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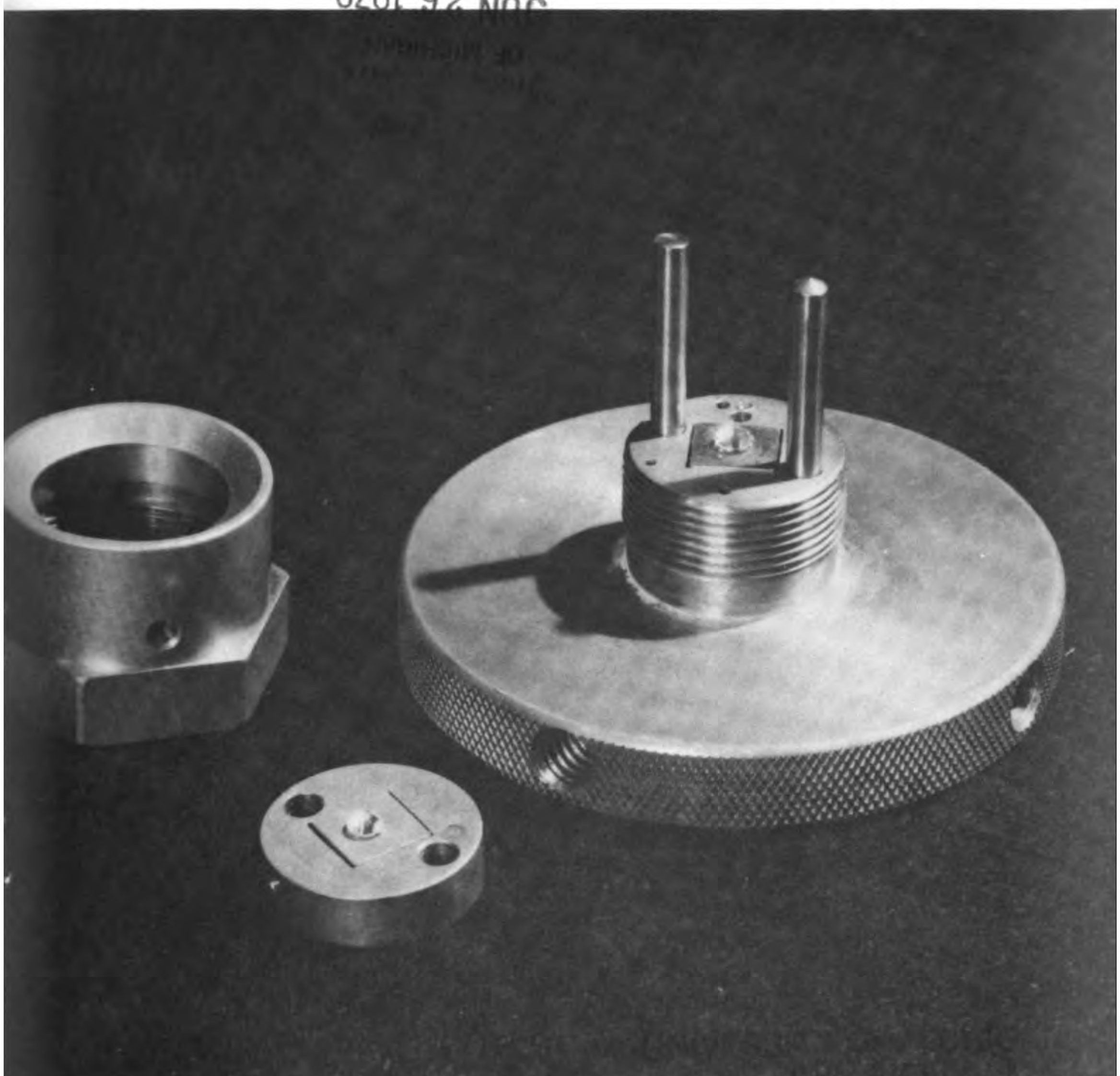

PROFILES IN SCIENCE

Professor Hans Wolfgang Liepman

Dr. Hans Liepman is the Charles Lee Powell Professor of Fluid Mechanics and Thermodynamics at the California Institute of Technology. For 27 years Professor Liepman has been a contractor for the Office of Naval Research directing some of the outstanding research in the areas of laminar instability, turbulence, aerodynamic noise, magnetofluiddynamics, and rarefied gas flows. Problems associated with fast aircraft during World War II led Professor Liepman to pioneer some of the important research for better understanding the phenomena of shock wave boundry layer interaction, transonic flow, and skin friction in high speed flows.

Professor Liepman is a member of the National Academy of Engineering and the National Academy of Sciences. His many awards include the Ludwig Prandtl Ring of the German Society for Aeronautics and the First Dryden Lecturer of the American Institute of Aeronautics and Astronautics.

Application of Advanced Light Scattering Techniques to the Study of Material Properties

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Introduction

It has been well established that a polymer's propensity to wear is related to its viscoelastic properties. Unfortunately, the specific material variables contributing to a material's 'toughness' are not well understood nor easily measured. This paper will discuss the types of relaxation phenomena and relaxation times that are important to the viscoelastisity of a material, their molecular basis, and the various optical techniques available for the characterization of these properties. Specifically the application of Raman, Brillouin, and correlation light scattering techniques to the characterization of solid polymeric materials will be discussed with particular emphasis placed on the relationship between types of information one can obtain from these light scattering experiments and the strength of polymeric materials. The office of Naval Research continues to support this work in order to meet the material needs of the Navy.

Single component polymers can vary in molecular weight, dispersity, crystallinity and morphology, all of which affect material strength and wear. Indeed, a polymer can manifest a range of macroscopic properties (density, tensile strength, etc.) while its chemical composition, molecular weight and molecular weight distribution are kept constant. This is possible because the microscopic properties of molecular conformation and orientation profoundly affect macroscopic properties. Thus if we are to understand fully the mechanisms of strength and wear in polymers we must be able to probe them on the molecular level.

The response of a polymeric material is dependent on the frequency of the applied load, making it important in polymer characterization to measure material properties over a wide frequency range. Information on time scales not measurable by available technqiues is typically obtained by making use of the time/temperature superposition principle

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(which implies equivalence of frequency and temperature for some systems): dynamical mechanical measurements made over a limited frequency range at a series of temperatures are converted to plots spanning a wide range of frequencies at a single temperature. It is clearly preferable to be able to measure a material's response in real time thereby avoiding the assumptions inherent in time-temperature superposition. Recently, progress has been made towards this goal with the application of light scattering techniques to the problem of polymer characterization.

Information about the internal dynamics of a polymer is obtained from the frequency changes light undergoes when it is scattered. A single frequency f_o of light from a laser strikes a sample and is scattered with a new frequency or frequencies. The change in frequency Δf is characteristic of some process in the sample. Thus Δf may be a doppler shift caused by reflection of the light from a moving particle, or else it may be the frequency of a sound wave in the sample or of a molecular vibration.

Light scattering can be divided under the broad subheadings of correlation, Brillouin, and Raman scattering according to the ranges of the frequency shifts involved. Figure 1 indicates the frequency ranges spanned and the molecular processes expected to occur within those frequency domains.

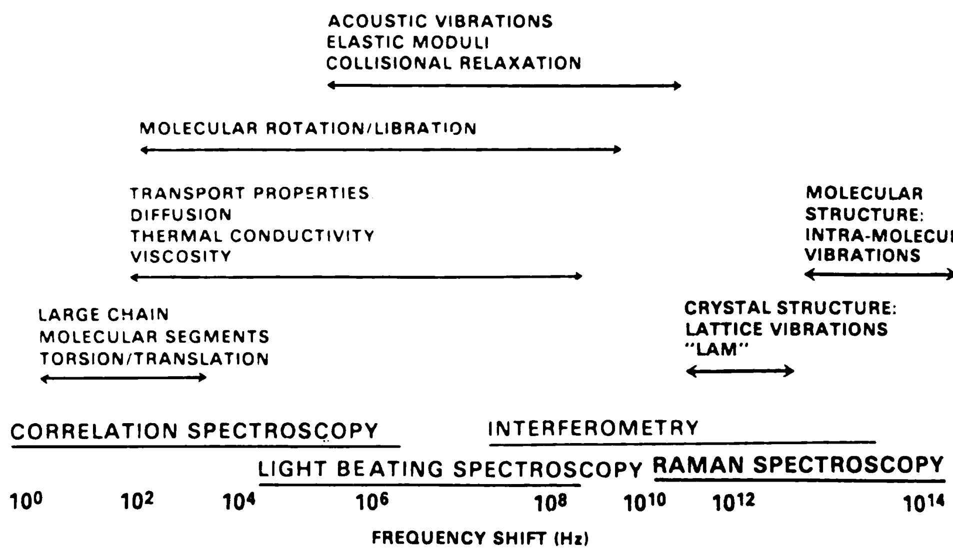


Figure 1 — Range of frequency shifts encountered in correlation, Brillouin and Raman spectroscopy and the excitation frequencies in various samples which these techniques may be used to measure.

Correlation spectroscopy deals with the lowest frequencies detectable by the light scattering technique. The name, correlation, refers to the electronic technique of processing the detected optical signal. The resulting correlation function can be fourier transformed to give its frequency spectrum (the range is roughly 0.1 Hz to 1 MHz). As indicated in Figure 1 this range corresponds to the slow, diffusive motions of large polymer chains and chain segments. The technique is used to observe the Brownian motion and rotation of polymer molecules in solution (light scattered from the moving particles is doppler shifted) and slow relaxations in solids near the glass transition, T_G. It also can be used to determine thermal conductivity, viscosity, and other transport properties through the local density fluctuations these processes cause.

At higher frequencies interferometric means can be used to measure frequency shifts. The lower frequency limit is about 1-10 MHz (depending on laser frequency stability). The upper limit is usually about 100 GHz although there is no reason in principle why one could not work at frequencies several orders higher than this. Figure 1 shows that this range deals mainly with Brillouin scattering, i.e. scattering due to sound waves. The technique determines the elastic moduli (or in fluids, the compressibilities) governing sound propagation. In turn these moduli depend on high frequency collision-induced relaxations. In fluids the tumbling of smaller molecules, depending upon high frequency viscosity, falls into this range, as does the librational motion of small molecules and molecular segments in crystals and plastic crystals.

In Raman scattering, dealing with the highest frequency shifts, 10^{10} to 10^{14} Hz, spectral information is measured by diffraction grating. In this regime light scattering is a true molecular probe, as shown in Fig. 1, revealing the motions of atoms relative to each other, and sensitive to crystallinity and molecular conformation. In the lower end of this region are found the so called longitudinal "acoustic" modes (LAM's) whose frequencies are inversely proportional to the length of straight molecular chain segments in polymers. There is currently much interest in LAM's because of the information they yield about molecular conformations.

Optical measurements have the additional useful properties: (1) we can see the part of the sample that is being probed by the light beam, (2) the beam can be focused to a spot as small as a few microns if desired for looking at very small samples or regions of samples, and (3) light scattering can be done remotely on samples located inside of pressure cells, temperature baths, or even at great distances such as the tops of factory smokestacks...

The typical sample has many processes occurring within it which cause light scattering so that there is usually a great deal of information available in a spectrum. Interpretation of this information is the chief task of the spectroscopist. Light scattering is used in combination with X-ray diffraction, neutron scattering, deuteration and other isotopic substitution, chemical labeling and substitution, computer modeling and other techniques to classify and identify spectral features seen in different circumstances in different compounds and classes of compounds. Since the discipline of light scattering is mature, a considerable library of information is now available that can be brought to bear upon new problems. The art of sorting out the details of a spectrum, drawing upon this pool of techniques and past work, has advanced considerably. Today there is the potential of utilizing this experience in the pursuit of a fuller understanding of the observed macroscopic properties of polymeric materials.

Correlation Spectroscopy

The correlation technique (1,2) has been used in light scattering for about fifteen years. The technique has had broad application to problems both biological and physical. Among the first uses were investigations of transport properties of fluids near their critical points (2,3,4), and of the diffusive motions (translational and rotational) of large macromolecules and viruses for the purposes of determining their sizes and shapes. (1,3,5) Another type of experiment has been measuring chemical reaction rate constants by observing fluctuations in the fluorescence of reacting species. (6). Liquid crystal dynamics and viscoelastic constants have also been observed. (1)

Correlation spectroscopy has been used to measure doppler shifts caused by blood flow in the arteries of living animals (7), to determine particle velocities in wind tunnels and jets (8), and to obtain the viscosities of lubricants by measuring the velocity with which a slug falls through the viscous liquid. (9) This last technique is quite new and extends the range of viscosities which can be measured by the falling slug method by one or two orders of magnitude (to about 10^8 poise), while reducing the time required for the measurement from hours to minutes. To determine still higher viscosities (up to 10^{11} poise) correlation measurement of the distribution of fluid structural relaxation times (the diffusive "Mountain mode") has been shown to give good results in lubricants subjected to very high pressures and characterizes the dynamic viscosity over a range of frequencies. (10) Figure 2 shows the distribution of relaxation times for a pair of lubricants whose short time lubricating abilities differ sharply because of the difference in their short time relaxation behavior.

A substantial amount of the work done by correlation spectroscopy has been in the area of determining relaxation times for polymer chains in dilute solution. (11) The relaxation times for depolarized light scattered in the forward direction from polymer molecules were measured and extrapolated to infinite dilution. The relaxation times obtained were compared initially to the predictions of the Rouse-Zimm model and found in general to disagree except for the longest wavelength internal motions. (12) It was found, again contrary to prediction, that the local diffusive relaxation of fluctuations in position of small polymer segments in a large random coil resenbled that of independent small molecules. Recent measurements by Caroline and Jones (13) show good agreement with an improved theoretical model.

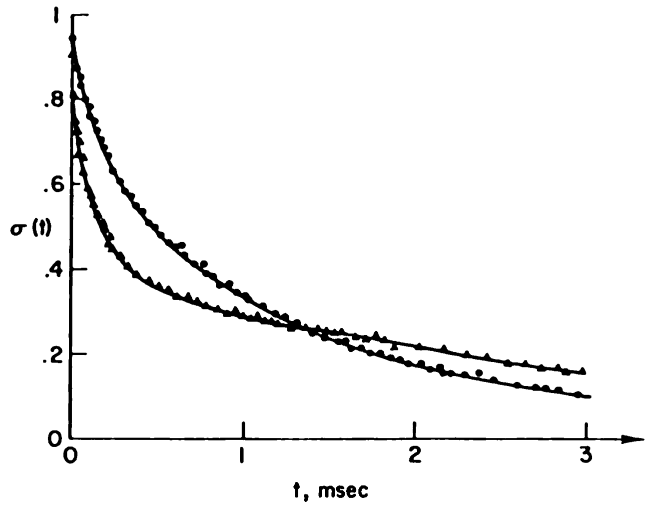


Figure 2 — Correlation functions σ(t) for a polyphenyl ether (0) at 1.2 kbar pressure and for a short chain methyl phenyl siloxane (Δ) at 2.1 kbar. The two curves illustrate relaxation functions for liquids which have the same low frequency, long time scale viscosity. The latter polymer will quickly relax a suddenly applied stress whereas the former will not. (Permission of C. Montrose (ref. 10) to reproduce this figure is gratefully acknowledged.)

All of the above cases have involved fluids or suspensions of particles in fluids. Use of a correlator with solid materials is rare because of the strong stray light scattering from such samples. However, recently the method has been used to measure low frequency motions in PMMA (14,15) as a function of temperature near the glass trnsition. Two relaxation times were observed of order .1 sec and .01 sec. The shorter time changed as a function of temperature below T_g. Its activation energy was found to be lower than that assigned to the side-chain molecular reorientations from dielectric and NMR measurements. The internal motion observed from the correlation spectroscopy experiments was thus thought to arise from a coupling of this side-chain motion with the low activation energy process of torsional oscillations of the chain segments about their equilibrium positions. The longer relaxation time observed was temperature insensitive below T_g but merged with the backbone main chain relaxation at T_g. The measurements of this internal relaxation mode above T_g in the bulk phase by correlation spectroscopy agreed reasonably well with those obtained by mechanical and dielectric measurements. The relaxation below T_g, which has not been observed by other techniques, was thought to represent a rearrangement of free volume or of "configurational entropy."

Brillouin Spectroscopy

Brillouin spectroscopy (16) is light scattering caused by high frequency (10 MHz to 100 GHz) sound — i.e. random thermal oscillations which are always present in a sample with a non-zero temperature. The mechanism of scattering resenbles that of Bragg X-ray diffraction, with a sound wave causing diffraction instead of crystal layers. As with Bragg scattering the scattering angle determines the sound wavelength observed, but since the sound wave is moving the scattered light is doppler shifted in frequency relative to the incident frequency. From the doppler frequency shift one can determine the velocity of sound. The absorption of sound is determined from frequency broadening of the scattered light. In turn one can then find the viscoelastic moduli of the sample and related transport properties, such as viscosity, thermal conductivity, and diffusion coefficients. (1,17) We note here that processes at such fast rates — on the nanosecond time scale — are difficult or impossible to obtain by ultransonic methods and that X-ray and nutron techniques which do go to such frequencies are considerably less accurate and more difficult, expensive, and sample-damaging.

A very large amount of work has been done on a wide variety of fluids and solids to determine their moduli, transport properties, and relaxation times. We will restrict our attention to a few examples chosen from the field of polymers. Energy in such systems is exchanged between molecular internal vibrations and external translational motions. (18) Processes which occur faster than such energy exchange encounter considerably different compressibilities and viscosities, for instance, than slower processes do. (1,19)

Paraffin oils have been examined in depolarized Brillouin scattering. (20) The tumbling of such chain molecules produces a spectral line whose width is related to viscosity. Linewidths were measured as a function of chain length and temperature and the values of the rotational relaxation time were compared with those obtained from flow birefringence. The values were similar but not identical, indicating a possible change in paraffin chain flexibility with longer chains. The relaxation times exhibited an Arrhenius temperature dependence and yielded rate-activation energies which had a chain length dependence.

Brillouin spectra have been obtained for poly (dimethyl siloxane) (PDMS) of molecular weight 7.7×10^4 and reveal four relaxation peaks in the hypersonic absorption as a function of temperature. [22] These data with microwave and dielectric relaxation times show Arrhenius type behavior for higher temperatures and WLF behavior below, with a sharp break at $\sim$ 180°K. The authors suggest this to be the Debye temperature of PDMS.

The amorphous polymer poly (methyl acrylate) (PMA) appears to be one of the few solids in which a frequency dependent hypersonic relaxation has been observed. [22] Frequency dispersion in solid polymers often occurs at considerably lower frequencies than are encountered in Brillouin scattering so that the parameters obtained, such as the velocity, are generally the infinite frequency values. For PMA the glass temperature is $\sim$ 6°C. Relaxation is observed at temperatures above

5°C in both the hypersonic velocity and attenuation, and the size of ıe relaxation phenomenon is frequency dependent. Using a single re-ıxation time theory the infinite frequency velocity and the relaxation me were determined. The value of the activation energy (7 :cal/mole) suggests the relaxation is of the β type (side chain).

The Landau Placzek (LP) ratio — the ratio of the elastically scat-ered (zero frequency shift) light intensity to the Brillouin intensity — s often used as a probe of solid polymer behavior under stress. The Brillouin intensity should be relatively constant as it is an intrinsic pro-erty of the material. The elastic scattering on the other hand is sensi-ive to impurities, domain boundaries, strains, inclusions, etc. Mitchell nd Guillet [23] and Coakley et al. [24] have studied the effects of an-ıealing upon the LP ratio and they have suggested that as the tempera-ure of a sample is dropped the naturally occurring fluctations in the naterial are "frozen" in below the glass temperature. The LP ratio then s related to the amount of strain energy stored in the glass.

One of the difficulties of Brillouin scattering in amorphous solids is 'contrast," the ability of the spectrometer to distinguish the Brillouin ines, which are weak, from the nearby elastic scattering peak, which is very strong. In recent years considerable progress has been made in mproving contrast by the technique of multipassing [25] which in-creases contrast by many orders of magnitude. Dil et al. [26] and, very recently, Sandercock [27] have reported use of 5 and 7 pass systems to observe Brillouin scattering in metal surfaces. Since the penetration depth of light into a metal surface is small the technique yields elastic moduli for the region within a few hundred angstroms of the surface. Other phenomena such as the propagation of Lamm acoustic waves in thick films also can be observed. [27]

Raman Scattering

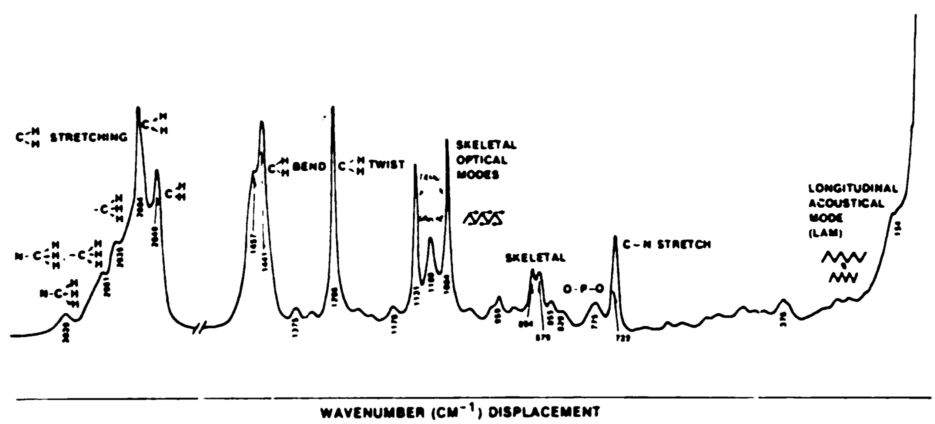
In the Raman scattering process [28,29] the motion of an atom relative to its neighbors in a molecule or lattice causes fluctuations in the atomic or molecular polarizability. Since the first observation of the effect almost 50 years ago Raman spectroscopists have used a variety of techniques to try to determine the nature of the molecular motions which give rise to the Raman spectral lines they observe. This has involved the use of infrared spectroscopy, crystallography, symmetry, substitution of isotopes of different masses onto molecules, and calculations using computer models of molecules and molecular force fields.

One body of work of particular interest in the polymer field has been the application of Raman spectroscopy to the study of crystalline polymer morphology. Many polymers crystallize by folding their long chains into short segments which lie side by side like stacks of soda straws or sheaves of wheat, forming lamellae. The frequency shift of one of the bands of the Raman spectrum, the LAM, is a function of the lamellar thickness. Initial work was done on polyethylene and the *n*-paraffins. [30,31] The latter were used to determine the proportionality constant between the Raman frequency shift and the inverse of the straight chain length as a function of the number of carbon atoms. Frequency shifts obtained from polyethylene samples having lamellar morphology could then be correlated with lamellar thickness assuming that the Raman bands correspond to chain segments whose fold length was that of a similar *n*-paraffin. [31] For polyethylene single crystals where the tilt angle between the chains and the lamellar surface could be determined independently, lamellar thicknesses determined by the Raman method agreed fairly well with those obtained using small angle X-ray scattering (SAXS). [32] Comparison has been more difficult for samples crystallized from the melt, since the tilt angle is generally unknown. Recent work has focused on the effects of the gauche (twisted) segments in the amorphous loop region [33], and of conformational [34] and mass defects [35] on the frequency of the LAM. These data have yielded information on the nature of the chain fold in polyethylene.

Despite initial difficulty, LAM's have now been observed in the helical polymers polyethylene oxide [36], isotactic polypropylene [37,38], polyoxymethylene [38] and in the copolymers (random) tetrafluorethylene — hexafuoro-propylene [39] and (block) polyetheylene oxide — polypropyleneoxide [40], making it possible to use this Raman band in the study of the crystallization and structure of polymer lamellae. It should be noted that the advantage of the Raman scattering technique is that it does not depend [33] on the regularity of the lamellar stacking as is necessary for SAXS. This has permitted the observation of double lamellar populations. [32]

If the polymer chain is regarded as a uniform rod the proportionality constant between the LAM frequency and the inverse of the chain length is the sound velocity along the rod, $\nu = (E/\rho(^{1/2}$, where E is Young's modulus and ρ is the density. Thus, if an estimate of the tilt angle in the lamellar crystal is made, SAXS long period measurements can be combined with Raman frequency shifts to determine the ultimate Young's modulus of a polymer chain. Reports thus far [38,39] indicate that estimates made in this way agree with those determined from inelastic neutron scattering, but are substantially larger than those determined from wide angle X-ray scattering

One particular class of problem which has received a great deal of theoretical attention of the past 30 years or so has been the mode structure of long chain molecules of the polyethylene type. [41,42] Considerable progress has been made in this effort and, of particular interest to us, not only have the normal modes of the ideal straight chain been identified but also the effects upon the spectra of chain kinking have begun to be understood. In addition to the LAM's which give information on the length of straight segments between kinks, spectral features have been identified (see Figure 3) which reveal the relative number of gauche and trans bonds (the "optical skeletal" bands) [43], and the ordering of chains and chain segments relative to each other (the "methylene stretching" bands [44] and crystal field splitting [45]). These bands have been used to investigate the effects of annealing on polymer lamellae thicknesses [46], the relative elastic moduli of crystalline and amorphous polymers [47], the effects upon chain order in model biological membrane chain molecules caused by phase changes and other perturbations [48], the effect of high pressure upon polymer structure and crystallinity [49], and the effect of high pressure upon chain kinking in the liquid alkanes. [50] In the latter case it has been seen that high pressure (up to 20 kbar) causes short chain alkanes (heptane, octane) to kink up and longer chains (polyethylene) to straighten out to the "super extended" chain phase. Work of this nature is continuing now to try to determine the relation between lubricant chain conformation and "lubricity," polymer structure and strength, and the influence upon these properties of pertubation such as temperature, pressure, chain length and dispersity, sample history, etc.



RAMAN SPECTRUM OF DIPALMITOYL PHOSPHATIDYL CHOLINE
(EXCITATION SOURCE; Kr LASER AT 647 nm)

Figure 3 — Raman spectrum of the model biological membrane molecule, dipalmitoyl phosphatidyl choline which shows many of the features typical of paraffin and polyethylene molecules. Each spectral band is labeled with the type of atomic motion causing it and the numbers give the frequency shifts in wavenumbers. (1 waveumber = 3×10^{10} Hz). The LAM at 154 wavenumbers is fairly weak in this sample whereas in polyethylene and the n-paraffins it is quite strong.

Conclusion

We have discussed briefly correlation, Brillouin, and Raman spectroscopies and have attempted to demonstrate in a general way their use and range of applicability. We have tried to show some of their unique abilities while at the same time emphasizing the need to employ them in concert with other spectroscopies and mathematical modeling techniques. We believe that light scattering is unusual and exciting because it is both new and old: new in the sense of new and dramatically improved instrumentation and a lengthening list of materials and fields in which it is finding use; and old in the sense of being a mature science with a great store of information and technology available to help with experimentation and interpretation.

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Black Holes in the Nuclei of Galaxies?*

The concept of a black hole is almost too fantastic, even for science fiction. Yet, it is an inevitable consequence of Einstein's theory of relativity. A black hole has a surface through which anything can fall, but nothing can emerge—a cosmic "disposal".

Matter within a black hole is crushed to infinite density and infinitesimal volume. The gravitational pull is so strong that even light is trapped in its grip It curves space and warps time.

Our galaxy must be filled with millions of black holes that result from the collapse of massive stars. When these stars have burned out all their nuclear fuel, they cannot generate enough pressure to resist the overwhelming pull of gravity.

After millions of years and stable nuclear burning, all of the mass overlying the burned out nuclear furnace suddenly comes crashing down in less than a second. If the collapsping star is ten times heavier than our sun, it will disappear inside a black hole only 30 miles in radius.

The universe is filled with, perhaps, a hundred billion galaxies. Most seem to spin serenely, but every now and then an explosion of incredible force takes place at the center of a galaxy. The most brilliant example is the quasar.

Quasars appear to be active galactic nuclei that normally radiate a hundred times the visible power of the Milky Way from a volume less than one millionth its size. They vary in brilliance over a matter of days, even flaring to

*This article by Herbert Friedman, Superintendent of NRL's Space Science Division and Chief Scientist of the E.O. Hulburt Center for Space Research, outlines the current state of the search for conclusive proof of the existence of black holes.

(Continued on page 29)

Why Working Women Fail: The Maintenance of Sex Roles and Stereotyping in Work Groups

Kirsten Hinsdale and James W. Cook*

Validated Instruction Associates, Inc.
Albion, Michigan

Imagine two hypothetical Navy recruits:

> Seaman **A** is described by superiors as a strong and dominant personality who relates to others in a forceful and assertive manner. Highly competitive by nature, Seaman **A** often acts as a leader, displaying high levels of independence, self-reliance, and self-sufficiency. When challenged, **A** is willing to take a stand and defend strong beliefs. **A** also is willing to take risks, and employs an analytical approach to problems which promotes fast and accurate decision-making.
>
> Seaman **B** is described by superiors as a gentle and compassionate person who shows great concern for the well-being of others. **B** is sensitive to others' needs, sympathetic, and eager to soothe hurt feelings. In short, **B** is a warm and affectionate personality. Often shy and soft-spoken, **B** refrains from using harsh language. In interpersonal confrontations, **B** most often is willing to yield, but still maintains a cheerful attitude. While at times flatterable and gullible, **B** is very loyal to peers, superiors, and the Navy in general.

Which recruit is more likely to succeed in the Navy?

Intuitively, one might predict that while Seaman **B** would make a terrific friend and coworker, Seaman **A** is more likely to succeed in the Navy — or in the working world in general. This is because **A**

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possesses traits which are widely assumed to be *adaptive* in the workplace — traits which facilitate the achievement of personal, professional, and organizational objectives. These adaptive traits and their associated behaviors — independence, assertiveness, competitiveness, and the like — have been described by researchers as instrumental rather than expressive [1], as task-oriented rather than people-oriented [2], and as initiating structure rather than providing consideration [3]. Most recently, they have been described as masculine rather than feminine [4].

Thus, one might further predict that Seaman **A** is a man and Seaman **B** is a woman. And because **B** lacks the specific traits and general *chutzpah* of Seaman **A**, it is unlikely that she will prevail in a workforce which values traditionally masculine characteristics [5,6].

Personality traits. The contrast between these two hypothetical recruits illustrates one major problem faced by many career-oriented women, a deficiency in traditionally masculine personality traits. Although Seaman **B**'s personality is an exaggerated example of this problem, it does represent a great deal of research which suggests that in varying degrees, women lack those traits which are adaptive in the world of work. This deficiency presumably results from cultural expectations for the female sex role which stress passivity, attractiveness, and emotional responsiveness, and which discourage independence, self-reliance, and achievement orientation [7,8,9]. Because these cultural expectations are reflected throughout the socialization process [10,11], the resulting deficiency in adaptive traits is assumed to be firmly entrenched in a woman's personality by the time she reaches adulthood — a development disability, as it were. Compounding this problem is the fact that many traditionally feminine traits — dependence, flatterability, gullibility, and so on — are believed to be *maladaptive*, or directly detrimental to the achievement of personal and professional goals [8].

Motivational constructs. Unfortunately, a maladaptive personality is not the only psychological hurdle the aspiring career woman must negotiate; she also may bring to the workforce an unflattering variety of damaging motivational constructs, or fears and assumptions. These fears and assumptions comprise a second major problem encountered by the working woman. To continue with our example, if Seaman **B** possesses the typical female psyche, she probably lacks self-confidence [12] and fears that success will diminish her femininity [13,14]. She also tends to be low in self-regard, to underestimate her own abilities and performance, and to expect failure [14]. Perhaps because of this, she may set low aspirations for herself [15], even though she can expect to spend 20 to 40 years in the work-force [16]. What success Seaman **B** does experience she will tend to attribute to luck; failures she will attribute to her own lack of ability or competence [17].

Finally, Seaman **B**, more than her male counterparts, is likely to posses an "external locus of control," or to allow herself to be controlled by the expectations of others [18]. Unfortunately, the research in this area suggests that the expectations of others in Seaman **B**'s immediate work group will be based on sex-role stereotypes, or cultural expectations for sex-appropriate behavior [19,20].

Sex-role stereotyping. Popular authors have been quick to note that the man who barks orders is a leader, while the woman is a tyrant; that the man who shouts and carries on in board meetings is strong-willed and charismatic, while the woman is overly emotional; that the man who pays careful attention to detail is conscientious, while the woman is picky [21,22,23]. These and other sex-role stereotypes comprise yet a third major problem which plagues the working woman. As a result of them, Seaman **B** will be pressured externally to conform to precisely those standards of behavior she has internalized as a result of growing up female. If she insists on deviating from these standards, the negative response she receives from work group members may magnify her already massive fears and insecurities, which in turn will discourage her from future deviation. The net result is that Seaman **B** is coerced both from within and from without to maintain a traditional sex role.

In sum, the overall picture of Seaman **B** which emerges from the research literature is of a woman in a double bind: if she does display adaptive traits she risks being stereotyped, and if she doesn't, she risks her professional competence. Her career may be sabotaged not only by her own deficient personality and counterproductive motivations, but also by the ways in which they interact with the stereotypic expectations of peers, superiors and subordinates.

Organizational vs. individual change. Unfortunately most change models designed to promote the upward mobility of women do not consider these psychological aspects of achievement. Instead, they concentrate on eliminating discrimination at the organizational level through affirmative action and other equal opportunity programs.

Although change on this order is certainly a necessary first step, it seems to have done little to improve the overall status of women workers. For example, the percentage of women in professional and technical occupations decreased from 42% in 1960 to 39% in 1977, while during the same period of time, the percentage of women clerical workers increased from 68% to 79% [24]. Although the military, unlike the civilian workforce, has greatly increased the assignment of women to scientific, technical, and labor specialties [25], attrition rates remain relatively high [26].

It seems reasonable to suppose, then, that organizational change is not the entire answer to upward mobility for women — that a complementary, grass-roots effort is needed to help women overcome the internal and external obstacles they face on a daily basis in themselves and in their work groups. Such an effort would address the problems typified by Seaman **B**. It would, in effect, provide an individual change model in support of large-scale organizational change.

From theory to application. When seen from this perspective, the research on sex roles and stereotyping takes on new importance in terms of its potential applications. However, the utility of this research is limited, for two reasons. First, much of it was conducted on samples of college women or under laboratory conditions, and therefore cannot validly be generalized to working women in their organizational environments. Second, most of the research is descriptive rather than clinical; it assumes that stable, developmental personality traits, motivational constructs, and attitudinal variables are responsible for the problems of women in male-dominated domains. Because of this, it offers no avenues for addressing these problems, with the possible exception of long-term therapeutic intervention.

A more fruitful approach, and one with more potential for application, might involve investigating the behavioral manifestations of sex roles and stereotypes — in the real wold and on working women. Such an approach necessarily would consider the interactions between the problems internal and external to women and, in so doing, might shed new light on their situational nature. It is quite possible, for example, that fear of success [7] is not, as initially formulated, a stable personality characteristic, but rather a clear perception of anticipated negative consequences for cross-sex behavior. Conversely, it is quite possible that a great deal of sex-role stereotyping represents little more than observed and generalized sex-typed behavior. When viewed from this behavioral perspective, the problems of working women become more amenable to resolution.

But before solutions can be devised, research into the behavioral and situational aspects of sex roles and stereotyping is needed. How, for example, do traditionally feminine traits translate into behaviors in work groups? How does sex-role stereotyping translate into behaviors of work group members? How are sex-typed behaviors maintained in women, and adaptive, cross-sex behaviors discouraged? An most importantly, can women systematically cultivate adaptive, cross-sex behaviors in themselves?

The Cycle of Defeat

The Hinsdale Validated Instruction Associates, Inc. (VIA) Psychosocial Model of Defeat (HVPMD) [27] provides a logical framework within which these and related questions currently are being addressed.

The HVPMD describes in behavioral terms how sex-role stereotyping interacts with female motivational constructs to produce a "cycle of defeat" whose net results are to maintain sex-typed behavior and sex-role stereotyping in work groups. The model suggests, first, that as a result of feminine motivational constructs, women gravitate toward the use of sex-typed behavior and tend to avoid cross-sex behavior which might be adaptive in the workplace.[1] It further holds that work group members — supervisors, peers, subordinates — are predisposed, by sex-role stereotypes, to reward sex-typed behavior and punish cross-sex behavior in women. Finally, the model proposes that this reward system ultimately reinforces feminine motivational constructs, thereby maintaining sex-typed behavior and completing the cycle of defeat.

Figure 1 shows the six areas of investigation and associated variable categories in the HVPMD.

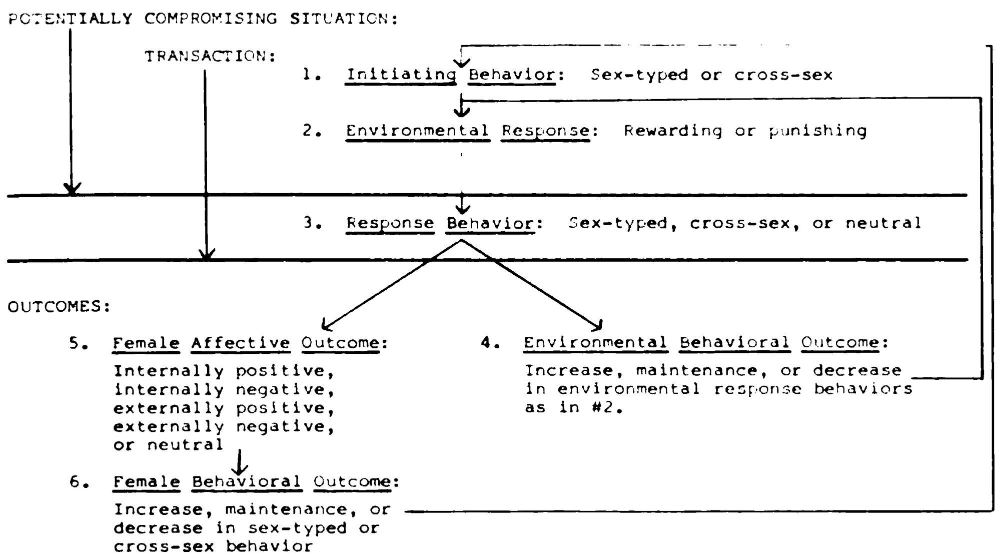

Figure 1 — The six areas of investigation in the HVPMD.

As its first basic unit of research, the HVPMD desribes four types of "potentially compromising situations," or "PCS's" which are initiated by a woman's behavior and completed by an "environmental response," or reaction from work group member(s) (see Figure 1). In order of predicted decreasing frequency, the four PCS types are:

Type 1: Reward for sex-typed behavior.
Type 2: Punishment for sex-typed behavior.
Type 3: Punishment for cross-sex behavior.
Type 4: Reward for cross-sex behavior.[2]

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[1] Most behavior in work groups undoubtedly is neither clearly sex-typed nor cross-sex, but simply human in nature. While the HVPMD accomodates neutral behavior, it is not a focus for study except insofar as it initiates situations which activate the cycle of defeat.

[2] While technically speaking, reward for cross-sex behavior is not "potentially compromising," the inclusion of the Type 4 PCS in the model is critical to studying the frequency and outcomes of the four possible combinations of initiating behaviors and environmental responses.

Implicit in this sequence are first, the relative frequency with which women are thought to employ sex-typed and cross-sex behavior, and second, the probabilities for reward and punishment as predicted from the research on sex-role stereotyping.

Each of the four PCS types elicits from the woman involved a "response behavior" which may be sex-typed, cross-sex, or neutral (see Figure 1). This response behavior, which completes a "transaction," comprises the second unit of research in the HVMPD.

A given transaction results in three outcomes, which are the remaining units of research in the HVPMD. These are the "environmental behavior outcome," or the behavioral consequences of the transaction for work group member(s), the "female affective outcome," or how the woman feels as a result of the transaction, and the "female behavioral outcome," or how the transaction predisposes the woman to behave in the future.

The following example illustrates the kinds of interactions contained in the model.

Suppose Seaman **B** has gone into an occupational specialty like aircraft maintenance and repair and has become Petty Officer **B**. A flight of bombers has just landed at her installation, and she and a male coworker are tying down aircraft in a rising wind. She initiates a transaction like this:

Initiating Behavior:

> "Harry, can you give me a hand with these lines? I can hardly fight the wind!"

Environmental Response:

> "This is too hard for you. Go get Joe, and he and I will get the job done."

In this Type 3 potentially compromising situation, Seaman **B** has received a negative response from Harry for attempting an historically cross-sex behavior[3] — tying down an aircraft. Harry's punishing response clearly has the potential for damaging her credibility as a member of the crew. However, if the compromising nature of the situation eludes Petty Officer **B** or if she is afraid to respond appropriately to Harry, she might answer as follows:

Response Behavior:

> "Okay, thanks, I'll send him right out."

If Petty Officer **B** is unaware that her integrity has been damaged by this transaction, her affective outcome will involve appreciation ("Isn't

[3] For research purposes, cross-sex and sex-typed behaviors are defined as behaviors consistent with the masculine and feminine traits defined by Bem (1974).

he considerate?") or perhaps even flattery ("He really treats me like a lady") — both of which are externally positive affective outcomes. On the other hand, if she is aware of the ramifications of allowing herself to be replaced on the job, she may experience internally negative affective outcomes like feelings of helplessness, incompetence, or self-pity ("They never give me a fair chance . . ."). In either case, feminine motivational constructs are reinforced and the behavioral outcomes are the same: Petty Officer **B**'s cross-sex behavior is discouraged, while Harry's stereotypic responses are maintained.

To defuse this potentially compromising situation, Petty Officer **B** would need to provide an alternative response behavior such as, "Thank you, but by the time Joe gets here we can be finished. Besides, you and I are just as good a team."

This cross-sex response will give Petty Officer **B** an opportunity to prove her competence,[4] thereby challenging Harry's assumption that she's the wrong "man" for the job and decreasing the likelihood that he will stereotype her as frail and helpless in the future. It further will lead to an internally rewarding affective outcome for Petty Officer **B**, who will now feel competent, worth her pay, and more fully accepted as a member of the work group. These affective outcomes will increase the likelihood that she will continue to respond assertively to members of her work group. Thus, the promise for turning the cycle of defeat into a "cycle of success" is inherent in adaptive, cross-sex response such as this.

Unfortunately, a range of research and rhetorical literature suggests that numbers of women are unaware of the potential for being compromised in Types 1, 2, and 3 situations. Others, with greater awareness, still do not possess the behavioral skills to defuse these situations. The HVPMD holds that it is these two deficiencies, coupled with women's maladaptive motivational constructs, which contribute to the cycle of defeat, the perpetuation of sex-roles and stereotyping in the workplace.

Some Preliminary Findings

Under sponsorship from the Office of Naval Research (ONR), the Navy Personnel Research and Development Center (NPRDC), and the Bureau of Naval Personnel, both applied and basic research into the validity of the HVPMD is going forward. While the basic research — that sponsored by ONR — is investigating the ways in which the cycle applies differently to women and to men, the applied research already has accumulated a data base which provides some evidence in support of the model as it applies to women [28]. These data were gathered in

[4]VIA research shows that 71.1% of E-4 and E-5 women have at some point had to "prove themselves" on the job.

the course of a series of training needs assessment interviews conducted with 133 E-4 and E-5 women prior to the design of a training program to assist Navy women in breaking the cycle of defeat.[5] Selected results are presented below.

Sex-role stereotyping. To determine the nature of the sex-role stereotypes upon which PC's are predicated in the Navy, interviewees were asked to respond to a series of questions in which common stereotypes of women were implicit. They were asked, for example, if any of their work group members underestimated their abilities, failed to take them seriously, treated them as children, and so on. The results are shown in Table 1.

Table 1
Encountered Stereotypes
($n = 133$)

The People I Work With:	%Yes	%No
Underestimate my abilities	51.6	48.4
Fail to take me seriously	45.0	55.0
Expect me to perform tasks beneath my level	42.2	57.8
View me as a threat	33.3	66.7
Interpret my comments and suggestions as nagging	31.2	68.8
Withold information I should have	30.2	69.8
Think I am too sensitive	27.9	72.1
Make me feel helpless	26.6	73.4
Treat me unfairly	25.8	74.2
Treat me like a child	25.0	75.0
Monitor my activity too closely	23.6	76.4
Think I'm unreasonable	18.6	81.4
Try to do my job for me	17.8	82.2
Think I complain excessively	15..7	84.3

It is apparent in Table 1 that there is no dearth of stereotypes of women in the Navy — at least as perceived by E-4 and E-5 women. These stereotypes undoubtedly formed the basis for many of the PCS's described by these women.

Potentially compromising situations. To investigate the extent to which cross-sex and sex-typed behaviors produced the behavioral/motivational chains described in the HVPMD, interviewees

[5]E-4 and E-5 women were selected as the target population for this research and development effort because it is at these paygrades that enlisted women begin to experience increasing dissatisfaction with their peers and superiors, while men begin to experience increasing satisfaction (Durning and Mumford, 1976). This may be symptomatic of the cycle of defeat at work.

were asked to recount work-related situations which clearly were initiated by cross-sex or sex-typed behaviors, i.e., behaviors consistent with the definitions of masculinity and feminity developed by (4). In keeping with the six general areas of investigation in the model, interviewers pursued the following line of questioning for each situation:

1. What did you do? (initiating behavior)
2. What was the response? (environmental response)
3. What did you do then? (response behavior)
4. How did this make you feel? (affective outcome)
5. What would you do if the situation arose again? (Female behavioral outcome)
6. What should you like to do instead? (female behavioral preference)[6]

A total of 309 situations were elicited from interviewees through this series of questions. Analysis of the resulting data indicated that PCS's tended to arise more from the use of cross-sex than sex-typed behavior; 67.7% of PCS's were initiated with masculine behaviors, while 32.4% were initiated with feminine behaviors.[7]

As hypothesized by the HVPMD, cross-sex behaviors were most likely to result in environmental responses which respondents perceived as negative, and sex-typed behaviors were most likely to result in consequences perceived as positive. 66.0% of all cross-sex behaviors resulted in perceived punishment, or Type 3 PCS's, while 78.0% of all sex-typed behaviors resulted in perceived reward, or Type 1 PCS's. Conversely, perceived punishment for sex-typed behavior, or Type 2 PCS's, occurred relatively infrequently (for 22.0% of all sex-typed initiated behaviors), as did reward for cross-sex behavior, or Type 4 PCS's (34.0% of cross-sex initiating behaviors). The relative frequency of all four types is shown in Table 2.

Response behaviors. In response to all PCS types, interviewees showed a marked tendency to reduce the rate at which they employed cross-sex behaviors. 51.4% of all response behaviors were cross-sex, while 48.6% were sex-typed. These figures provide a clear contrast to

[6] Due to the time constraints in the needs assessment interviews, it was not possible to investigate environmental behavioral outcomes, which are more important to model validation than to training program design. Instead, item #6, female behavioral preference, was used to investigate perceived behavioral deficiencies. Environmental behavioral outcomes will be investigated as part of the basic research sponsored by the Office of Naval Research.

[7] The reader should keep in mind that these figures do not reflect the relative frequency with which respondents employ cross-sex and sex-typed behaviors, but rather the frequency with which these behaviors result in potentially compromising situations.

Table 2
Frequency of Types 1 through 4 PCS's

PCS Type	#/% of Total situations (n = 309) n	%
Type 1: Reward for sex-typed behavior	78	25.2
Type 2: Punishment for sex-typed behavior	22	7.1
Type 3: Punishment for cross-sex behavior	138	44.7
Type 4: Reward for cross-sex behavior	71	23.0

the frequency of cross-sex and sex-typed initiating behaviors (67.6% and 32.4%, respectively). In keeping with the HVPMD, they indicate a trend for women to back down from potentially compromising situations.

Affective outcomes. Also as predicted by the model, women who used sex-typed response behaviors to PCS's were more likely than women using cross-sex responses to experience internally negative affective outcomes such as guilt, selfpity, or feelings in incompetence or helplessness. On the other hand, women who used cross-sex response behaviors were more likely to experience internally positive affective outcomes, or feelings of competence, control, or self-pride. These findings are shown in Table 3.

Of particular interest in Table 3 is the finding that women who used sex-typed response behaviors, as compared to those using cross-sex responses, experienced a smaller proportion of externally negative affective outcomes (e.g., anger, hostility, frustration), as well as the larger proportion internally negative affective outcomes noted above. These findings are consistent with Deaux and Emswiler's (1974) research on attribution theory, which describes the predisposition of traditional women to blame theselves for their failures, rather than bad fortune or others in their environments. [18]

Behavioral outcomes and preferences. Further support for the HVPMD is provided by the behavioral outcomes and behavioral preferences of needs assessment subjects. For 85.7% of the situations reported, interviewees indicated they would handle the situation in exactly the same manner if it arose again (= behavior outcome). However, for 33.6% of situations, the women indicated they would prefer to respond with more masculine behaviors (= behavioral preference). Thus, it can be inferred that the 85.7% anticipated maintenance of current behavioral patterns does not result from satisfaction with their net outcomes, but rather from a sense of powerlessness — a sign of the cycle of defeat at work.

Table 3
PCS Affective Outcomes, by
Response Behavior

Affective Outcome	Response Behavior	
	Cross-sex	Sex-typed
Internal Positive	31.5%	25.8%
External Positive	7.1%	5.0%
Internal Negative	22.8%	36.7%
External Negative	38.6%	32.5%
Total	100.0%	100.0%

The Cycle of Success

The skeletal validation of the cycle of defeat described in the preceding section begs the question: Can this cycle be reversed? Can women replace maladaptive behavior with adaptive, goal-oriented behavior, and in so doing, overcome self-defeating motivational constructs and defuse sex-role stereotyping? In other words, is there really a "cycle of success," and can it be learned?

The New Navy Woman Seminar: Self-Management and Career Advancement addresses these questions. The seminar, whose design is based on the needs assessment data, includes three full days and a half-day follow-up session. As of this writing, it has undergone four developmental iterations involving 116 female participants.

The purpose of the *New Navy Woman Seminar* is twofold. First, it raises participants' awareness of their personal goals and the ways in which their traditionally feminine traits, behaviors, and motivational constructs may deflect them from achieving these goals by activating the cycle of defeat. Second, it imparts to participants the behavioral skills required to break the cycle of defeat — that is, to move toward goal achievement while preserving their own integrity and the integrity of work group members. Thus, the seminar intervenes in the cycle of defeat in two ways — both by challenging maladaptive feminine psychology and by providing alternatives to current maladaptive behavior patterns.

Logically, one might expect this training intervention to reverse the cycle of defeat, i.e., to result in the increased use of adaptive, cross-sex behavior, while at the same time challenging feminine motivational constructs and countering sex-role stereotyping. One further might anticipate increases in job satisfaction and productivity on the part of women who break the cycle. Finally, one might project that in time, like the cycle of defeat, the cycle of success would become self-perpetuating as a result of increased skill mastery and self-confidence. To determine whether or not these predicted outcomes followed the four developmental sessions of the *New Navy Woman Seminar,* a variety of validation instruments were developed and implemented during and after each seminar. Selected results are discussed below.

Seminar validation. Much of the seminar validation data lends support to the notion that the cycle of defeat may be broken and that this does in fact lead to increased job satisfaction and productivity, as well as improved relationships with work group members. Table 4 contains selected results of a telephone follow-up interview conducted with a random sample of 30 seminar participants from nine to eleven weeks after the seminar.

Table 4
Participant Phone Interview Follow-Up Data
($n = 30$)

Item	$\bar{x}/\sigma$
Extent to which seminar has:	
1. Been useful in solving on-the-job problems	2.77/1.09
2. Improved relationships with coworkers and subordinates	2.67/1.04
3. Improved relationships with supervisors	2.83/1.24
4. Improved general job satisfaction	2.87/1.31
5. Improved general productivity	2.97/1.22
6. Helped in the achievement of career goals	2.77/1.36
7. Increased self-confidence at work	2.60/.88
Averaged Estimated Hours Saved Per Week	2.47 hours

Key: 1 = To a very great extent
2 = To a great extent
3 = To some extent
4 = To a little extent
5 = To a very little extent

On Table 4 it is apparent that overall, the seminar resulted in improved on-the-job problem solving, improved relationships with supervisors, coworkers, and subordinates, and increased job satisfaction, productivity, career goal achievement, and self-confidence. Of particular interest is the reported increase in self-confidence — a hypothesized spinoff of breaking the cycle of defeat, and one whose effects are thought to be cumulative. This, more than any other finding, suggests that through self-awareness and new behavioral skills women can learn to set the cycle of success in motion. The fact that the findings in Table 4 were reported nine to eleven weeks after the seminar attests to the lasting impact of the training intervention, which in turn implies the existence of a cycle of success.

To determine if any effects of the seminar were apparent to supervisors of seminar participants, interviews were conducted with a random sample of fifty supervisors from three to eight weeks after the seminar. Generally speaking, these interviews corroborated the perception of participants that the seminar had contributed to improved problem-solving, job satisfaction, productivity, and work group functioning. 49.0% of the supervisors interviewed had observed at least some improvement in the attitude and/or performance of subordinates who had attended the seminar.

The most dramatic seminar validation finding, however, was 20.0% of Day Four participants whose initial intention was not to reenlist or uncertain (n = 50) had reassessed that intention and were, as a direct result of the seminar, considering reenlistment. At least for a minority of participants, this figure points to a certain identification with the cycle of defeat and a certain willingness to attempt to reverse it within the Navy system.

Some Further Considerations

The Hinsdale-VIA Psychosocial Model of Defeat and its spinoff research and training projects raise some intriguing questions about the concepts of masculinity and feminity as they relate to the workplace. Because it is firmly rooted in the research literature, the HVPMD does subscribe to what has been called a "male managerial model," a deficiency model which encourages women to break free from trandi-tional sex roles, to challenge many of the psychological and behavioral correlates of traditional womanhood, and to acquire certain conventionally masculine competencies. Certainly, the seminar validation data suggest that this emphasis is expedient.

However, unlike many models, the HVPMD does not assume that women must pattern themselves and their behavior entirely after men and men's behavior. Instead, the model accommodates the concept of "psychological androgyny," which holds that masculine and feminine traits are not only compatible, but necessary to a sound and well-developed personality — regardless of sex.

Several studies support the supposition that androgyny is in fact adaptive for both women and men. For example, Bem has demonstrated that androgynous individuals, unlike sex-typed individuals, perform well on both sex-typed and cross-sex tasks [29]. Similarly, Spence and Helmreich have shown that androgyny is positively related to self-esteem and academic and extra-circular honors [30]. In short, there appears to be increasing empirical support for Bem's contention that "behavior should have no gender" [31].

The implications of this evolving body of literature for working women and men are as yet largely unexplored. However, as a first step in this direction, VIA basic research suggests that many feminine traits previously devalued in the workplace are now perceived as positive human attributes [32]. As part of this research, a sample of over 300 Navy enlisted personnel at the E-5 through E-9 paygrades were asked to indicate the Bem Sex Role Inventory (4), the traits comprising the "ideal Navy enlisted man," the "ideal Navy enlisted women," or the "ideal Navy enlisted person." Contrary to expectations, an analysis of variance showed no significant differences among these three hypothetical personalities on the dimensions of masculinity and feminity. A factor analysis of the traits comprising the ideal Navy enlisted person generated the four factors discussed below.

Factor 1, the *Masculinity Factor.*[8] Most strongly associated with this factor were a preponderance of traits defined as masculine in the research literature. Among them were, "acts as a leader," "self-reliant," "independent," and "ambitious." These traits were tempered by several neutral items also related to Factor 1, including "truthful," "loyal," and "helpful." The weighted average score for the items in Factor 1 was 6.42 on a seven-point scale. This indicates that the ideal Navy enlisted person *almost always* displays these traits.

Factor 2, the *Femininity Factor.* Such feminine items as "compassionate," "gentle," "tender," "affectionate," and "understanding" loaded heavily on Factor 2. "Happy" and "friendly," two neutral items, also were associated with this factor. The weighted average for the items in Factor 2 was 5.66, almost a full point lower than that for the Masculinity Factor, indicating that the ideal Navy enlisted person *usually* displays Factor 2.

Factor 3, the *Loser Factor.* Loading heavily on Factor 3 were a number of socially undesirable traits such as "jealous," "conceited," "theatrical," "secretive," "inefficient," and "moody." The one feminine item related to the factor was "gullible." Needless to say, the weighted average score on Factor 3 was low (2.42), indicating that the ideal Navy enlisted person *rarely* to *infrequently* displays the constituent traits.

Factor 4, the *Force Factor.* Most strongly associated with this factor were such masculine items as "aggressive," "forceful," "willing to take a

[8]The names of the first two factors were devised by VIA, Inc. researchers based on definitions of masculinity and feminity found in the research literature. Names for the remaining factors were devised intuitively.

stand," and "self-sufficient." The weighted average score was 5.27, revealing that the idelal Navy enlisted person *usually* displays this factor, but not quite as often as Factor 2, the *Femininity Factor.*

The hypothetical ideal Navy enlisted person described in these four factors is, overall, somewhat more masculine than feminine. Nevertheless, Factor 2 introduces a spectrum of feminine traits which, combined with Factors 1 and 4, produces a highly androgynous individual.

Perhaps the realization of this ideal will someday make the issues of sex roles and stereotyping obsolete. However, whether or not an androgynous ideal is in fact practical or feasible depends on the degree to which our work institutions are able to accommodate, assimilate, and value androgynous individuals. This raises a new set of research questions. To what extent, for example, are masculine and feminine traits actually adaptive in the workplace? To what extent do they help or hinder career advancement? And in what situations?

Addressing these questions is the next step in VIA's basic research on the cycle of defeat. Still, our initial findings — in both our training and research efforts — hold a certain promise that in the future, adaptive human behavior, in the Navy and elsewhere, may indeed have no gender.

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(Continued from page 12)
10,000 times the brightness of a normal galaxy. Thermonuclear power falls far short of meeting the energy requirements of quasars. Only gravitation, acting on a cosmic scale, can concentrate the required energy.

Scientists have, therefore, come to speak of massive black holes, created by the capture of a million to a hundred million suns, lurking in the nuclei of explosive galaxies. As stars orbit near such a black hole, tidal forces rip them apart and the debris is gobbled up by the gravitational trap. A great cloud of gas envelops the black hole and is heated to enormous temperatures by friction. Some theorists postulate temperatures of billions of degrees, which create an intense flood of X-rays.

Recently, this picture seems to have been supported by observations of the giant elliptical galaxy M-87 in Virgo. About a dozen years ago the Naval Research Laboratory discovered that M-87 was a powerful X-ray source. Now, optical astronomers at Palomar and Kitt Peak have found evidence for a great concentration of mass in the very heart of the galaxy. Per unit of luminosity, the mass is 60 times as great as the sun's. They suggest that the nucleus of M-87 contains a black hole of perhaps 5 billion solar masses.

The nucleus of our own galaxy, now seemingly calm, shows evidence of a past convulsion of catastrophic proportions. A doughnut shaped molecular cloud, containing the mass of a hundred million suns, surrounds the nucleus and is blowing outward like a gigantic smoke ring. Its diameter is about 260,000 miles per hour, implying a great explosion only a million years ago.

Still farther out is a rapidly rotating disk of hydrogen gas, expanding at a rate of a million miles perhour, signifying an even earlier explosion.

At the very center of the galaxy is an intensely bright radio source, Sgr A West, which has a compact core smaller in diameter than our solar system. Radio astronomers have speculated that this is a black hole of some 10 million solar masses, which would measure less than four astronomical units in diameter (1 A.U. equals the distance from earth to sun). The black hole may have powered past explosions and now be storing energy for another cosmic outburst.

To test this speculation, the Naval Research Laboratory astronomers flew a rocket to study X-ray emission from the galactic center. No X-rays could be detected from Sgr A West, although several individual X-ray sources were scattered through the general vicinity of the galactic nucleus.

Perhaps these are black holes enclosing long dead stars that have been wandering for eons through the galaxy and now happen to be passing through the dense bulge at the center of the galaxy, swallowing gas and radiating X-rays.

The NRL study of the galactic center offers no support for the idea of a massive black hole. Perhaps the black hole blew away most of the surrounding mass in an explosion a million years ago and is sucking back new material to be stored up for a new explosion in the future. In the interim, its X-ray luminosity may be too faint to detect.

Some theorists suggest that a massive black hole at the center of the Milky Way may be enveloped by a cloud so thick that the outer fringes of the cloud are no hotter than perhaps 10,000 degrees and radiate mostly ultraviolet light.

Unfortunately, we cannot observe visible or ultraviolet light from the center of the Milky Way, because the disk of the galaxy is filled with dust that blocks our vision. Only X-rays, infrared and radio waves penetrate the murk.

But we can infer what exists at the center of the Milky Way if we examine its twin, the Andromeda galaxy, 2-million light-years distant. Andromeda is a giant spiral galaxy whose disk is tilted towards us at about 30 degrees, so that we can see directly into its nucleus.

George Carruthers of NRL has flown a powerful electronic ultraviolet camera to photograph Andromeda. His picture of the nucleus does not show a brilliant ultraviolet core that could be attributed to a massive black hole.

The black hole score card therefore reads as follows: a bright core in M-87 suggests a billion solar mass black hole and appears to be a powerful X-ray source; the nucleus of the Milky Way reveals a brilliant radio source but shows no similar X-ray source; and Andromeda reveals no ultraviolet source consistant with black hole models.

Perhaps quasars and other explosive galaxies do contain massive black holes which set off violent outbursts lasting about a million years. Our Milky Way may alternately suck and blow matter around a massive black hole in its nucleus. The last blow-off occurred millions of years ago. It may now be gathering energy for another blow.

The search for conclusive proof of the existence of black holes has become a major endeavor of the entire astronomical community. NASA's HEAO (High Energy Astronomical Observatory) series of satellites play a key role. It would be very appropriate if strong proof should emerge within the next year when the world will be celebrating the 100th anniversary of the birth of Albert Einstein.

TITLE INDEX 1978

AUTHOR INDEX 1978

Cryogenic Cooler for Ship Propulsion Systems

A novel helium liquefier, a refrigeration device designed to provide the thermal environment needed for the superconductive motors and generators to be used in some Navy ship propulsion systems in the future, has been developed by Dr. Sameul C. Collins of the Naval Research Laboratory. The invention was developed as part of a research effort in cryogenics sponsored by the Naval Ship Research and Development Center (NSRDC) at Annapolis, Md.

NSRDC is attempting to adapt superconductive motors and generators for ship propulsion uses in the Navy's new, fast surface effects ships. These machines must operate at a temperature only a few degrees above absolute zero (-459.4 F).

Dr. Collins, who also invented an airborne oxygen liquefier for aircraft and the Collins Cryostat (the first commercially feasible helium liquefier), reports his new liquefier is 20% more efficient and is smaller than other liquefiers presently available, and it is made to withstand heavy shocks.

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Waste Demulsifying Technique

The chemical technique for demulsifying and separating oily waste from ship' bilges, which was recently developed by the Naval Research Laboratory, is being used by the Oil Recovery Group at the San Diego, California Naval Station to help alleviate water pollution in the San Diego harbor area where effluent laws are strictly enforced.

The unique collection and treatment system, developed by the Naval Facilities Engineering Command, consists of a doughnut-shaped, 26,000 gallon tank aboard a Waste Oil Raft (WOR), which is towed to ships in the harbor. The bilge waste is pumped into the WOR tank at the ship site and then returned to dockside for the demulsification process.

Certain quanternary ammonium compounds used in the NRL technique are throroughly mixed in the oily waste at the dockside site where the oil is separated from the mixture. The water recovered from the bilge waste is then clean enough to be returned to the environment, and the oil is sold to refining companies.

The NRL technique is not only a means of diminishing oil pollution problems, but is also a more effective and economical way to dispose of oily waste matter from ships than can be offered by demulsifying agents commercially available today.

The Last *Naval Research Reviews*

This issue, December 1979, is the last *Naval Research Reviews*. For thirty-one years the magazine has informed the Navy and scientific community about many of the projects supported by the Office of Naval Research and its laboratories. ONR will continue to inform the Navy and scientific community of its research programs through two new publications which will appear this year: (1) a montly newsletter which will be directed primarily to the Fleet and (2) a quarterly magazine which will be directed to the scientific community.

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 730. 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. Subscription price: $11 per year in the U.S. and Canada: $13.75 per year, foreign: $1 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

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IN THIS ISSUE

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To understand the mechanisms of strength and wear in polymers it is necessary to probe them on the molecular level. Recently light scattering techniques have been used for polymer characterization.

Organizational change is not the entire answer to upward mobility for women. A complementary, grass-roots effort is needed to help women overcome the internal and external obstacles they face on a daily basis in themselves and in their work groups.

Cover Caption

Diamond anvil cell used for high pressure Raman spectroscopy. Cell can obtain pressures as high as 100 KB. (See page 7).

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