial weakness problems, is to modify the surface composition or structure of the material. For steels, for example, the surface is frequently hardened using one of several techniques. Shot peening is used to cold-work the surface layer, thereby pinning dislocation motion. More common, however, is nitriding or carbiding by which N or C is diffused into the surface layers at high gas temperatures and pressures. The latter treatments produce finely dispersed precipitates that harden the surface layer. Since these techniques do not grow a film on top of the original surface, they eliminate the interfacial weakness problem.

Thermally-driven diffusion processing, however, has limitations. Only soluble atoms can be introduced into host lattices. Moreover, neither the number of solute atoms nor their distribution can be reproducibly controlled. To escape these constraints, the semiconductor device industry successfully turned to ion implantation as a means of modifying surface composition. In the ion implantation process, atomic or molecular ions are accelerated to energies in the range of 10-500 keV. At these energies, ions impinging on a surface can penetrate up to a micron (typically 100 nm) depending on the incident energy and the mass ratio of the implantation to host atoms. In addition to introducing a new species, ion implantation may also change the surface properties of the host material through radiation damage and sputtering.

Compared to the research on implanted semiconductors, there has been relatively little effort to establish changes which take place in implanted metals. Preliminary investigations[10] at the Atomic Energy Research Establishment at Harwell, England and at the Naval Research Laboratory (NRL)[11] indicate that implantation of selected ions can significantly improve the tribological properties of metals. The sliding friction coefficient decreases, for example, when the ions of tin, molybdenum, sulfur or the stoichiometric combination, molybdenum plus two sulfur atoms, are implanted in metals. One interesting result is that the latter combination produced a larger decrease in friction than either species alone, leading to speculation that molybdenum disulfide, a popular solid lubricant, might have been formed.



Wear resistance can also be improved by ion implantation. In the experiment illustrated in Figure 5, the sliding wear resistance was increased several orders of magnitude after 304 stainless steel was implanted with nitrogen ions at high doses ($10^{17}$/cm$^2$ at 40 keV). A first thought might be that the nitrogen implant was equivalent to nitriding (thereby case hardening) the surface. However, it was found that the improved wear performance persisted after removal of enough surface material to exceed the penetration depth of the implanted nitrogen, suggesting something more complicated than nitriding.

Implantation in other metal systems has also been shown to improve corrosion resistance and fatigue life. While these phenomena are not directly tribological, they do play a major role in the structural integrity of mechanical systems. Corrosion, for example, rivals friction and wear as a cause of bearing failures.

The lag in the application of implantation to metals as compared to semiconductors is due, in part, to the dosage required. For semiconductors, a typical implantation dose is approximately $10^{14}$ ions/cm$^2$. The recent studies for friction/wear applications in metals indicate that dosages of $10^{16}$ to $10^{17}$ ions/cm$^2$ are required. Wide scale use of metallic ion implantation awaits further research and development efforts and the anticipated availability of high current ion beam accelerators.

Ion implantation is not the only new opportunity for surface modification. The availability of high power lasers and high current electron beams raises prospects for rapid heating and cooling of surfaces by injecting large amounts of pulsed radiation. It is known that metals quenched from temperatures near or at the melting point may retain-long range disorder, i.e., may be produced in an amorphous or glassy rather than crystalline state. Glassy metals have quite different properties from their crystalline analogs and, in particular, may have much higher corrosion resistance. Although no tribological investigations have been carried out on these new materials, there has been speculation that reduced crystallinity may improve wear properties as well.

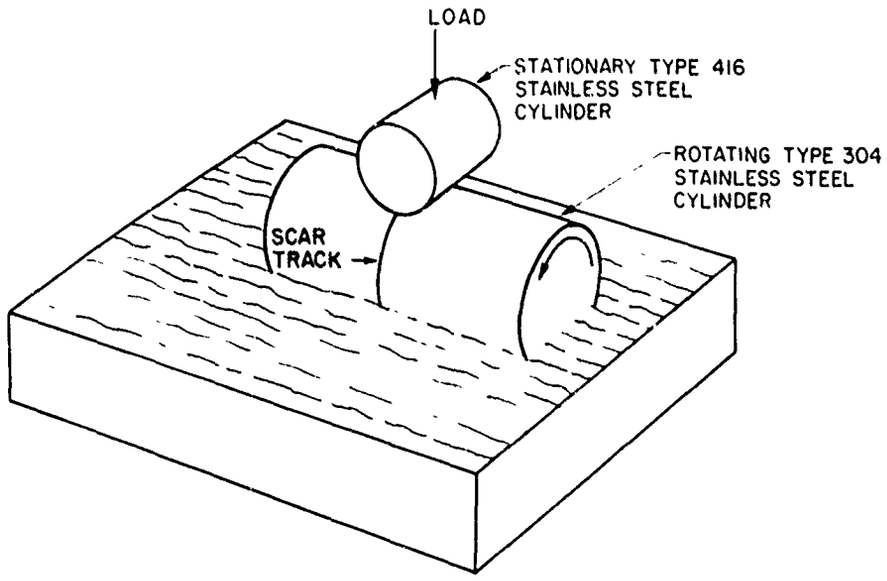
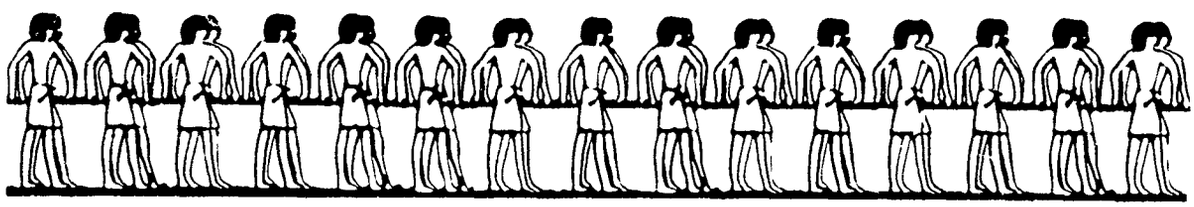



*Figure 5: Experimental arrangement used to test the sliding-wear resistance of stainless steel*



## Conclusions

In keeping with its title, "New Opportunities in Tribology," this article has discussed the present state of knowledge of this research area, but more importantly, the promise of what further research will accomplish. So, it is appropriate, at this point, to recapitulate the areas which hold that promise, pending the research that will develop and release it into practical applications.

The analysis of surface properties is clearly important to the development of tribology. At present, AES and XPS are the most valuable spectroscopies; however, they only measure electron energy levels. And anyone who has tried to identify an unknown substance will recognize that electron spectroscopies can provide only part of the necessary information. Spectroscopies sensitive to the vibrational levels (IR, Raman), the molecular mass (mass spectroscopy) and structure (X-ray and electron diffraction, NMR, Mossbauer) are also needed. There are no well-developed extensions of these latter techniques to surface studies although progress is being made[10,11]. Some of the optical techniques such as IR, Raman, and fluorescence are gaining in sensitivity, especially with Fourier transform IR or resonance Raman approaches and show signs of becoming workable surface tools. A mass spectroscopy for surface analysis, called static secondary ion mass spectroscopy (SIMS), is now well into the development stage; it is certain to become a very powerful tool when research has developed its capabilities and defined its limitations. An electron diffraction technique, electron channeling, appears promising for monitoring deformations in crystalline surfaces. Mossbauer spectroscopy is now being performed in a backscattering mode and in high vacuum to study conversion electrons, thereby increasing its sensitivity to surface chemistry. Awaiting exploitation by tribologists are the maturing nuclear back-scattering techniques, which can reveal both structure and composition of surface layers[12].

The surface-sensitive analytical tools of today require a vacuum/solid interface. This prevents *in situ* studies at an interface with an ambient atmosphere or liquid environments. The optical techniques mentioned above can feasibly extract information from such interfaces and therefore have considerable potential value.

The application of present surface analysis capability to tribological investigations has not reached its full potential. There is no question that a multi-analytical approach is necessary and that both spectroscopic and tribological approaches are required to elucidate the complex phenomena occurring at the surfaces of interest. At present there are few such multidisciplinary efforts; only three laboratories, NRL and NASA Lewis in the U.S. and Cambridge University in the U.K., have credible programs. Of these the NASA and Cambridge efforts are addressing model microscopic systems; NRL is working to elucidate the macroscopic real world systems. Perhaps the most useful development will be the correlation of the macroscopic and microscopic properties of the surfaces.

The area of surface modification should also see a twofold approach—an empirical study based on today's intuition in order to quickly establish which systems will yield improved performance, and a model study which will provide the understanding which forms the basis for tomorrow's intuition. An assessment of profitable areas of implantation research with specific naval applications has recently been reported by Naval Air Development Center Warminster[13]. Even a modest success in these areas will ultimately result in large benefits to both the defense and civilian sectors. ■

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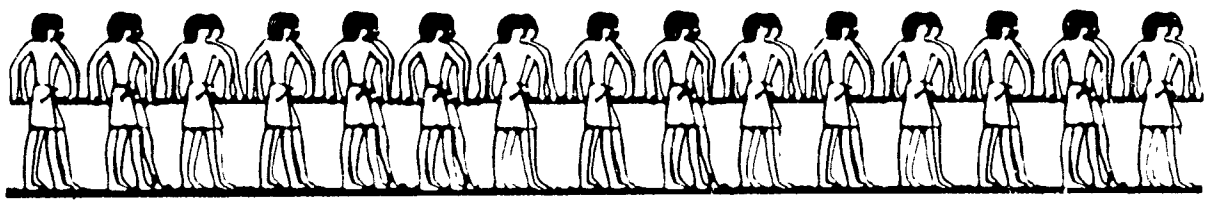

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# profiles in science

Eric Baer, who is Professor of Macromolecular Science and Dean of Case Institute of Technology at Case Western Reserve University, is a renowned pioneer in the field of polymer science. After joining E. I. Dupont in 1958, he developed the concept of a "Modulus Accuracy Limit", which allowed designers to make accurate predictions and to minimize costly safety factors. He was one of the first researchers to apply elementary plasticity theory to plastics by introducing the concept of time-dependent yield stress.

While studying the behavior of polymeric solids under pressure, Professor Baer published some of the earliest evidence that polymers can be crystallized in an extended chain morphology under pressure. Recently, supported by the Office of Naval Research, Professor Baer discovered unique brittle-to-ductile transitions in polymeric solids under pressure. This research has brought new insight into the mechanism of stress cracking.

For many years Baer and co-workers studied the mechanism of epitaxial crystallization on the surfaces of single crystals. This work has shown that epitaxial crystallization can be applied to virtually all crystallizable macromolecules.

Also Professor Baer has achieved noteworthy accomplishments in polymer research by studying reactions on polymer crystal surfaces, microdeformation processes, and relaxation processes under cryogenic conditions. His many publications include over one hundred original research papers and four books. The scientific community has recognized Professor Baer; he was awarded the Curtis W. McGraw Research Award and the International Award of the Society of Plastic Engineers. He is a Fellow of the American Physical Society and the American Institute of Chemists. Recently Professor Baer served on the National Materials Advisory Board of the National Research Council.

# Navy Clinical Trials for Treating Septic Shock

by

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and

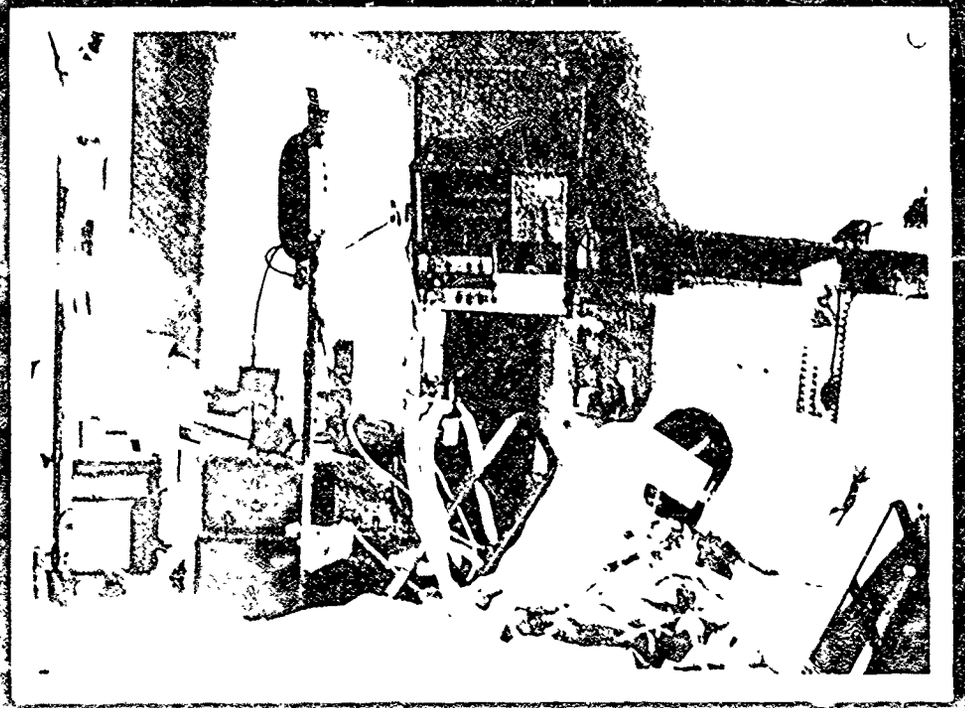
Captain Raymond Fletcher, USN and Lieutenant Commander Larry Casey, USN
Naval Medical Research Institute

Shock is a serious clinical situation; the blood pressure falls precipitously and every organ is at risk since it may not recover from the inadequate blood supply. Shock is caused by hemorrhage, severe allergic reactions, and by septic infections. This latter situation is called septic shock. Most cases of septic shock are due to the gram-negative class of bacteria. These are bacteria which are normally in the [illegible] flora. This is the reason why so many cases of appendicitis and why belly wounds that perforate the bowel are serious. The mortality is high (60-80%) even in highly equipped hospitals. In combat (Viet Nam) more than [illegible] deaths were caused by septic shock. The use of antibiotics, massive doses of [illegible], steroids, and transfusions to maintain circulation. In the U.S. about 150,000 to [illegible] individuals die every year of septic shock. Prior to 1900, sepsis was the major killer in childbirth. It was known as puerperal fever. The maternal morbidity and the mortality was markedly reduced by the introduction of aseptic techniques. However, even in the latter gram-negative infection is a risk factor. The fetus, membranes and placenta may be infected from the vagina through the cervix. The perinatal deaths due to this is approximately 10,000 per year in the U.S. The morbidity, or frequency of the results of the infection, such as brain damage, has not been estimated.

## Current Treatment of Septic Shock

The major treatment of septic shock is antibiotics and the cleaning and drainage of infectious foci. After antibiotic therapy, the goal of the Intensive Care Unit is to maintain the microcirculation, the perfusion of tissue and the arterial oxygen tension (Figures 1 and 2). This is done by fluid reloading, colloid expanders, correction of plasma pH, respiratory support, vasoactive drugs and diuretics. Large doses of anti-inflammatory steriods are also used in the U.S. The mortality rate is still high in spite of these drugs, and it is generally considered that they have failed to be effective. However, since no alternative treatment exists, these steroids are widely used. The issue is confused, conflicting and unsettled.

Extrapolation from the animal studies to the human disease entity of septic shock is difficult. There has been only one clinically controlled study showing increased survival after treatment with corticosteroids; others have not been able to obtain a beneficial effect. Theoretically, steroids in massive doses have potential beneficial effects in stabilizing lysosomes, decreasing capillary permeability and decreasing peripheral vascular resistance. One of the



*Marie Foegh, M.D., is a Danish-trained gynecological surgeon, who is in the Department of Obstetrics and Gynecology, Georgetown University Hospital, Washington, D.C. She has participated in the initiation of the study of lidocaine treatment of patients in septic shock in Denmark and Sweden, and is the Clinical Monitor of the study. At the same time she works together with the other co-authors on studying the possible mechanisms by which lidocaine exerts its effect in endotoxin shock as well as the possible involvement of prostaglandins.*

*Peter Ramwell, Ph.D., is a Professor of Physiology at Georgetown University School of Medicine and has been involved in prostaglandin research for fifteen years. His particular interest is the application of the laboratory studies to the clinic.*

*Captain Raymond Fletcher, MC, USN, is a Navy surgeon who has been interested in the treatment of sepsis in the combat casualty. Dr. Fletcher is Head of the Surgery Research Branch at the Naval Medical Research Institute, attending surgeon at the National Naval Medical Center, and Professor of Surgery at the Uniformed Services University of the Health Sciences, Bethesda, Md.*

*Lieutenant Commander Larry Casey, MC, USN, is an internist and a research medical officer in the Surgery Research Branch, Naval Medical Research Institute. Dr. Casey's scientific interests are related to pulmonary failure in the combat casualty. His Ph.D. thesis work at Georgetown is directed to studying the mechanism of the protective effect of lidocaine and establishing how endotoxin releases prostaglandins.*

major reasons for the discrepancy between animal studies and the lack of beneficial effects in many human trials could be due to the difference in sequence, i.e. in animal studies he steroids are given *prior* to challenge, whereas in patients the steroids are given *after* the infection has occurred.

**Bacterial Endotoxin**

Why is infection with gram-negative bacteria so devastating and likely to cause such severe hemodynamic disturbances and organ failure? Most of the manifestations of septic shock are thought to be caused by a part of the bacterial wall which is called endotoxin. Endotoxin is a complex of lipids, proteins and carbohydrates. The toxicity of endotoxin lies in the lipid component called Lipid A. Endotoxin is used for imitating the clinical situation because the injection of live bacteria causes shock in an unreproducible manner. A large number of vaso- active substances such as the biogenic amines, e.g., histamine, serotonin and catecholamines and polypeptides such as bradykinin are released during the endotoxin shock syndrome. Many attempts have been made to identify which of them is the primary mediator of the shock situation. Unfortunately none of these humoral subtances has been convincingly implicated in the clinic. Consequently, with the disappointing effectiveness of steroids and the failure to implicate biogenic amines and polypeptides, it was necessary to search for other candidates if the mortality rate were to be reduced. This is particularly the case in combat since septicemic shock is a major cause of death.

## The Prostaglandin Involvement

In 1972 the first suggestion was made of the involvement of a new class of substances in endotoxin shock called the prostaglandins, which are hormones[1]. Prostaglandins are highly vacoactive substances which can be synthesized by every mature cell. They are not stored in the cells like other hormones. The precursor is a ubiquitous polyunsaturated fatty acid known as arachidonic acid. When cells are traumatized by cold, fresh water or strong saline, burns and scalds and by torsion, this fatty acid is released from the phospholipids of the cell membrane (Figure 3). As soon as the release has taken place, the free arachidonic acid is rapidly oxygenated to form prostaglandin endoperoxide. A major discovery was made at the Royal College of Surgeons in 1971 that this process is prevented by aspirin and other anti-rheumatic drugs[2]. This explains why high doses of aspirin are highly useful in treating the pain and swelling which are associated with trauma. We now know that prostaglandin endoperoxide is the cause of some of these symptoms.

The question arose as to the relationship between prostaglandins and endotoxin shock. Kessler[3] discovered in 1973 a prostaglandin-like material with

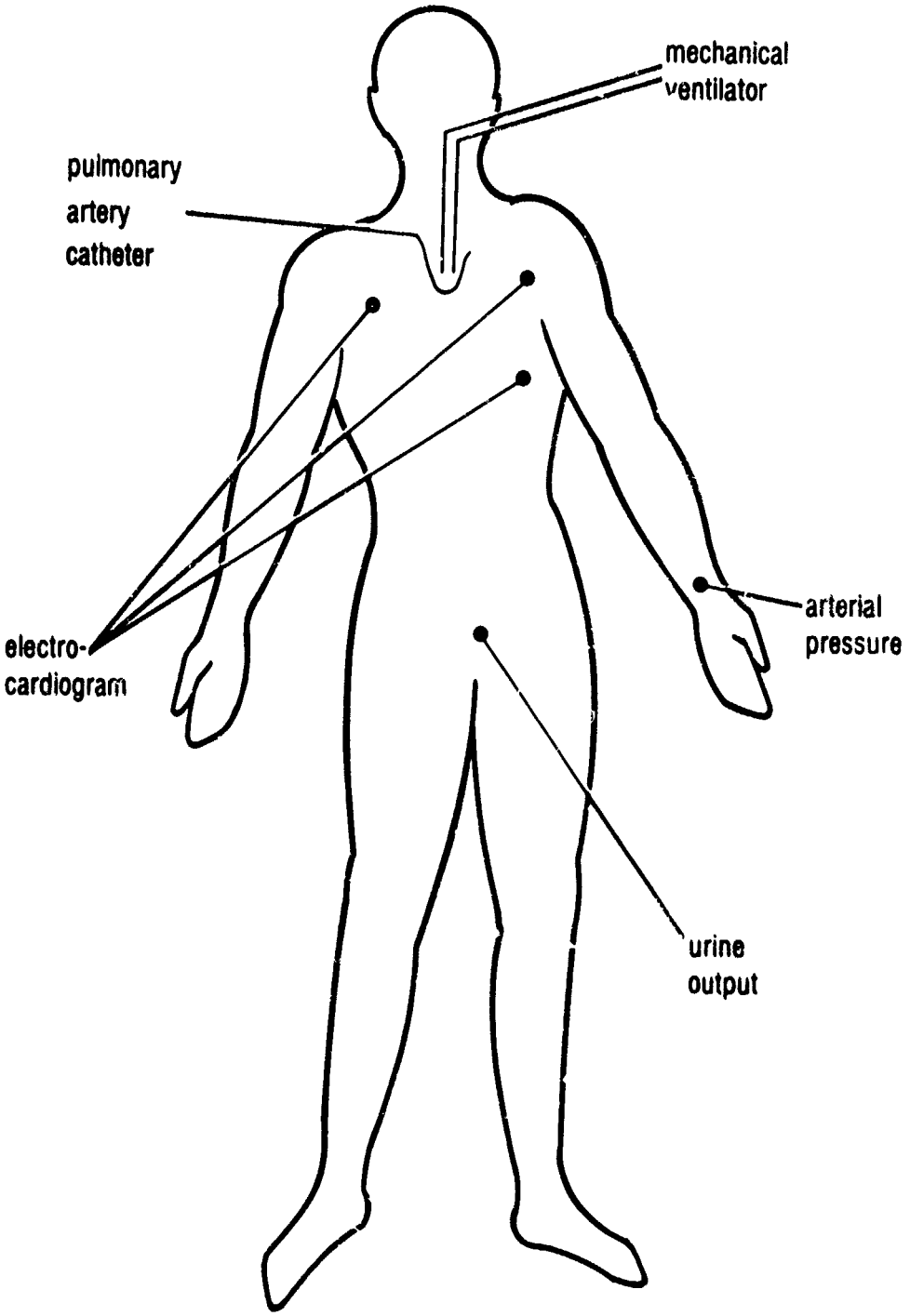



*Figure 2 Diagram of catheters, pressure lines and EKG monitors of a patient in septic shock*

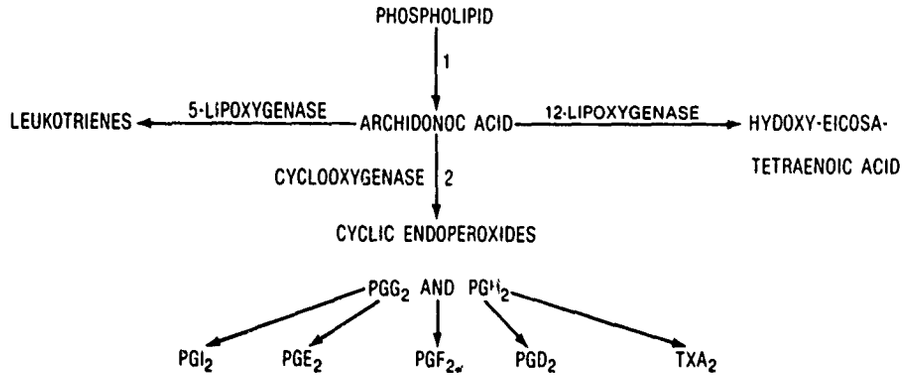



*Figure 3. Arachidonic acid—prostaglandin diagram.*

vasodepressor properties in the plasma of dogs in endotoxin shock. Collier[4], using a bioassay, reported the presence of a prostaglandin-like material in venous renal blood in dogs in either endotoxin or hemorrhagic shock. The first radioimmunoassay of prostaglandin levels during endotoxin-induced shock was performed in 1975 by Anderson[5] in dogs. He found increased levels in the portal and renal veins, but not in the aorta.

We found high prostaglandin levels in the blood of patients in septic shock at the National Naval Medical Center, Bethesda, Marlyand.[6] However, in order to study experimental endotoxin shock we had to overcome the major problem of the marked species variation in response to endotoxin. Fortunately, owing to the seriousness of the military problem of sepsis, a shock laboratory had been developed at the Navy Medical Research Institute in the Division of Experimental Surgery. Here, a baboon endotoxin shock model was used in which the primate was kept conscious (but tranquilized) to avoid the circulatory changes brought about by anesthesia. We were able to establish a correlation between the changes in hemodynamics (cardiac output, systemic blood pressure and pulmonary artery pressure) and plasma prostaglandin levels in these subhuman primates[7,8].

Since the plasma prostaglandin levels are increased by endotoxin, the question arises as to which of them may be responsible for the shock syndrome, since a variety of highly vasoactive compounds are formed from the prostaglandin endoperoxide (Figure 3). These compounds include the vasodepressor substances $PGE_2$, $PGD_2$ and $PGI_2$. In some species (but not primates), $PGF_2\alpha$, has the opposite effect. Finally, thromboxane $A_2$, which does not have the cyclopentane structure of the prostaglandins, is a powerful aggregator of platelets and constrictor of all types of vascular muscle.

Following endotoxin administration to baboons, we found that all these compounds which we could measure, i.e. $PGE_2$, $PGF_2\alpha$, and the chemical breakdown products of thromboxane $A_2$, i.e. $TxB_2$ and prostacyclin, i.e. 6-Keto $PGF_1\alpha$, were all elevated (Figure 4). Both prostacyclin and $PGF_2\alpha$, are unlikely to be the mediators of shock, since infusion of these compounds affords protection[9]. Although not tested, $PGE_2$ and $PGD_2$ are also likely to afford protection, especially the latter, since it inhibits platelet aggregation. It is difficult to test thromboxane $A_2$ since it has not yet been synthesized. However, we tested an inhibitor of thromboxane synthetase, which blocks the conversion of the prostaglandin endoperoxide to thromboxane $A_2$. Preliminary data show that this inhibitor prevents the characteristic rise in pulmonary artery pressures seen following endotoxin administration and it also improves survival. Consequently, we tentatively conclude that in the primate, thromboxane may be a primary mediator of endotoxin shock. Similar data have been obtained by others in rats employing another thromboxane synthetase inhibitor, and also by using a thromboxane receptor blocking drug[10].

Unfortunately the thromboxane synthetase inhibitors or receptor antagonists are not clinically available since they are experimental drugs.

## Use of Indomethacin

Why is the correlation between hemodynamics and plasma prostaglandins important? The reason is that if a component of the prostaglandin system mediates shock, then there are two widely used clinical drugs available which can block prostaglandin synthesis. The most common, but the weakest, is aspirin, referred to earlier. A far more effective drug is indomethacin which is more powerful in treating inflammation. Pretreatment with this drug was encouraging. It was given as soon as the baboon was in shock (systolic blood pressure below 90 mm Hg) and it delayed the drop in blood pressure and prevented the increase in pulmonary artery pressure induced by the endotoxin[7].

Our second series of experiments were designed to use these drugs in clinical doses to improve survival in dogs and baboons injected with endotoxin. To do this we used a dose of endotoxin which would kill only some of the animals so that any improvement in survival could be detected. Clearly, if an overwhelmingly lethal dose of endotoxin were used, then only a miracle drug could affect survival. When a dose of endotoxin was used which killed 50 or 75% (i.e. Lethal Dose LD50 or LD75), we obtained survival of all the endotoxin treated animals when 1.5 mg of indomethacin per kilogram of body weight was given twice (45 minutes previously and 3 hours after the endotoxin)[11,12]. This dose is within the clinical range for treating rheumatic diseases. In a third experiment to mimic the clinical situation, indomethacin was given after the administration of endotoxin and survival was increased from 30 to 85%[13]. Indomethacin has not been approved by the Food and Drug Administration for intravenous use. Consequently, it was necessary to seek an acceptable alternative.

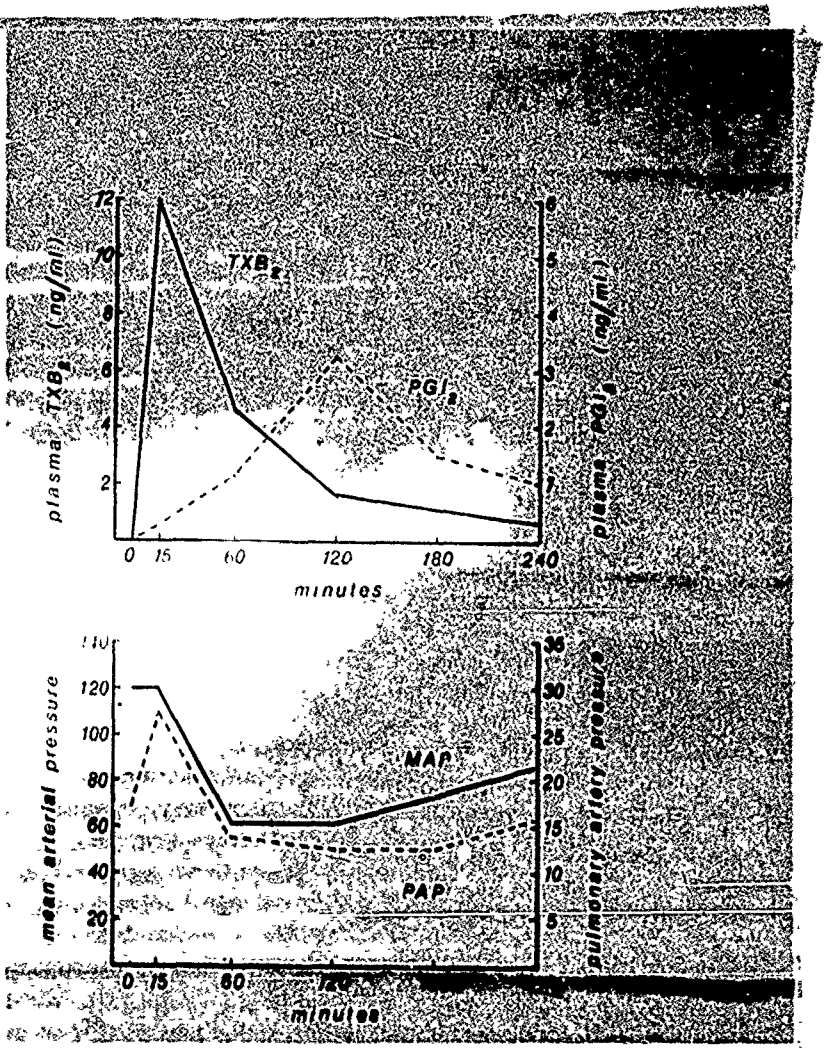



*Figure 4. Correlation of plasma prostaglandins and hemodynamics in a baboon in shock.*

## Animal Shock Studies with Lidocaine

The rate-limiting step is the release of free arachidonate from phospholipid (see Figure 3). This step is mediated by a phospholipase and it is believed that local anesthetics stabilize membranes so that such enzymes are not activated. A widely accepted local anesthetic which has been used intravenously almost universally for preventing arrhythmias in myocardial infarction is lidocaine. Consequently, we tested the effect of lidocaine infusions before administration of endotoxin[12,14]. Survival of the primates was increased and moreover survival was also increased even when the lidocaine was infused about one hour later when the animal was in shock[15].

What is the protective mechanism of lidocaine? Our studies of the prostaglandins in blood showed that lidocaine did not reduce plasma prostaglandins and thromboxane either by itself or during endotoxin shock. In fact, lidocaine was found to actually increase some of these values. Further studies in rats showed that when lidocaine is added to tissues *in vitro*, as expected, prostaglandin production is decreased. However, when the lungs, for example, are perfused after treatment of the rat with lidocaine, the production of prostacyclin from the lungs is increased[16]. Subsequently, when this prostaglandin was infused into endotoxin-treated dogs the survival was improved. Whether or not is one of the mechanisms whereby lidocaine exerts its protective effect is conjectural. More likely mechanisms by which lidocaine protects may be in stabilizing membranes and decreasing membrane permeability and thereby protecting cell function. Whatever the explanation for the protective effect of lidocaine in dogs and baboons in endotoxin shock, the high increase in survival in

those animals offers hope for decreasing the high mortality rate of humans in septic shock.

## Clinical Trials on Lidocaine

The dog and baboon studies which showed improved survival after LD50 and LD75 doses of endotoxin, with prostaglandin synthetase inhibitors (aspirin, indomethacin) and lidocaine, give the directors of the Intensive Care Unit a choice. However, because lidocaine is already a known and more importantly, a widely used intravenous preparation, it was chosen for the first series of studies on treatment of septic shock in patients, at six centers: (1) Michael Reese Hospital, Chicago; (2) Washington Hospital Center, Washington, D.C.; (3) Georgetown University Hospital, Washington, D.C.; (4) Linkoping Hospital, Sweden; (5) Herlev Hospital, Denmark; and (6) Johns Hopkins Hospital, Baltimore. Each center is using its standard treatment for septic shock. For examle, two centers (Herlev and Linkoping) do not use anti-inflammatory steroids as treatment for septic shock.

## Criteria for Accepting Patients in Study

A fall in blood pressure associated with sepsis and lack of response to transfusion are all criteria for entering into the study. The diagnosis of septic shock can be confirmed only by subsequent culture of the bacteria in the blood. Once a patient has entered the study he will get either lidocaine (2 mg/kg/h) or placebo as well as the usual treatment. Since neither the patient nor the physician knows whether lidocaine is being used, this procedure ensures that bias will not be introduced. This is therefore a double, blind drug trial. Lidocaine is an interesting drug because it is easily absorbed by the lungs. To bring the blood concentration to levels effective in treating myocardial infarction, a procedure of giving a loading or bolus dose of 50 mg is normally employed before infusing at 2 mg/kg/hour. However, the baboon studies showed that increased survival on thellidocaine treatment occurs without such bolus injections. Thus the risk of toxic effects with the chosen dose should be minimal even if the metabolism and excretion of lidocaine is decreased due to shock, especially in the shocked lung syndrome. Nevertheless, one protocol includes the possibility of using a bolus.

## Ethics and the Role of the Clinical Monitor

Permission to perform such drug studies is always obtained from a Clinical Research Committee of the responsible institution. This committee is charged with the responsibility of ensuring that the patient's rights are properly protected. The committee consists of physicians, scientists and lay persons, both within and without the University. Every Center has its own Committee, and the clinical protocol has to be approved, in addition, locally before the study may commence.

The Clinical Monitor collects the data from each Center and assesses them continuously so that the trial can be stopped immediately if there is any hint that the treatment is deleterious. On the other hand, the trial must be stopped if the treatment improves survival, so that every patient in septic shock can benefit from lidocane treatment. In a recent trial with respect to the treatment of transient cerebral ischemia, the trial was stopped early since the drug had significantly beneficial results.

## Summary

Septic shock is a severe clinical disorder due to gram-negative bacteremia, with drop in blood pressure followed by organ dysfunction. Between 140,000 and 200,000 people die each year in the United States, in spite of optimal treatment with antibiotics and hemodynamic supporting treatment. Lidocaine in clinical doses increased survival of baboons from 50 to 100%. The mechanism by which lidocaine works is not known, but studies indicate that an effect mediated by the prostaglandin system is possible. The animal data have now led to human trials of the treatment of septic shock with lidocaine. These studies have been funded by the Office of Naval Research and the Bureau of Medicine and Surgery. ■

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# Realistic Job Previews and Attrition*

Bruce M. Meglino

* *The definition of attrition applicable to this article is: leaving the service prior to completion of first term of enlistment*

Attrition prior to completion of the first term enlistment has increased since movement to the all-volunteer force. While it is neither feasible nor desirable to eliminate attrition, it is important to understand its causes and to seek to minimize attrition among potentially effective enlistees. With declining numbers of 18 to 21-year-olds in the population over the coming decade, excessive levels of attrition will place additional burdens on the recruiting function, increase budget requirements, and could detract from end strength and readiness.

The dimensions of the first term attrition issue are becoming more evident.[1,2] A number of research projects are underway directed toward gaining a better understanding of the causes of attrition and evaluating counter-attrition strategies. The research reported here is based on one such endeavor. Specifically, this article will discuss an experimental evaluation of a realistic job preview (RJP) among Marine Corps recruits. It will also discuss opportunities for applying the RJP concept elsewhere, and urge cautions with regard to viewing this approach as a panacea for attrition problems.

## Realistic Job Previews

Experiences encountered by individuals prior to and shortly after entry into a new organization have a profound effect upon their attitudes and behavior.[3,4] A number of studies have shown that early turnover is related to the new employee's lack of realistic information concerning the job and the organization.

Several recent studies of military and business organizations have suggested supplying new and potential employees with realistic information concerning the organization. In a review of career expectations in the military, Wiscoff[5] concluded that thought should be given to increasing group cohesiveness, providing reality-oriented training, and introducing more realistic leadership expectations. Glickman, Goodstadt, Frey, Korman, and Romanczuk[6] conducted a longitudinal study of the U.S. Navy. They concluded:

> The accuracy of expectations conveyed to recruits . . . needs to be enhanced. Inappropriate expectations lead to disenchantment on the part of recruits, which in turn leads to lessened interest in reenlisting, as well as negative feedback to prospective recruits among friends and relatives. (Glickman et. al, 1977, p. 7)


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* * *

*Dr. Stanley O. Horner earned his Ph.D. in Organizational Behavior at the University of South Carolina. His dissertation dealt with the organizational entry process in the Marine Corps and was selected by the American Psychological Association's Division of Industrial-Organizational Psychology as one of the five best dissertations for 1979. Dr. Horner is now Manager of Management Training and Development for Texas Instruments in Dallas.*

* * *

*Dr. Bruce M. Meglino is Associate Professor of Management at the University of South Carolina. He earned his Ph.D. at the University of Massachussetts and has extensive organizational experience having served with Litton Industries and Corning Glass. Dr. Meglino's research focuses on stress and attrition.*


Based on a longitudinal study of attrition in the Marine Corps,[7] Mobley, Hand, Baker, and Meglino suggested that an initial recruit depot program aimed at clarifying expectations as well as enhancing the recruit's expectancy of completing training may help reduce attrition among first-term male enlistees. In a more recent longitudinal study, Lau[8] suggested providing entering Navy recruits with realistic information as a procedure to reduce attrition.

A number of attempts have been made to reduce

attrition by providing potential or new employees with a realistic job preview (RJP). Wanous[4] reviewed six field studies concerned with the effects of RJP's on turnover and concluded:

> The use of realistic job previews in the recruitment of new members has shown consistent results in reducing the turnover of newcomers for a wide variety of organizations. Conclusions about the effect of realism on other facets of the entry process must remain tentative, however. (Wanous, 1977, p. 615).

A more recent review of 10 RJP studies[9,10] concluded that a distinction must be made between RJP's given before and those given after the employment decision. Further, while there is some evidence that RJP's can help reduce attrition, the evidence is inconsistent and the psychological mechanisms by which RJP's operate is not well understood.

In an attempt to explicate the possible contribution of RJP's to attrition reduction, a conceptual model was developed and tested using samples of Marine Corps recruits. A simplified version of this conceptual model is presented in Figure 1.

A number of major hypotheses result from this conceptual model. Specifically, realistic job previews may help reduce attrition by:

1. lowering job ambiguity;
2. providing role models;
3. increasing confidence;
4. increasing perceived ability to cope and perform;
5. changing role outcome values (the importance placed on role characteristics);
6. increasing trust and honesty in the organization;
7. changing expectations regarding the new role.

## Experimental Evaluation of the RJP

In order to evaluate the effectiveness of the realistic job preview (RJP) and to examine the processes by which it may influence attrition, a field experiment was designed. This experiment was conducted at the Marine Corps Recruit Depot (MCRD) at Parris Island, South Carolina. The experiment was labeled PIRATE, for Parris Island Recruit Assimilation Training Exercise.

**Subjects.** A total of 678 enlisted male recruits participated in the study. This did not include 43 recruits who were dropped from the organization due to fraudulent or erroneous entry during the time of the study. All participants were assigned to platoons in the usual MCRD manner. The platoon was the basic training unit and was used as the unit for assignment to experiment conditions. Once the data for starting the study were established, all incoming

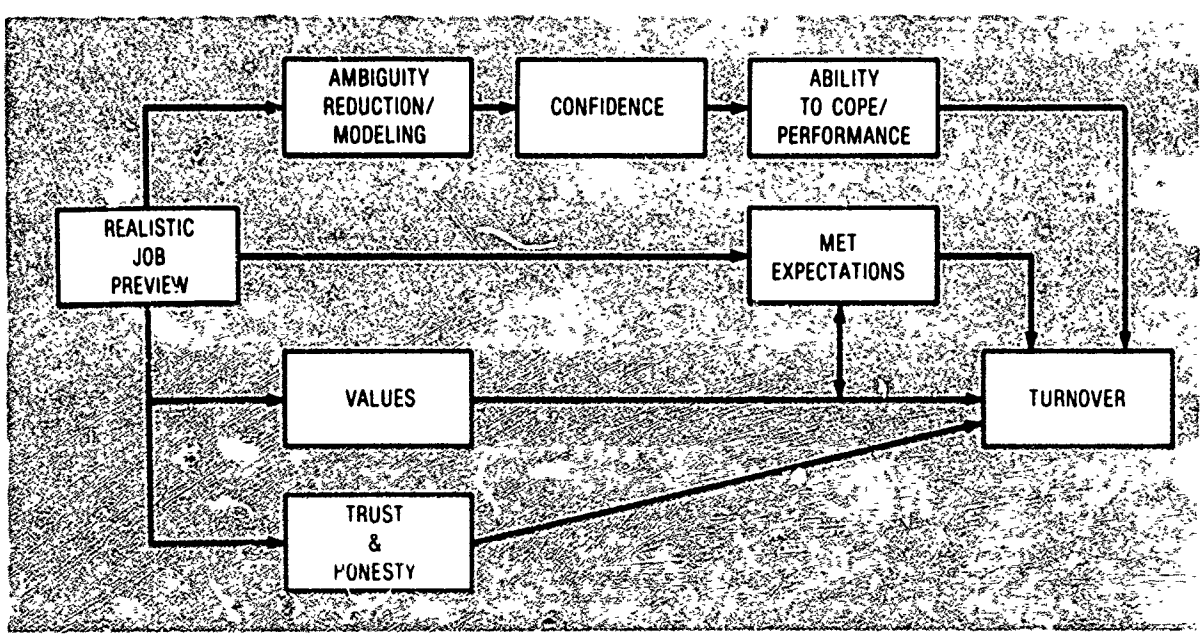


*Figure 1. Intermediate links between RJP's and turnover.*

recruits were included in the experiment with the exception mentioned above, until 12 platoons had been filled.

**RJP film.** The 80-minute color video RJP film was produced by the Training and Support Center (TSC) at Parris Island in close cooperation with the Center for Management and Organizational Research, College of Business Administration, University of South Carolina, (USC). Content for the RJP film and many of the questions included in the measures were based on observations of the training by the USC research team, previous research results, and on extensive interviews with over 300 recruits, drill instructors (DI's), and other Marine Corps personnel.

The RJP film was based primarily on information gained from these interviews. Those areas that the recruits said they wished someone had told them about early in their training were included. Recruits were shown experiencing those portions of training that were identified as the greatest causes of concern among recruits. Voices of recruits and their instructors were included on the sound track over the video picture. The voices explained how the recruit should react to certain situations and gave advice on how to cope with the training.

The film started with the recruits' arrival at Parris Island. The first few days of processing were shown. The participants in the study had already experienced most of the processing but it was hoped that if they were shown a realistic picture of what they had already experienced, they would be more likely to accept the rest of the film as being realistic. Since the main thrust of the study was to reduce early attrition, the first three weeks of events were shown in more detail than the later weeks of training. The film included many of the details of daily life, from the time the recruit first got up in the morning until he went to bed at night. All major events in training were covered. A special section was devoted to showing how the DI was trained and how DI's viewed recruits. The DI's told how they wanted new recruits to act and advised the recruits on how to cope with their DI's.

The role models chosen for the film were not preselected for voice or appearance. Most of the scenes were shot as the recruits were actually undergoing the training. The good as well as the average and poor performers were depicted in the film. The idea was to show each recruit a successful role model with which to identify. If only the best performers were shown, it may have been hard for some incoming recruits to identify with the role models.

The film also related factual information concerning such things as average improvement scores on the physical training tests, the number who fail academic tests, etc.

**Experimental design.** As shown by the experimental design (Figure 2), each of the four platoons in a series was assigned to one of the four experimental conditions: treatment, placebo, control I or control II. This design was replicated for each of the three training battalions.

The first questionnaire ($0_1$) was administered by the researchers to the first three platoons of each series on the morning of their second day at Parris Island. Recruits were assured that their answers would be kept confidential and that their participation was voluntary.

After the survey was completed, the first two platoons of each series were marched to a classroom building. One platoon was then designated at ran-

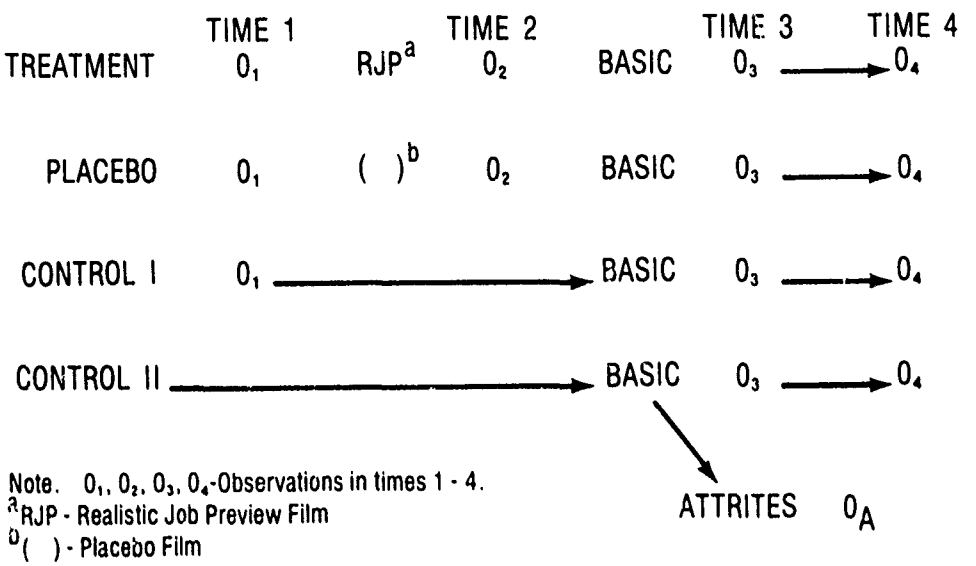


*Figure 2. PIRATE (Parris Island Recruit Assimilation Training Exercise) design.*

dom as either the treatment or placebo group. Both platoons were seated in separate but similar classrooms containing closed-circuit color TV monitors. The groups were read an introduction by the researcher. The treatment group saw the 80-minute color video-tape of what recruit training is really like. The placebo group saw a series of three traditional Marine Corps films. The traditional recruiting films were in color and lasted approximately 82 minutes. Both groups received a 10-minute break during the presentation. The breaks were staggered so that the two groups could not interact with each other.

After the presentations were completed, the platoons returned to the receiving area where they continued to be processed. The platoons were kept separated while being processed. That same afternoon the treatment and placebo groups returned to the classrooms in the receiving area and were administered the second questionnaire ($0_2$). This questionnaire was identical to the $0_1$ measure.

After three weeks of training, all platoons were administered the third questionnaire ($0_3$). This questionnaire was similar to the previous questionnaires except the recruits were directed to answer in terms of what training was like now. During the last week of training, the fourth questionnaire ($0_4$) was administered to each group. This questionnaire was identical to $0_3$.

**Measures.** Measures of turnover and demographic variables were obtained from the Recruit Accessions Management System (RAMS) computer file furnished by the organization. Performance measures were obtained from the personnel folders of each recruit. The attitudinal data were obtained from questionnaires.

## Results

Given the complex experimental design and multiple measures used in this study, space does not permit a detailed reporting of results. (A complete analysis of results is contained in references 9 & 10.) Only a summary of the major results are presented here.

Table 1 presents the results of the attrition analysis. At three, six, and twelve months after accession, the RJP groups had lower attrition than did the control groups. Although the three-month difference did not reach a satisfactory level of statistical significance, the six and twelve month differences

| Criteria | RJP Groups | Control Groups | Significance |
|---|---|---|---|
| 3 Months Attrition | 10.3% | 14.9% | .17 |
| 6 Months Attrition | 14.9% | 23.8% | .02 |
| 12 Months Attrition | 22.4% | 33.1% | .01 |

N=678

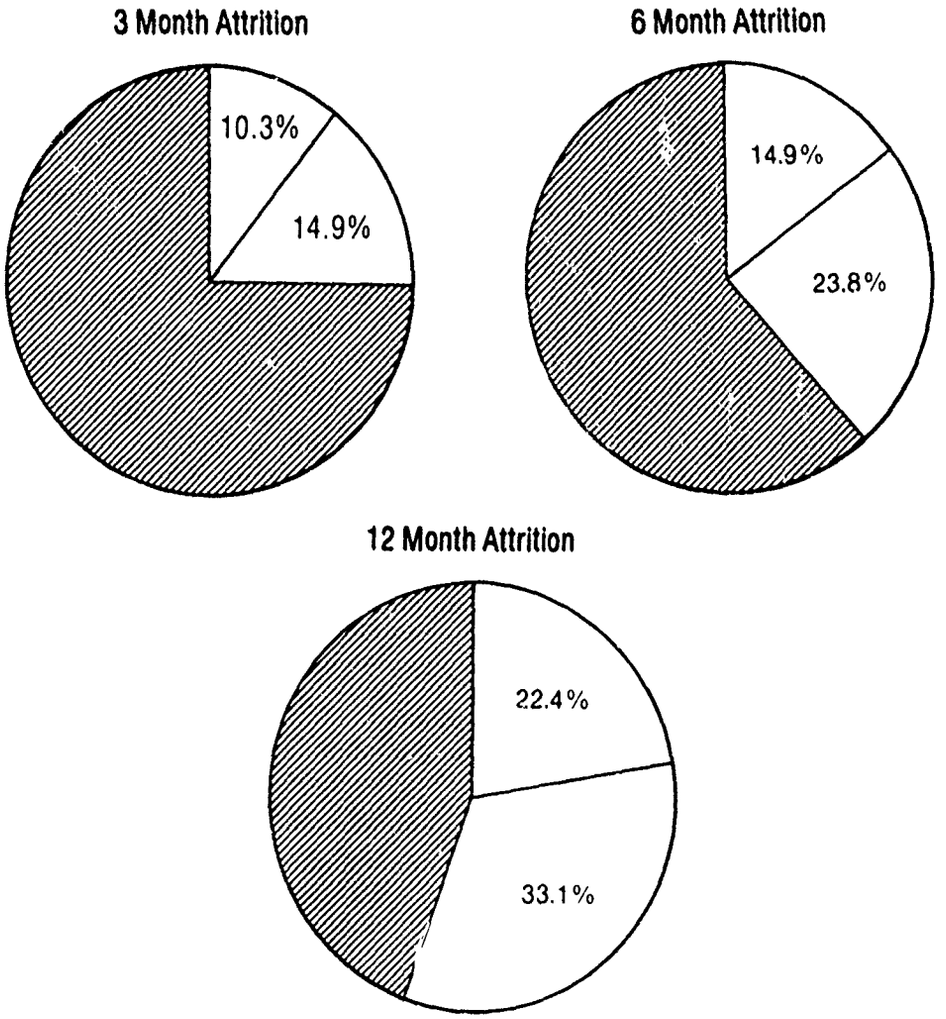


*Table 1*

*Summary of Pirate Attrition Results*

were statistically significant. A similar pattern of results was observed when survival days were used as the criterion.

Test results of some of the primary hypotheses regarding how the RJP operates are presented in Table 2. When the RJP groups were compared with the various control groups non-statistically significant differences were found for job and organizational expectations, and trust and honesty. However, the RJP group was significantly lower on expected job ambiguity, revealed significantly more change in role outcome values, and showed marginally significant higher scores in ability to cope. Further, when compared to the control groups the RJP group had significantly higher performance as measured by Military Skill Marks (MSM).

Although the RJP did not significantly influence measured expectations, it is well to note that when an individual-level analysis was conducted over all groups, the extent to which expectations were not met was significantly related to attrition.

## Discussion and Implications

The results of this study indicate that a realistic job preview given shortly after organizational entry can help reduce attrition. The fact that the attrition reduction effect became stronger over time may be due to a statistical artifact, i.e., relatively low variance in the early months. Alternatively or additionally, the RJP may have a delayed or cumulative effect.

The results dealing with the conceptual model suggest that the RJP may have its influence through several mechanisms. The literature on organizational entry and socialization notes the importance of role clarity in successful assimilation of new members. The present results demonstrated that the RJP significantly reduced expected role ambiguity.

There also was indication that the RJP group was better able to cope with their environment as reported prior to graduation ($p<.07$). The coping mechanism is a compelling conceptual variable in designing RJP's. Further research is underway to attempt to evaluated more directly the effects of teaching coping skills via an RJP.

The fact that the RJP group had significantly higher performance as measured by Military Marks Scores is encouraging. It may well be that the reduced ambiguity and coping skills modeled in the RJP served to enhance performance.

The finding that the RJP group demonstrated more change in role-outcome values than did the controls illustrates the potential socialization influence of RJP's. The organizational socialization literature notes that in new environments, values are subject to modification. To the extent an RJP reflects values appropriate to the organization and to the extent such values are not too discrepant from original values, the RJP may be a valuable socialization strategy.

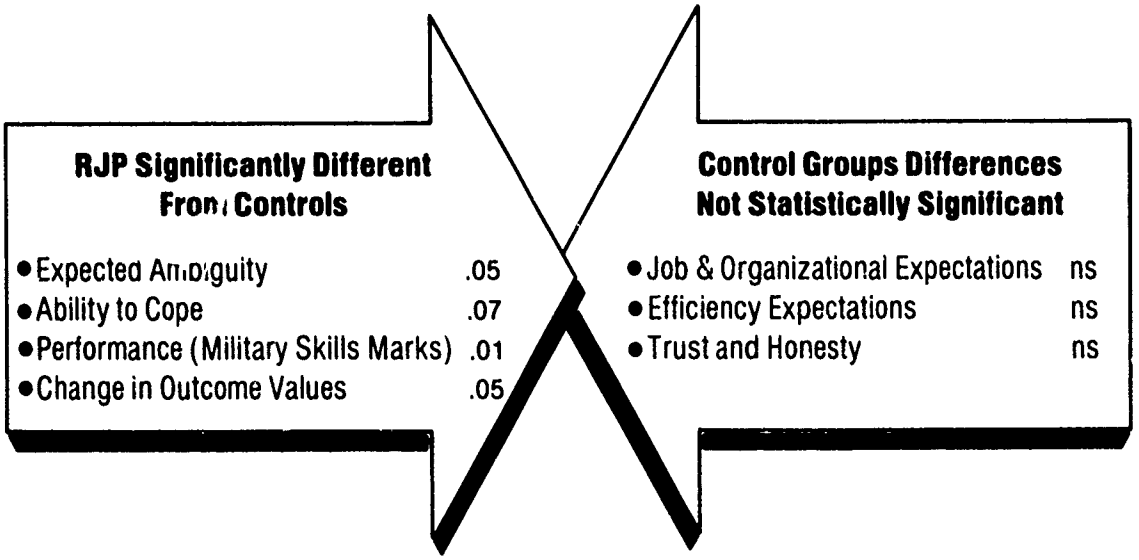


*Table II*

*Summary of Pirate Results: RJP vs Control Groups*

## Conclusions

This experiment serves to illustrate the potential utility of realistic job previews as a counter-attrition and organizational socialization strategy. Given the relatively low cost of developing an RJP compared to the costs of attrition, the RJP appears worthy of broader implementation and evaluation.

However, several cautions are in order. Since the present study was done in only one location at limited points in time, additional evaluations are in order. Further, it must be emphasized that an RJP is neither a recruiting film nor a casual gathering of information about the organization. Rather, the RJP should be a carefully developed, realistic, situation-specific treatment designed to illustrate effective coping behaviors, reduce ambiguity, illustrate desired values, convey information which is salient to the target audience, and provide identifiable role models.

Given these cautions, it is suggested that RJP's may have application beyond recruit training. Use of RJP's at the recruitment stage may encourage better self-selection and thus reduce later attrition. Use of RJP's at any major transition point, for example from recruit training to advanced training, from training to duty station, from one duty station to another, may facilitate adjustment and help reduce undesired attrition.

Realistic job previews will not be a panacea for personnel adjustment and attrition problems. Selection criterion, organizational and job design, leadership, policies and practices are among the variety of other relevant variables and processes. However, RJP's may well be one important strategy for effective human resource development and management. ■

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# research notes

## Improved Processing Matrix Method for High Strength Polymers

The use of lightweight polymeric structural materials such as fiber-reinforced organic matrix composites has led to longer operating range, reduced fuel consumption and greater payload for naval vehicles. Opportunities to lower vehicle weight further by the use of polymeric structural materials provides a compelling driving force for research on new approaches to high strength polymeric materials. Processing studies of known polymers can provide unexpected avenues to new high-strength polymeric materials. Alternately, processing studies can lead to more efficient routes to high-strength polymers.

Professor Roger Porter's research at the University of Massachusetts has shown that both higher-strength materials and more efficient ways to obtain them can be attained simultaneously through improved processing methods. Nylon 6 is usually plasticized for processing with polar organic compounds of low volatility. However, retention of plasticizer in the engineering plastic lowers mechanical properties. Professor Porter has found that ammonia can be used as a volatile plasticizer for nylon 6. The ammonia is retained through the processing stage by cooling the sample and pressurizing the Instron extruder. After coextrusion, using a unique split billet technique developed at the University of Massachusetts, desorption of ammonia occurs at atmospheric pressure at the exit of the extrusion die. The products display higher crystallinity, melting points and tensile moduli (ca. 13GPa) compared to those obtained previously. A more detailed evaluation of this novel plasticization process which is amenable to other deformation techniques and to thermoplastics with interchain hydrogen bonding is presently under investigation. ■

(Kenneth Wynne, ONR)

## New Book on Physics of Aerodynamics

Mr. Henry V. Borst has completed his book based on the technical contributions in aerodynamics of the late Dr. A. Lippisch. The production of this book entitled *Physics of Aerodynamics* has been funded under ONR contract by Naval Air Systems Command.

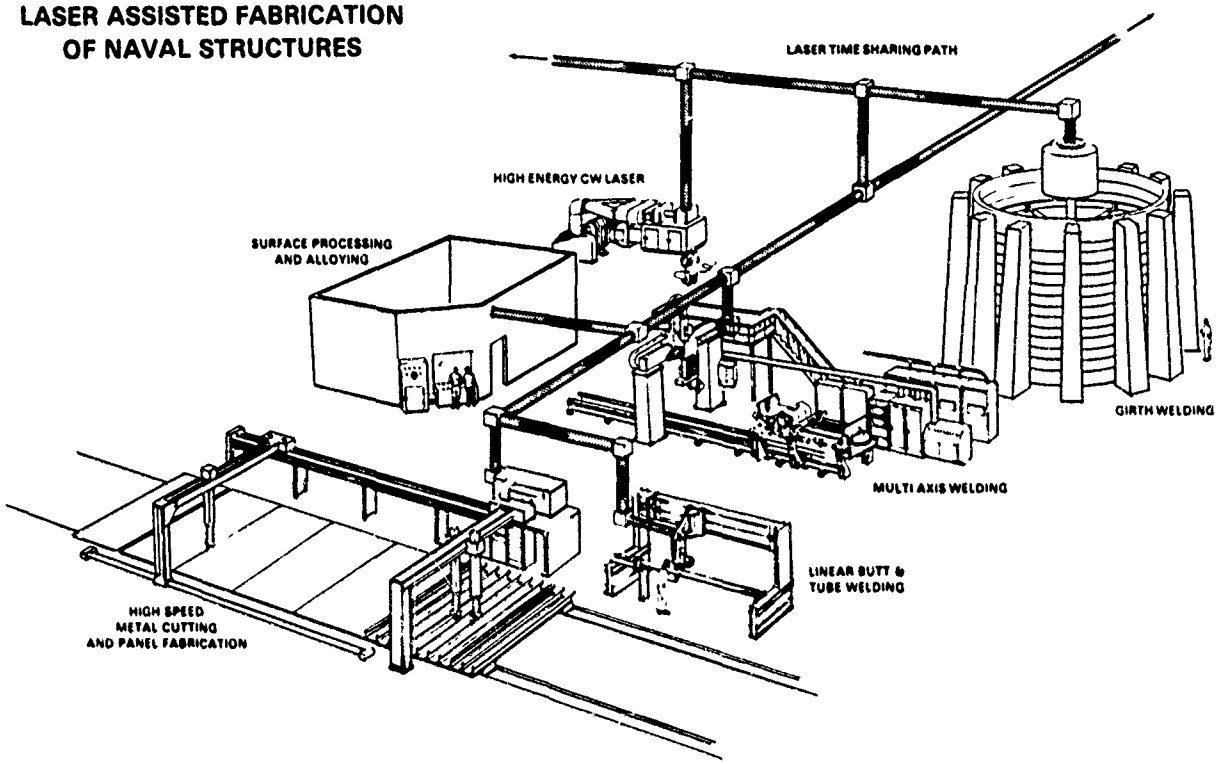
It is anticipated that this comprehensive manual on aerodynamics technology will assist Navy engineers in producing improved designs of V/STOL aircraft and ground-effect machines and will furnish information on basic aspects of technical problems and new concepts.

Beginning chapters of the book were devoted to the following topics: Physical Characteristics of Flow; Basic Concepts and Their Application to Aerodynamic Analysis; V/STOL Concepts; Effect Machines (WIG—wing in ground effect); and Delta and Swept Wings.

The final chapter, entitled "New Concepts," covers all the material founded on ideas that Lippisch had that were not directly applied or tested by him and not covered in previous chapters. Included is the theory of flapping wing flight and devices at the wing tip to improve the induced efficiency. Based on this, several ideas were investigated for recovering vortex energy at the wing tip and methods are presented that permit the calculation of energy recovery for winglets and associated devices. These devices have potential for all types of aircraft, both existing and future. The book should be available in the fall. ■

(S.W. Doroff, ONR)

**LASER ASSISTED FABRICATION OF NAVAL STRUCTURES**




## New Laser Welding Technology

Naval Research Laboratory (NRL) scientists will establish an ultra-high speed laser welding facility as a manufacturing technology program at the FMC Corporation's Northern Ordnance Division in Minneapolis, MN.

The facility will examine automated high-energy laser welding as a revolutionary advancement over conventional welding processes, and determine its value to the Navy in terms of reduced costs, increased structural integrity and increased production rate for Navy vehicles and weapons systems.

By combining the demonstrated high-speed laser welding capability with well-established numerical control of machine tooling, it is projected that the new facility should be able to increase welding speeds tenfold and greatly reduce current dependence on labor-intense, manual welding. Although initial emphasis is on laser welding in the new program, similar savings are expected to evolve in other areas of processing, such as cutting, heat treatment, cladding and in areas unique to laser processing, such as surface alloying. How such a system could work with a single, high-energy laser serving several work stations in a time-sharing mode of operation is envisioned in the above schematic drawing.

In addition, the new facility would serve as a "springboard" for establishing similar capabilities in other Navy fabrication plants, shipyards, and private industries.

Large scale introduction of fully automatic, laser welding into naval contruction is the leading manufacturing technology candidate to reduce cost and improve reliability of Navy and Marine Corps weapons systems and other defense materials. ■

(R. L. Hettche, NRL)

## Progress in Seismic Data Interpretation

In the so-called "layer cake" models of the earth, the velocity-depth structure is assumed to consist of a number of homogeneous layers separated by plane horizontal interfaces. For such a structure, the geometries of the common shot-

or-receiver, common depth point (CDP), and common mid-point (CMP) seismic experiments are equivalent and, indeed, the reflected rays in the CDP have a true common point of reflection. However, none of the above is true for the more realistic situation of dipping earth structure. Recently, under ONR support, Drs. John Diebold and Paul Stoffa at Lamont-Doherty Observatory, Columbia University have derived a travel-time equation for the CMP geometry which is valid for dipping earth structure and which allows a comparison of CMP and CDP data. In addition, Diebold and Stoffa have developed a mapping of seismic data from the time-distance domain to the so-called tau-p plane which organizes all turning rays into a well-defined trajectory. Based on this trajectory, a method has been developed for "inverting the trajectory" to obtain the velocity-depth function applicable to both refracted and reflected arrivals. An important feature of the method is its validity for an arbitrary velocity function. ■

(Dr. J. M. McKisic, ONR)

## JJ A/D Converters Exceed Semiconductor Performance

Using six two-junction Josephson device interferometers monolithically integrated onto a single substrate scientists at National Bureau of Standards, Boulder Laboratories have recently demonstrated a significant advance in high speed analog to digital (A/D) converter performance. Clock frequencies from audio to 1.2 GHz were used to obtain 6 bit precision for a 7.2 gigabit/second data rate. Josephson junction (JJ) technology had previously demonstrated 4 bits at 800 MHz clock speed. Monolithic semiconductor technology state-of-the-art currently is 8 bits at 400 MHz for 3.2 gigabit/second data rate. This is the first time that JJ A/D technology has exceeded semiconductor performance. While the present silicon semiconductor technology may, at best, be expected eventually to double its maximum clock speed to 800 MHz, the JJ approach should be viable to frequencies exceeding 10 GHz. GaAs semiconductor technology is expected to provide 4 bits at 5 GHz within a year. ■

(M. N. Yoder, ONR)

## Superconducting Array Breaks Nanowatt Barrier

Josephson junctions provide the possiblity of oscillators which have the potential for rapid tunability over wide frequency ranges. To overcome the limitations imposed by the low power and wide linewidth of the radiation emitted from individual non-resonant junctions, it has been recognized that coherent arrays of junctions are required.

Professor James Lukens of Stony Brook has made the first 99-junction superconducting array of indium microbridges. Successful initial tests show that the bridges self phrase-locked and gave a maximum power of 4 nanowatts at 8 GHz. This power level is about 100 times that of Lukens' previous 10 bridge array. ■

(E. A. Edelsack, ONR)

## Advances in Magnetoencephalography

Mrs. Lloyd Kaufman and Samuel Williamson of New York University recently succeeded in comparing the transient magnetically evoked fields associated with somatic stimulation (SEF) with the electrical potentials evoked by the same stimulation (SEP). The SEF is the important measurement of this study which enables specific location of brain response. The SEP is a long-established measurement used here as a reference standard. The SEF's were strongly lateralized; i.e., detectable over a limited region on the side of the head opposite to the stimulated wrist. In contrast, the SEP's were found bilaterally and with approximately equal strength on both sides. The SEF is strikingly similar to recordings from the brain surface made by other investigators. Further, the SEF lacks the very late components found with the SEP. This suggests that late components of the SEP ( 200 ms) originate in areas distant from the primary sensory cortex. Taken together, these findings, strongly suggest that the SEF may be used to identify areas of the brain active in different stages of information-processing with a specificity not previously possible in humans. ■

(D. P. Woodward, ONR)

## ONR Scientist Honored

Dr. Arthur J. Emery Jr., ONR Program Director, Microbiology received on 17 April 1980 Egypt's Order of the Gummuhria (Republic), Second Class. His Excellency the Minister of Health, Professor Mamdouh Gabr, on behalf of His Excellency Anwar El Sadat, President of the Arab Republic of Egypt, presented the award.

This award was presented to Dr. Emery for his initiation, guidance and direction of medical and biological research programs in Egypt over a period of ten years. Furthermore, the award was given for his recognition of the need for, and organization of an international meeting of world experts, to coordinate research relating to the disease schistosomiasis, and to formulate a countrywide plan to control this disease in Egypt. This plan is now being formulated into an official program under the Ministry of Health in Egypt. ■

## Safer Ship Mooring Line Under Development

A means of substantially reducing the major hazard caused when a ship mooring line suddenly breaks under tension is under development at the Naval Ocean Research and Development Activity (NORDA), under sponsorship of Naval Sea Systems Command. The problem stems from the use of lines made of nylon and similar synthetic materials. Over the past 20 years the Navy and the Marine community in general have converted from manila rope mooring lines to nylon because it is lighter and stronger and does not rot. A major disadvantage however, is that the greater elasticity of nylon can cause the line to stretch and under heavy strain part suddenly. The broken ends snap back with tremendous force, causing serious injury and even fatalities to personnel. The accident rate has increased lately, with several deaths recorded in just the last few years.

A mooring line made of Kevlar with a built-in safety feature has been designed by NORDA's Ocean Technology Division. This Division has had extensive experience in developing applications for that material. Kevlar, an aramid fiber, has strength comparable to steel but has little stretch. The mooring line is constructed by braiding Kevlar around a nylon line core, which provides the safety feature. The Kevlar line is additionally covered by an outer jacket made of non load-bearing polyethylene. If the Kevlar line should break, the inner safety nylon line remains intact, and the broken ends of the Kevlar line do not whip back. The low stretch quality of Kevlar, which

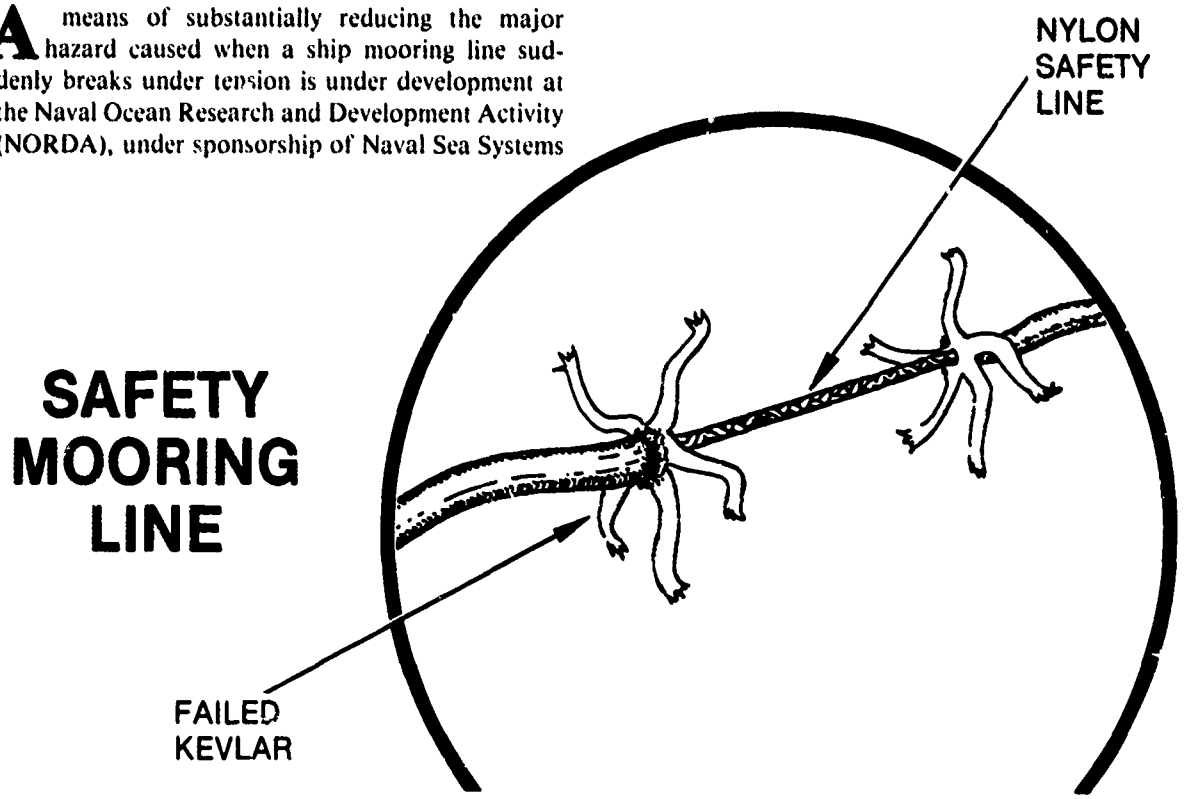



*Figure 2*

bears the main load, allows the transfer of the kinetic energy of the broken ends into the potential energy of the stretchy nylon, thereby restraining the ends from recoiling. It is anticipated that the Kevlar lines would be employed only for bow and stern mooring lines which are used in maneuvering the ship into and out of the moor.

In addition, the low stretch Kevlar, along with the outer jacket, allows the line not to cling as it is wound around the ship's capstan, thus producing a smoother payout rate. This reduces the chance of the line surging or riding off the capstan, which is also dangerous and has caused a number of injuries.

The Ocean Technology Division has already tested a half-inch model of the line, which has demonstrated that the design concept is feasible. A one-inch, 80,000-pound breaking strength model of the Kevlar line will be tested soon. The program calls for the fabrication and testing of a 2-inch, 250,000-pound breaking strength line in 1981 with subsequent testing aboard selected ships in 1982. Another major advantage of the Kevlar line is that it can be fabricated with existing ropemaking machinery and retrofitted directly into the fleet. ■

(Richard Swenson, NORDA)

## Editor's Note *(continued from page 3)*

• excellence and creativity of the principal investigator as evidenced by previous publications and reputation within the community,

• relationship to Navy needs,

• relationship to previously stated program thrusts, and

• evidence of uniqueness and appreciation for other similar efforts being funded by other government agencies in the field.

Thus, an information peer review system exists, but the final decisions rest with the scientific managers.

One mechanism that ONR utilizes frequently to explore the promise or suitability of specific scientific research areas is the workshop, topical conference, or symposium. Sponsorship of informal meetings, with at least certain key members of the research community specifically invited, has proven to be an effective way to stimulate thinking in areas of Navy interest. Some of these result in an influx of new proposals and programs. Others result in publicizing ONR program plans; and still others produce a decision to defer funding due to the lack of potential payoff, the lack of interested or capable researchers, or the lack of adequate resources to implement a meaningful progam.

Another important element in the ONR manner of executing and implementing research programs is the use of military personnel. Perhaps not visible to cursory external inspection, military officers play a key role in program management. Several are employed as scientific program managers. Still others have senior management positions in the central management and the program directorates of ONR.

Now, in a time of increasing budgets for defense research, ONR is seeking new ways to enhance the quality and scope of interaction with both the Navy and the research community. ONR initiated the Selected Research Opportunities (SRO) programs in 1979 to improve interaction with the scientific community.

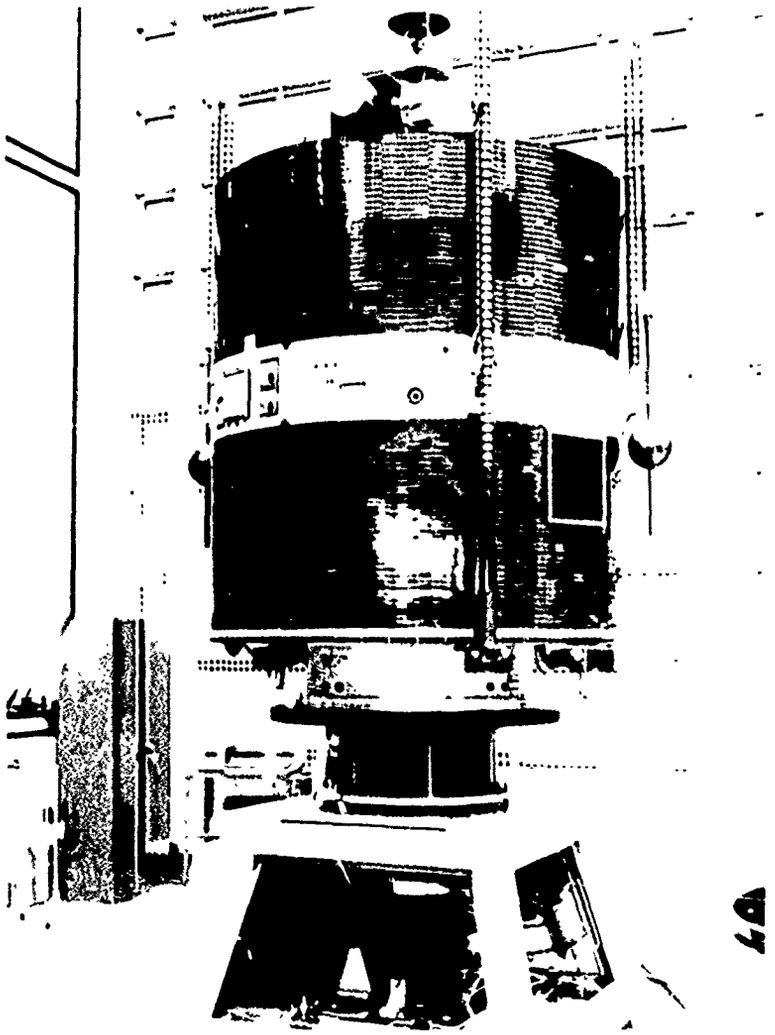
SRO, while part of the Contract Research Program, places emphasis on larger, multidisciplinary projects and specifically encourages the academic researcher to collaborate with Navy and industrial laboratories. Annual funding levels of $200,000 to $500,000 are appropriate for SRO programs, permitting investigators to assemble sufficient resources to make a significant impact in the research area. Contracts are normally written for three years. A set of five research areas of high Navy interest has been selected for the next phase of SRO. These areas are human-computer interaction and decision behavior, highly parallel computation, environmental factors related to ELF/VLF/ULF communications, non-Gaussian signal processing, and environmental effects on optical propagation.

During the past 30 years a new Navy has been brought into existence characterized by nuclear propulsion, missile armament and the reliance on modern electronics and a variety of sensors, managed by computers, for intelligence and communications. These are technologies which have sprung from the

fields of research which ONR helped to initiate and advance during its early years.

In the same manner, the shape of the Navy which this country will build in the 90's is now being formed in the research presently conducted and supported by ONR. This research is being marshalled toward Navy needs through such means as identifying and interpreting research advances of relevance to the Navy's many scientific and technical problems and conducting exploratory development experiments.

ONR was the first Federal agency to establish close working relationships with basic research investigators on the university campus. ONR, in the years ahead, will continue to devote a large part of its funds to the support of university research. At the same time, the ONR o ganization is flexible enough to plan and conduct, on its own initiative, research and engineering experiments to meet changing naval requirements. In this way, the Office of Naval Research will continue to blend the talents of the civilian scientific community with the needs of the Navy for rapid technological advances in order to create the strong, capable new Navy that must evolve during the coming decades. ■



*The SCATHA (Spacecraft Charging at High Altitude) satellite jointly supported by the Office of Naval Research, Air Force, and National Aeronautics and Space Administration is investigating interactions between geosynchronous satellites and the energetic ions and electrons in their environment. This interaction can cause large electric fields across the spacecraft which can result in outages and even damage to satellites. A better understanding of the interaction will permit cost effective construction of satellites designed to prevent such outages and damage*