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ADDENDA TO
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FORT MONROE, VIRGINIA
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The Near Millimeter Wave Properties of High Temperature
Superconductors

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**The Near Millimeter Wave Properties of High Temperature
Superconductors***

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Abstract

The on going exploration of the near millimeter wave and IR response of high temperature superconductors in sintered, thin film, single crystal and even single grain form continue to provide new information about the electrodynamics of these unusual materials both in the normal and superconducting states.

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Introduction

The far-IR properties of the high T_c compounds[1] in sintered polycrystalline, thin film and single crystal form continue to surprise and fascinate solid state spectroscopists in ever increasing numbers. Although the experimental situation is in constant turmoil nearly everyone agrees that in the visible the material is black as coal with a low reflectivity like that of a wide band gap semiconductor while in the far infrared the reflectivity in the superconducting state corresponds to that of a metal not a lossless metal, characteristic of a superconductor at frequencies below the energy gap, but still a good metal. Divining more than this from the data is what continues to produce controversy but, on the other hand, it is also what makes these materials of spectroscopic interest. To appreciate the fundamental IR problems it is useful first to review the electromagnetic response for low temperature superconductors.

In general, a nonlocal relation between the current density and the electric field together with Maxwell's equations must be used to describe the fields inside a pure metal at low temperatures. The surface impedance concept permits a reformulation of the problem in terms of a boundary condition on the fields at the metal surface. The defining equation is

$$\mathbf{E}_t = \mathbf{z} \mathbf{H}_t \times \mathbf{n} \quad (1)$$

where the subscript t signifies the external tangential fields evaluated at the boundary, the normalized surface impedance $\mathbf{z} = \mathbf{Z}/\mathbf{Z}_0$ with $\mathbf{Z}_0$ the impedance of free space and $\mathbf{n}$ is the normal to the metal surface. The complex coefficient $\mathbf{z}$ completely characterizes the medium so the normal incident reflectivity R and the absorptivity A are related by

$$A = 1 - R = \frac{4r}{(1+r)^2 + x^2} \quad (2)$$

For most metals $r, x \ll 1$ so that the absorptivity reduces to

$$A = 4r. \quad (3)$$

The absorptivity of a dirty metal in the far infrared corresponds to the classical skin effect limit. In this regime the electromagnetic skin depth δ is large compared to an electron mean free path $v_F\tau$ so that a local conductivity $\sigma(\omega)$ can be defined. If, further, it is assumed that the carrier scattering time is independent of energy and that the Drude model can be used to describe the a.c. conductivity then

$$\sigma(\omega) = \sigma_0(1 - i\omega\tau)^{-1}, \quad \sigma_0 = (\omega_p^2 \tau) / 4\pi \quad (4)$$

where σ_0 is the dc conductivity and ω_p is the plasma frequency. Note that two parameters τ and ω_p characterize the electromagnetic properties of the metal. The corresponding components of the surface impedance are

$$r = (1/2\omega_p\tau)(2\omega\tau)^{1/2}[(1 + \omega^2\tau^2)^{1/2} - \omega\tau]^{1/2} \quad (5)$$

and

$$x = - (1/2\omega_p\tau)(2\omega\tau)^{1/2}[(1 + \omega^2\tau^2)^{1/2} + \omega\tau]^{1/2} \quad (6)$$

In the far infrared, $\omega\tau \ll 1$ and the absorptivity at normal incidence has the simple Hagen-Rubens form

$$A_n(\omega) = (2\omega / \pi \sigma_0)^{1/2} \quad (7)$$

in which A_n increases as $\omega^{1/2}$. At a frequency of 100 cm^{-1} and a resistivity of $70 \mu\Omega\text{cm}$, $A_n = 0.03$. For larger infrared frequencies, in the limit where $1 \ll \omega\tau \ll \omega_p\tau$, the absorptivity has the constant value

$$A_n(\omega) = 2 / (\omega_p \tau) \quad (8)$$

At still larger frequencies, in the visible, transitions to other bands become important and the simple intraband absorption model given here is no longer applicable.

For materials with small conductivities the high frequency interband transitions can still influence the size of the absorptivity in the IR and FIR region through their effect on the displacement current in the medium. This effect can be seen most easily when the dielectric function of the medium $\epsilon(\omega)$ is written in terms of the contribution from the displacement and conduction currents so

$$\epsilon(\omega) = \epsilon_\infty + 4\pi i \sigma(\omega)/\omega \quad (9)$$

where ϵ_∞ is the constant low frequency contribution from the interband transitions. When this contribution is significant it is often useful to plot $\sigma_1(\omega)$ and $\epsilon_1(\omega)$ rather than $\sigma_1(\omega)$ and $\sigma_2(\omega)$ so that the two Drude parameters τ and ω_p will be evident. If the material has a magnetic response as well as an electric one then to compare theory and experiment in the local limit, the connection between the surface impedance and the different susceptibilities is

$$z = [\mu(\omega)/\epsilon(\omega)]^{1/2} \quad (10)$$

The dotted curve in Fig. (1) shows the measured surface resistance at room

temperature for an annealed lead foil in the far infrared spectral region[2]. A multiple parallel plate waveguide technique was employed to measure this small absorptivity. In this frequency region the displacement current is negligible compared to the conduction term and also $\mu = 1$. The solid curve in the figure is calculated from the Drude theory with the measured dc conductivity of the foil inserted into Eq. (7). With no free parameters good agreement is obtained between theory and experiment throughout this spectral region.

Because of Landau damping the FIR absorptivity of a pure metal at low temperatures no longer agrees with the simple Drude predictions based on a temperature dependent relaxation time. This anomalous skin effect regime has been well studied both in the normal state and in the superconducting state. The frequency dependent response of a superconductor in the extreme anomalous limit as calculated by Mattis and Bardeen[3] is shown in Fig. (2). The electromagnetic gap $\hbar\omega_g = 2\Delta = 3.5 k_B T$ for this weak coupling limit. The normal state conductivity σ_n is assumed to be entirely real in this frequency interval ($\omega\tau \ll 1$) and the results are shown as a ratio of the real σ_1 and imaginary σ_2 in the superconducting state to σ_n . These conductivity expressions also apply in the opposite or extreme dirty limit. The ratio of the extreme anomalous surface resistance in the superconducting state to the normal state for a bulk sample is also shown in Fig. (2). For the opposite limit Tinkham[4] has shown that the frequency dependence of the surface resistance remains qualitatively the same as in Fig. (2).

For a strongly coupled superconductor such as Pb the spectrum for the superconducting state is made complex by the appearance of the Holstein absorption process[5-8]. The coupling between electrons and phonons in metals makes allowed an infrared absorption process at low temperatures associated with phonon generation by the excited electrons. The product of the square of the electron-phonon matrix element and the phonon density of states in the metal can be obtained from a measurement of the difference in the FIR absorptivity between the superconducting and normal state.

Measurements[9] of the difference in the FIR surface resistance between super and normal for the extreme anomalous (Pb) and the extreme dirty (Pb-0.1In) limits are shown in Fig. (3). Above the gap frequency the absorptivity in the superconducting state exceeds that in the normal state up to frequencies about 10 x the gap frequency. Note that the alloy

sample has a much larger surface resistance in the normal state below the gap than does the pure Pb sample and that it also has a corresponding larger surface resistance in the superconducting state above the gap. These results illustrate the "Brändli sum rule" that the absorptivity in the normal state below the gap must equal the excess absorptivity in the superconducting state above the gap[9], i.e.,

$$\int_0^{\infty} r_s(\omega) d\omega = \int_0^{\infty} r_n(\omega) d\omega \quad (11)$$

Another interesting feature about the data shown in Fig. (3) is that the frequency dependence of the excess absorptivity in the superconducting state is completely different for the two cases. For pure Pb the profile is associated with the availability of phonons hence for $T = 0$ with the spectrum of the phonon density of states whereas for the alloy case the main ingredient is quasi-elastic scattering near zero frequency.

High T_c sintered Samples

The room temperature FIR reflectivity of sintered polycrystalline $\text{YBa}_2\text{Cu}_3\text{O}_{7-y}$ is represented by the solid line in Fig. (4a)[10]. The classical skin effect prediction (dashed line) for a dc resistivity of $800 \mu\Omega\text{cm}$ (the measured resistivity is $890 \mu\Omega\text{cm} \pm 10\%$) is also shown. At the lowest frequency limit of our data the two curves converge, but for higher frequencies, the reflectivity deviates strongly from the Drude prediction. We also observe very little temperature dependence to the reflectivity (100 K, dotted line) in agreement with other measurements at larger frequencies. While the dc resistivity changes by a factor of three from just above T_c to room temperature, the reflectivity changes by only a few percent[10].

Figure (4b) shows the room temperature reflectivity as a function of frequency on a logarithmic frequency axis, covering four decades in frequency. These results are similar to those reported by others[11-13]. The appearance of phonon modes such as those shown in the 100 to 1000 cm^{-1} region is not common in metallic reflectivity, but they have been seen in materials with small optical conductivity[14].

How can one analyze such sintered material data more quantitatively? With the definitive observation[15] in the FIR reflectivity of 2-dimensional optical conductivity in

the ab plane of single crystal La_2NiO_4 , a compound structurally isomorphic to $\text{La}_{1.85}\text{Sr}_{0.15}\text{CuO}_{4-y}$ (the 40 K superconductor), an effective medium modeling of the FIR data for both the superconducting and normal state of the sintered material becomes practical. For the grain size small compared to the wavelength and for 2-D conduction with the third direction in the grain insulating, the effective medium approximation (EMA) equation has a relatively simple form, with a fixed fill fraction of $f = 2/3$ for the metallic component. To make the problem tractable we have assumed that the crystallites are spheroids with the same symmetry as the conductivity tensor, so that a single parameter, the depolarization factor, L , along the c direction of the crystallite, specifies the EMA. The effective conductivity for the medium is obtained by solving the following equation[16]:

$$\frac{2}{3} \frac{\sigma_{ab} - \sigma_e}{(1+L)\sigma_e + (1-L)\sigma_{ab}} + \frac{1}{3} \frac{\sigma_c - \sigma_e}{2[(1-L)\sigma_e + L\sigma_c]} = 0 \quad (12)$$

where σ_e is the desired conductivity of the isotropic effective medium in terms of the known conductivities of the individual anisotropic grains.

For the case of spherical crystallites, $L = 1/3$ and Eq. (12) reduces to the standard EMA result for an anisotropic polycrystalline material. For needle-like crystallites $L = 0$ along the c axis, while for plate-like crystallites $L = 1$. We find that this EMA with Lorentz oscillator contributions for the phonons and a two dimensional Drude free carrier component provides a good description of the normal metal results for the sintered systems throughout the FIR region[16,17].

Figure 5(a) presents our FIR data on the reflectivity of $\text{La}_{1.85}\text{Sr}_{0.15}\text{CuO}_{4-y}$ in the normal state ($T = 40$ K, dashed curve) and in the superconducting state ($T=10$ K, solid curve)[10]. The dashed line fit shown in Fig. 5(b) demonstrates that the Drude term does not provide enough reflectivity at low frequencies. The calculated reflectivity for the superconducting state represented by the solid line in Fig. 5(b) makes use of the Mattis-Bardeen equations to model the 2D superconductivity in the a,b plane. This too reproduces some of the qualitative features observed in Fig. 5(a), for example, although 2D is chosen as 68 cm^{-1} , the onset of absorption occurs at about 35 cm^{-1} . Also the reflectivities cross at 73.7 cm^{-1} and the normal state becomes more reflecting than the superconducting state above this frequency.

To demonstrate the key role of grain geometry, Fig. 5(c) shows the reflectivity in

the superconducting and normal states as calculated with the EMA using identical parameters as Fig. 5(b), except that $L_c = 0.7$, corresponding to oblate spheroids. Immediately obvious is the dramatic loss of the enhanced absorptivity in the superconducting state above the gap and the shift in position of the equal reflectivity frequency which often has been associated with the frequency of the energy gap, 2Δ .

The qualitative agreement between the EMA calculations and the measured reflectivity on the sintered material in the long wavelength limit demonstrates that the individual grains are highly anisotropic in the far infrared spectral region. The good specular properties of the sintered samples in the visible indicate that the grains must be nearly isotropic at these wavelengths. Between these two limits the grain size is comparable to the wavelength of the radiation and the grains are anisotropic so that the surface appears rough and scatters radiation. So far there is no theory to describe the results in this region.

Optical Properties of composites

Recently there has been much controversy surrounding the origin and significance of a peak centered around 0.5 eV in the optical conductivity of sintered high temperature superconductors. Several reports[18,19] have been published on the IR spectrum of sintered $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ and $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$ which claim that the observed correlation between the oscillator strength of the "0.5 eV" peak and the degree of "superconductivity" in the samples might indicate that pairing in these materials is mediated by a high-energy electronic excitation such as an exciton[20]. Later, IR measurements of single crystals were made by many workers, using both reflectivity[21,22] and direct absorption methods[23]. Most of these measurements on single crystals have failed to show a strong "0.5 eV" peak although a broad absorption is observed to extend throughout the IR spectral region. Figure (6) shows an IR peak in the conductivity for three different sintered copper oxide compounds. The top trace is for the 40 K superconductor, the middle trace is for the 90 K superconductor and the bottom trace is for a non-superconductor[24]. The compound $\text{La}_4\text{BaCu}_5\text{O}_{13}$ can be viewed as a cubic perovskite with an array of channels of oxygen vacancies running parallel to the c axis, so the Cu-O network is three dimensional

but anisotropic[25]. The 3-D conductivity screens the phonon dipole moments and keeps the lattice component from showing up even in the sintered pellets.

Why the "0.5 eV peak" appears in the sintered copper-oxide perovskite-like materials is an interesting question even if it is not an intrinsic effect. Possible answers could involve: (1) effects of the composite nature of the system such as sphere resonances; or (2) the strong anisotropic nature of the material and the random orientation of the grains. In a recent Comment, Orenstein *et al.*, [26] proposed a simple model which explains the "0.5 eV absorption peak" in terms of the optical anisotropy of the material in the geometrical optics limit. While this model seems to reproduce qualitatively the presence of the peak in the mid-IR, we believe that the complete picture must be more complicated. In this region of the spectrum, the size of the anisotropic grains is such that neither the geometrical nor effective medium limits can be correct, and scattering effects must be important. It may be that the origin of the peak can be determined more clearly by careful studies in which the grain size and porosity of the materials can be controlled.

Films and Single Crystal Oxide Superconductors

It is useful to compare the superconducting response of sintered, thin film and single xtal FIR materials. Shown in Figure 7(a) is the ratio of the reflectivity of sintered $\text{YBa}_2\text{Cu}_3\text{O}_{7-y}$ in the superconducting state (10 K) to that in the normal state (100 K). The polycrystalline nature is accounted for again with the EMA[27]. The dashed curve in Fig. 7(a) is obtained from such a fit to the normal state data, followed by the application of the MB equations to model the free electron conductivity. Here a gap of 170 cm^{-1} was obtained for plate-like crystallites. An equally satisfactory fit is obtained with a gap of 150 cm^{-1} for spherical crystallites. The relative superconducting gap energies obtained from sintered samples of both $\text{YBa}_2\text{Cu}_3\text{O}_{7-y}$ and $\text{La}_{1.85}\text{Sr}_{0.15}\text{CuO}_{4-y}$ are thus seen to be similar, with $2\Delta/kT_c = 2.6$.

Contrasting with the behavior of the bulk samples, Figure 7(b) shows data for $1 \mu\text{m}$ thick films of $\text{YBa}_2\text{Cu}_3\text{O}_{7-y}$ on ZrO_2 . These films are of high quality, having $T_c = 85 \text{ K}$ and $J_c > 10^6 \text{ A/cm}^2$ at $T = 4.2 \text{ K}$. The films are somewhat oriented, with the c-axis preferentially perpendicular to the film surface. Using the same dielectric function in the a-

b plane obtained from fitting the data on bulk material, but with the measured dc resistivity of $200 \mu\Omega\text{cm}$ in the a-b plane, produces the dashed curve in Fig. 7(b). Here the choice of the gap energy indicates $2\Delta/kT_c = 6.4$, larger than the value obtained for bulk sintered material. The conductivity obtained from a Kramers-Kronig transformation of the reflectivity covering over three orders of magnitude in frequency does not show the electronic mode in the IR found for bulk polycrystalline samples.

Just as the relative gap parameter for the films exceeds that of the sintered material, so that of the single crystals exceeds that of the films. Single crystals have been pieced together to form a mosaic with the c-axis normal to the surface. Our reflectivity measurements shown in Fig. 7(c) and our determination of the gap parameter, $2\Delta/kT_c = 8$, are in agreement with those reported on single crystals by others [21]. Again the dashed curve is a fit to the data using the dielectric function determined on the bulk, with a dc resistivity of $200 \mu\Omega\text{cm}$. The gap value is determined from this fit. As for the films, the reflectivity signature of the superconducting state is not "complete" in that there is absorption of energy below 2Δ . Thus the dashed curve in Fig. 7(c) has been reduced by 50% to agree with the overall magnitude of the data. Our measurements on different single crystals show that this absorption below the gap is not the same from sample to sample hence it must be an extrinsic effect. This interpretation of the optical data and hence gap value is not unique.

Recently Timusk *et al.*, [28] proposed an alternate explanation for the R_s/R_n results which does not make specific use of a gap or equivalently assumes that $\tau^{-1} \ll 2\Delta$ so that the entire free carrier $\sigma_1(\omega)$ profile in the normal state is compressed into the delta function at $\omega = 0$ in the superconducting state. With τ^{-1} small and $\sigma_1(\text{dc})$ known for the normal state, the conductivity sum rule gives a small plasma frequency. From Hall measurements [29] an estimate of the density of free carriers can be obtained independently. This value together with the small plasma frequency implies a large carrier mass; however, specific heat gives a carrier mass which is not particularly heavy [30]. At present all of these results do not give a consistent picture.

Currently the far infrared (FIR) spectroscopic data on high T_c single crystals in the superconducting state can be interpreted as evidence for a large energy gap [31], a BCS-like

gap[32] or no gap at all[33]. The optical properties of crystals of variable quality make it difficult to conclude whether or not the peak observed in the ratio of the FIR reflectivity of the ab plane of $\text{YBa}_2\text{Cu}_3\text{O}_{7-y}$ in the superconducting state to that of the normal state should be interpreted as evidence for the energy gap[31,32] or as evidence for a zero crossing of the real part of the dielectric function[33]. The gap of $\text{La}_{2-x}\text{Sr}_x\text{CuO}_{4-y}$ is even less well determined because it has been difficult to grow single crystals at the Sr doping which produces the highest T_c 's. The optical properties of superconducting sintered $\text{La}_{2-x}\text{Sr}_x\text{CuO}_{4-y}$ have been analyzed in some detail[34] but the excess absorption in the superconducting state associated with transport between grains obscures the determination of a true gap signature. Compared to the extensive work on these polycrystalline[34,35] or single crystal samples[31-33], the FIR electrodynamics of high T_c superconductors in the isolated particle form have been ignored even though the relation between the bulk dielectric function and the small particle response is well known and has been investigated for many materials[36].

Isolated Superconducting Particles

Our most recent investigation has focused on the FIR response of small isolated $\text{La}_{2-x}\text{Sr}_x\text{CuO}_{4-y}$ particles in the normal and superconducting states[37]. A far infrared superconducting sphere resonance polarized along the c-axis has been observed to decrease in frequency with increasing temperature, increasing magnetic field or decreasing Sr doping. No corresponding resonance is found in the normal state. These observations indicate that an energy gap does exist in high T_c materials since the energy gap frequency must be larger than the c-axis sphere resonance value. These results will be described by Dr. Noh in an invited paper at the March "Solid State" meeting of the American Physical Society.

Before turning to the experimental data we summarize the different kinds of spectral signatures which can be expected to occur for small conducting particles. Let us consider two specific examples to identify qualitatively the spectral signature for superconductors in small particle form. Assume that a BCS energy gap separates the superconducting ground state from the single particle excited states, that $\omega_p\tau \gg 1$ and that either $(2\Delta)\tau \gg 1$ or

$(2\Delta)\tau \ll 1$ for a bulk low temperature superconductor. For the first case the entire normal state conductivity spectrum collapses into the delta function at zero temperature with strength $A_I = \int \sigma_n(\omega)d\omega = \omega_p^2/8$. For the second case, $\sigma_1(\omega)$ is zero up to a gap frequency 2Δ , above which it rises monotonically to the frequency independent conductivity of the normal state, σ_n , since ω is still $\ll \tau^{-1}$. The strength A_{II} of the $\delta(\omega)$ term comes from the missing area below the gap frequency[38], i.e., $A_{II} \approx 2(2\Delta)\sigma_n$. We show the expected results for the corresponding sphere resonances for these two cases at the top of Table 1 and below those the results for other possible sets of parameters. Depending on the relative size of ω_p , τ^{-1} , and 2Δ , various sphere resonance signatures can be expected in small metallic particles in the normal and superconducting states.

The FIR temperature dependence of the absorption coefficient, α , for 1% $\text{La}_{1.85}\text{Sr}_{0.15}\text{CuO}_{4-y}$ in Teflon is shown in Figure (8a). The absorption coefficient difference $\Delta\alpha(T) = [\alpha(T) - \alpha(T=40\text{K})]$ is plotted versus temperature. The low temperature absorption peak, located at 54 cm^{-1} , shifts to smaller frequencies and weakens as the temperature approaches T_c . No resonance is seen in the normal state. At the resonant frequency the absorption in the superconducting state is larger than the absorption in the normal state but far from the resonance the reverse is true. A six T magnetic field was observed to decrease the line strength by about 40% and produce effects similar to those obtained with increasing temperature. These observations, which are consistent with Case IV in Table 1, indicate that the resonance is associated with the appearance of superconductivity.

The Sr concentration dependence and hence the conductivity dependence of the absorption feature is shown in Figure (9). Since the absorption for the same material between 0.3% and 3% fill fraction scales with f , the difference between the absorption coefficients in the superconducting and normal states are normalized by the fill fraction, f , of the superconductor. The peak position and the linewidth of the absorption line increase monotonically with x . However, the normalized absorption value at the peak position and the strength of the resonant feature increase at low concentration of Sr but reach a maximum around $x=0.18$. Our samples with $x=0.225$ and 0.25 show no absorption lines up to 180 cm^{-1} , although they are superconducting. Also, no line is observed in non-

superconducting $x=0.02$ and $x=0.04$ samples.

The general behavior of the peak position and strength as a function of Sr concentration can be explained as a change in the value of σ_n . If σ_n along the c-axis increases with Sr doping like the d.c. conductivity of sintered materials, the position and the strength of the resonance should increase. The disappearance of the resonant feature above $x=0.225$ probably results from the resonant frequency becoming much higher than $2D$, so that the limit of Case V in Table 1 is in effect. The lack of a resonant feature below $x=0.04$ is due simply to the lack of superconductivity in those samples.

We have observed a unique resonance phenomenon in well dispersed superconducting $\text{La}_{2-x}\text{Sr}_x\text{CuO}_{4-y}$ particles in teflon. The observed strength and position of the resonance identifies for the first time the value of the c-axis conductivity for large Sr concentrations. The observed behavior of the resonant feature fixes the inequalities that the normal free carrier and superconducting parameters must satisfy, namely, the normal state carriers along the c-axis are heavily damped and the c-axis energy gap frequency is larger than the sphere resonance frequency but smaller than the normal state carrier scattering rate.

Conclusions

All of the data presented here show that the FIR properties of the high T_c superconductors do not correspond to the low temperature ones described in the background section. The sintered Cu-O materials can be described fairly accurately with the EMA but the sphere resonance results indicate that the derived gap value is too small. At higher frequencies, the IR peak in the effective optical conductivity of the sintered materials is an interesting effect which occurs in a region of the spectrum where composite media analysis is not valid. The IR peak in the conductivity does not appear to be intimately connected to superconductivity since it appears in both superconducting and normal Cu-O materials. A detailed analysis of the single crystal data is still complicated by the variability of the materials and by the as yet to be determined influence of the heavily twinned a,b plane on the optical constants. In principle, the influence of this single crystal twinning (on the scale of $1000 \text{ \AA}$) on the IR and FIR properties could be described with still another composite medium representation.

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Table 1.

The characteristics of sphere resonances in superconducting materials with various relative values of $\omega_p\tau$ and 2Δ . The dc dielectric constant from phonons and bound electrons is ϵ_0 .

Case	Conditions	Peak Position, ω_{rs}	Observable? (normal) (s.c.)		Characteristics
I	$\omega_p\tau \gg 1, (2\Delta)\tau > 1$	$\frac{\omega_p}{(\epsilon_0 + 2\epsilon_n)^{1/2}}$	yes	yes	The line width will narrow drastically upon cooling below T_c .
II	$\omega_p\tau \gg 1, (2\Delta)\tau \ll 1$	$\frac{\omega_p}{(\epsilon_0 + 2\epsilon_n)^{1/2}}$	yes	yes	The line width will not change upon cooling below T_c .
III	$\omega_p\tau \leq 2, (2\Delta)\tau > 1$	$\frac{\omega_p}{(\epsilon_0 + 2\epsilon_n)^{1/2}}$	no	yes	The peak position will not have a strong temperature dependence.
IV	$\omega_p\tau \leq 2, (2\Delta)\tau \ll 1$ and $\omega_{sr} < 2\Delta$	$\left(\frac{16\sigma_n(2\Delta)}{\epsilon_0 + 2\epsilon_n} \right)^{1/2}$	no	yes	The peak position will have a strong temperature dependence.
V	$\omega_p\tau \leq 2, (2\Delta)\tau \ll 1$ and $\omega_{sr} \gg 2\Delta$	$\left(\frac{16\sigma_n(2\Delta)}{\epsilon_0 + 2\epsilon_n} \right)^{1/2}$	no	no	The peak will be overdamped since $\text{Im}(\tau(\omega_{sr}) + 2\epsilon_n)$ is not small for both states.

Figure captions

Figure 1. Surface resistance of Pb at room temperature. The points are the experimental data. The solid curve is the Drude theory based on the experimental dc resistivity of the metal.

Figure 2. The frequency dependent response of the superconductor as calculated by Mattis and Bardeen. The energy gap is ω_g .

Figure 3. The difference in the surface impedance versus frequency for two kinds of superconductors. In each case the area below the gap is equal in magnitude but opposite in sign to that above the gap.

Figure 4. The reflectivity versus frequency of sintered $\text{YBa}_2\text{Cu}_3\text{O}_{7-y}$ in the normal state.

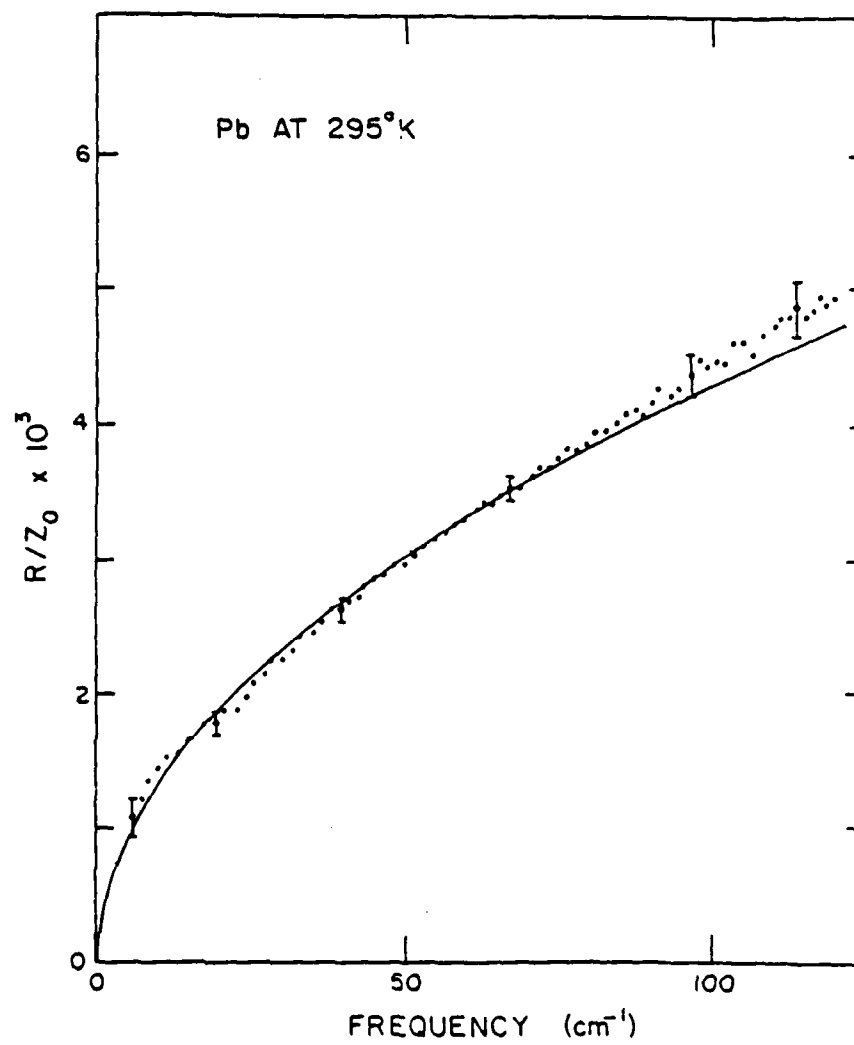
Figure 5. Normal incidence reflectivity of sintered $\text{La}_{1.85}\text{Sr}_{0.15}\text{CuO}_{4-y}$ in the superconducting (solid) and normal (dashed) states. (a) Experimental data. (b) Modeled with the EMA, a gap of $2\Delta/kT_c = 2.6$ and prolate shaped grains. (c) same but for oblate shaped grains.

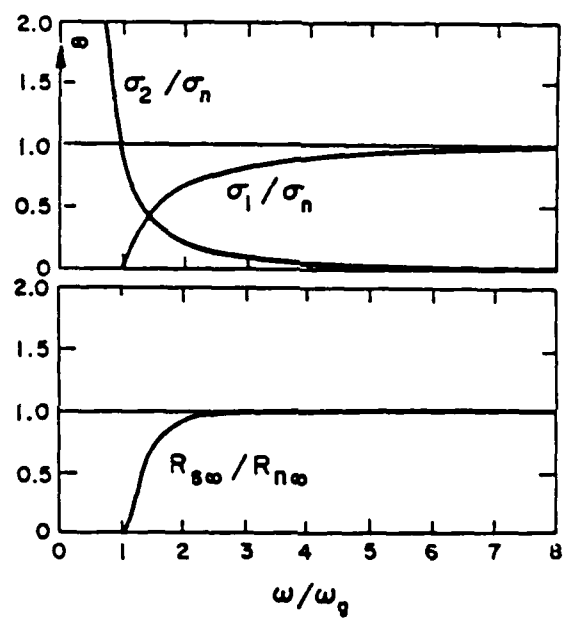
Figure 6. Comparison of the measured optical conductivity in the IR for three sintered copper oxide materials. The top two curves are for superconductors while the lower one is for a similar compound which is not superconducting. All three materials show a peak in the IR conductivity.

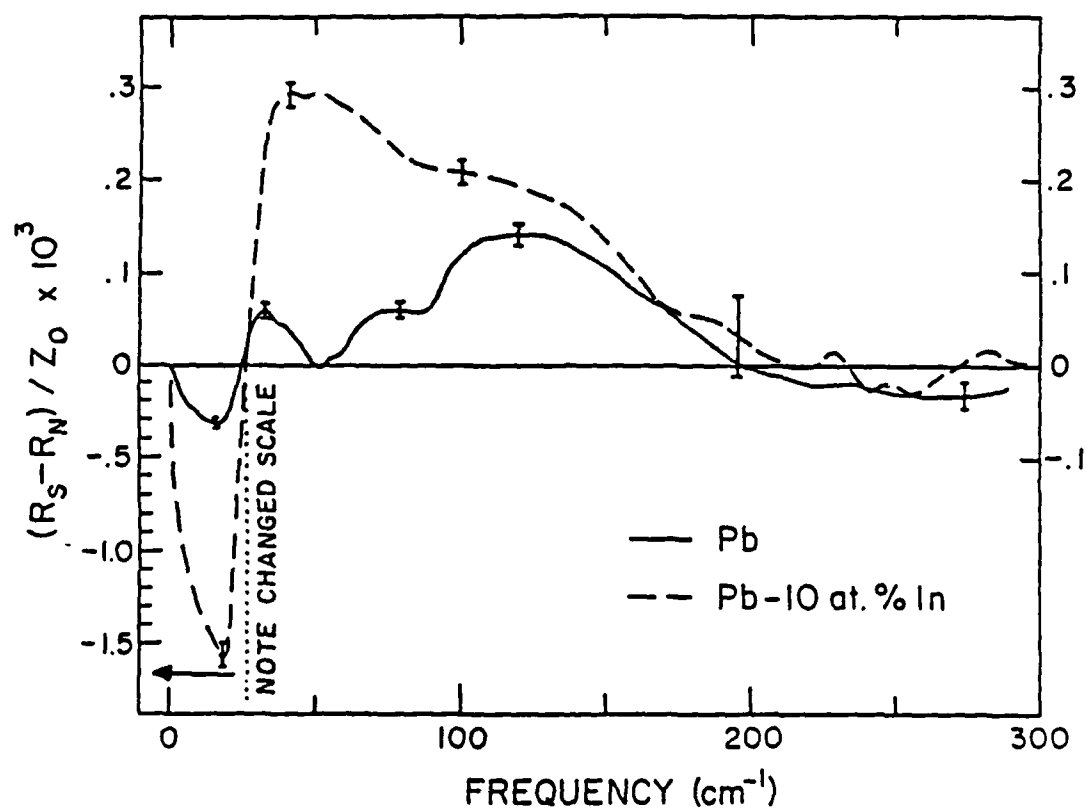
Figure 7. The measured ratio of the reflectivity in the superconducting state to that in the normal state for $\text{YBa}_2\text{Cu}_3\text{O}_{7-y}$. Dashed curves are fits to the data which are represented by solid curves. (a) Bulk sintered sample, (b) thin film, and (c) single crystal.

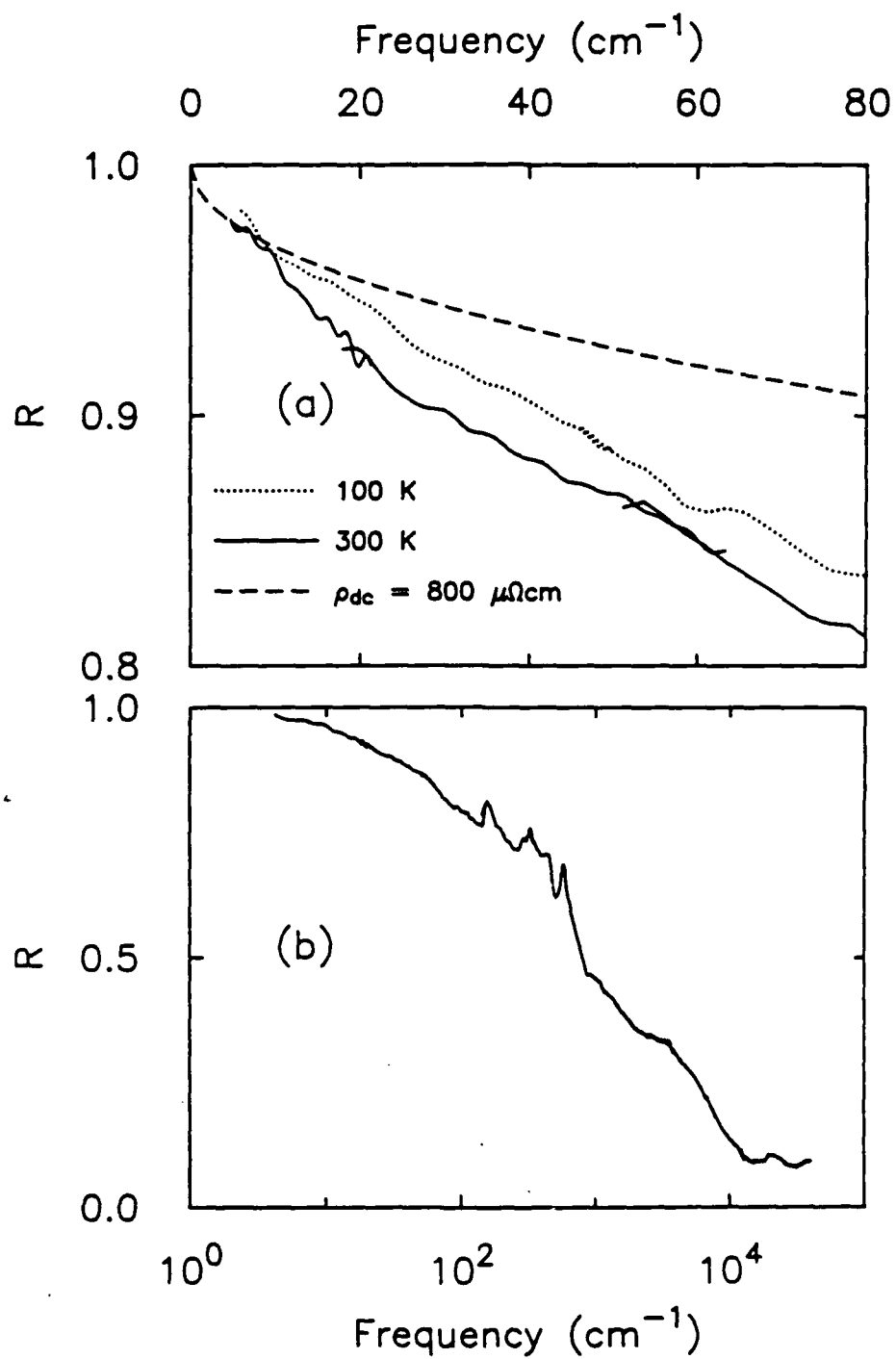
Figure 8. Absorption coefficient difference between the superconducting and normal state of small $\text{La}_{1.85}\text{Sr}_{0.15}\text{CuO}_{4-y}$ particles. (a) Experimental data. (b) Theoretical c-axis fit. The particle volume fill fraction is $f = 0.01$ in teflon.

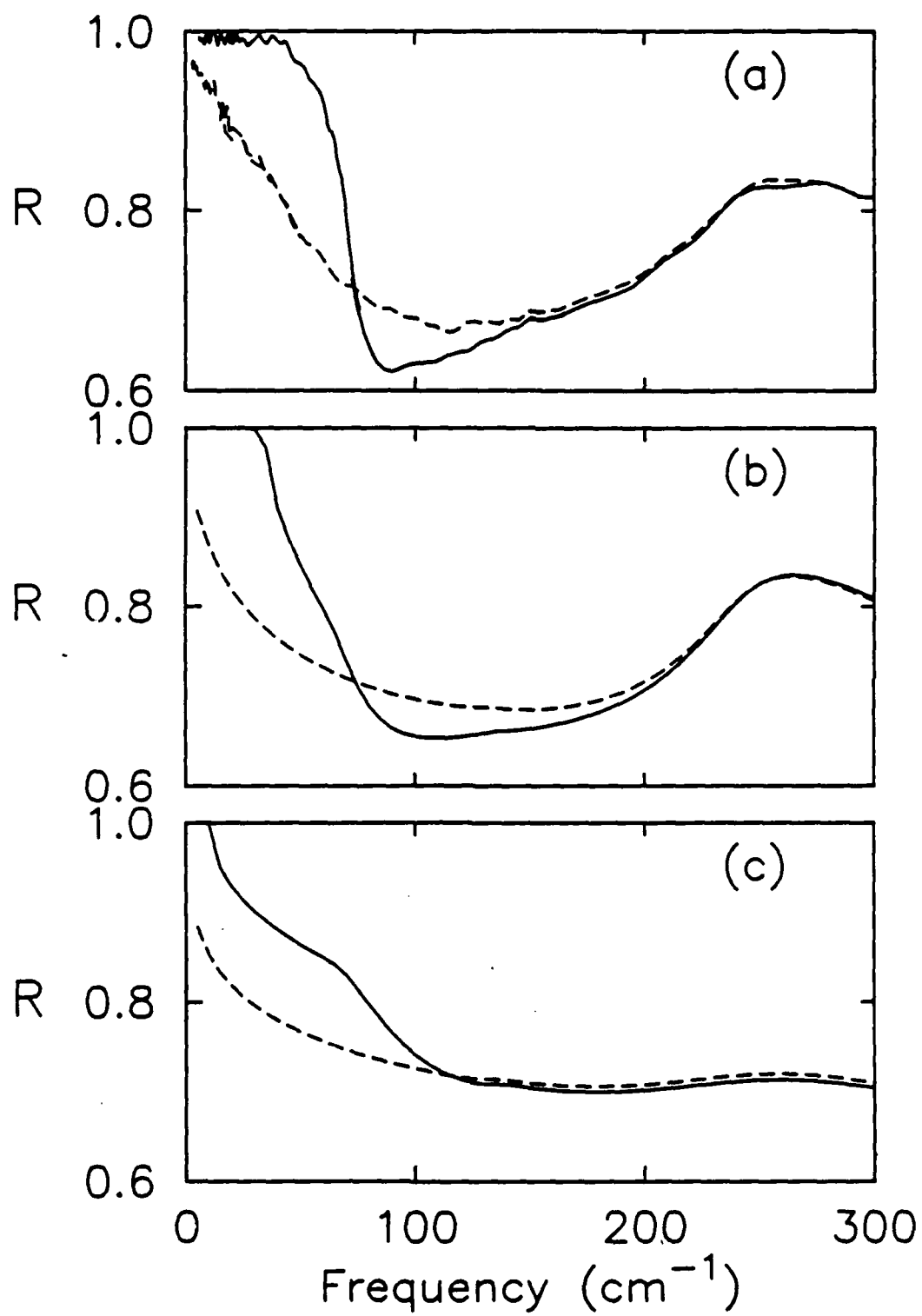
Figure 9. Dependence of the absorption coefficient difference for $\text{La}_{2-x}\text{Sr}_x\text{CuO}_{4-y}$ upon the Sr doping, x . The center frequency of the resonance increases with x , while the strength increases up to $x = 0.18$; no absorption lines have been observed in samples with $x > 0.2$.

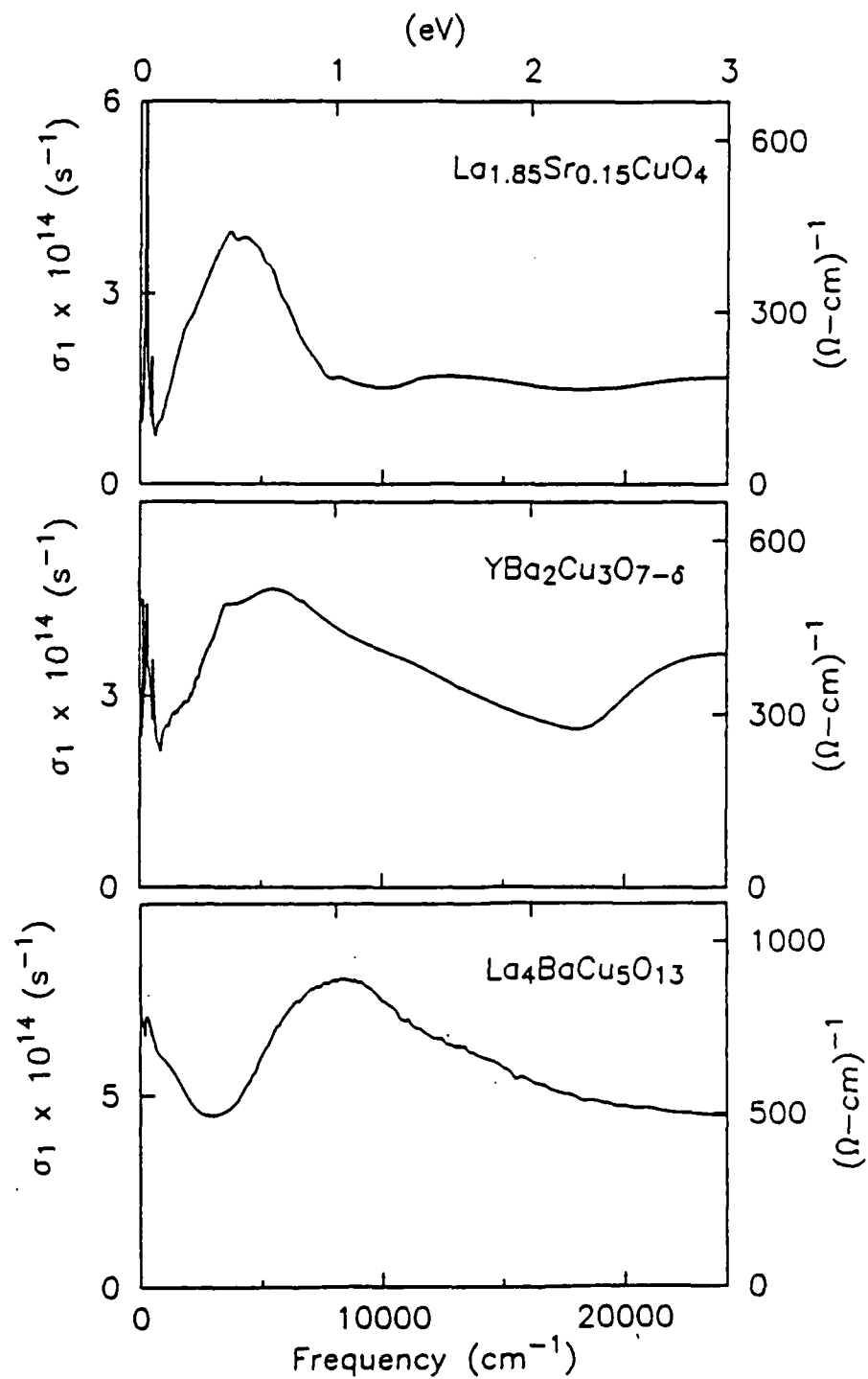


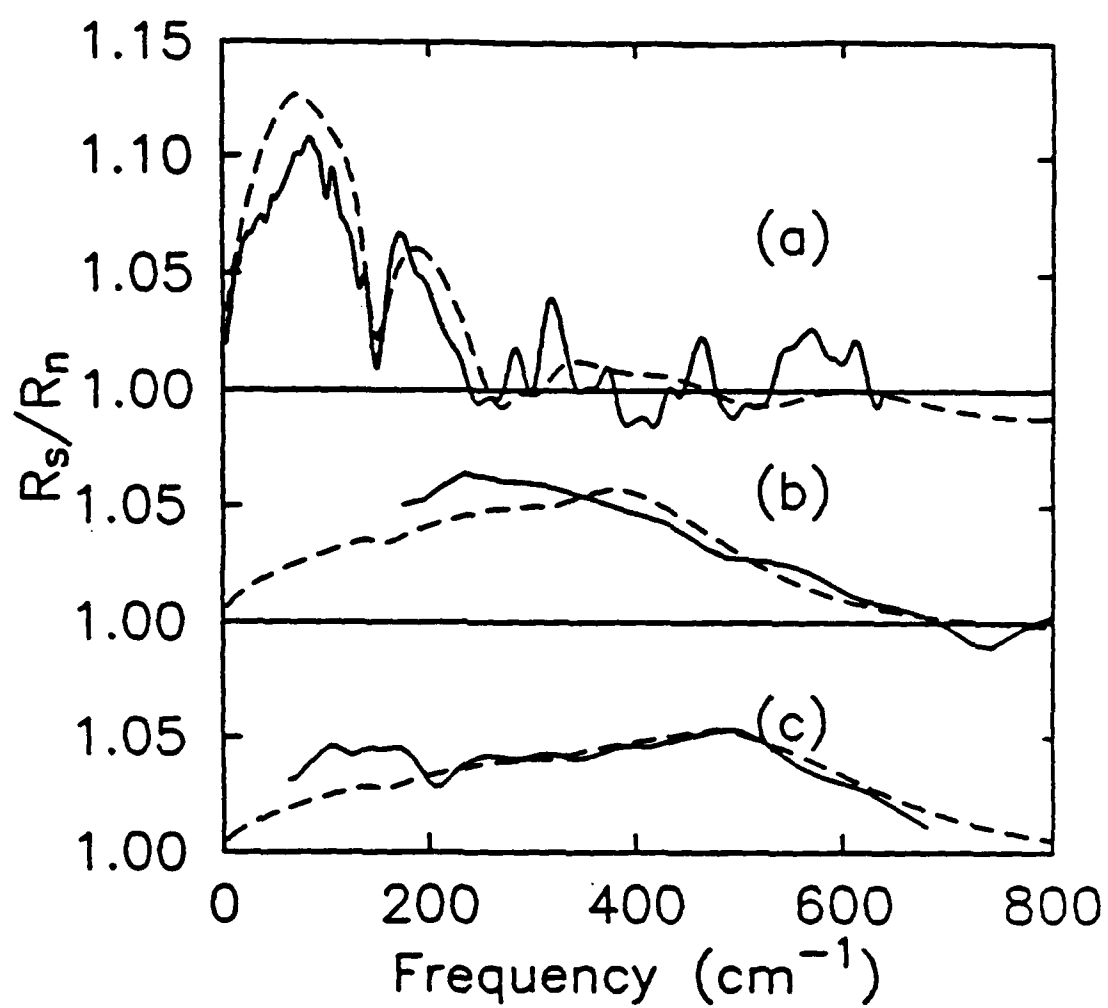


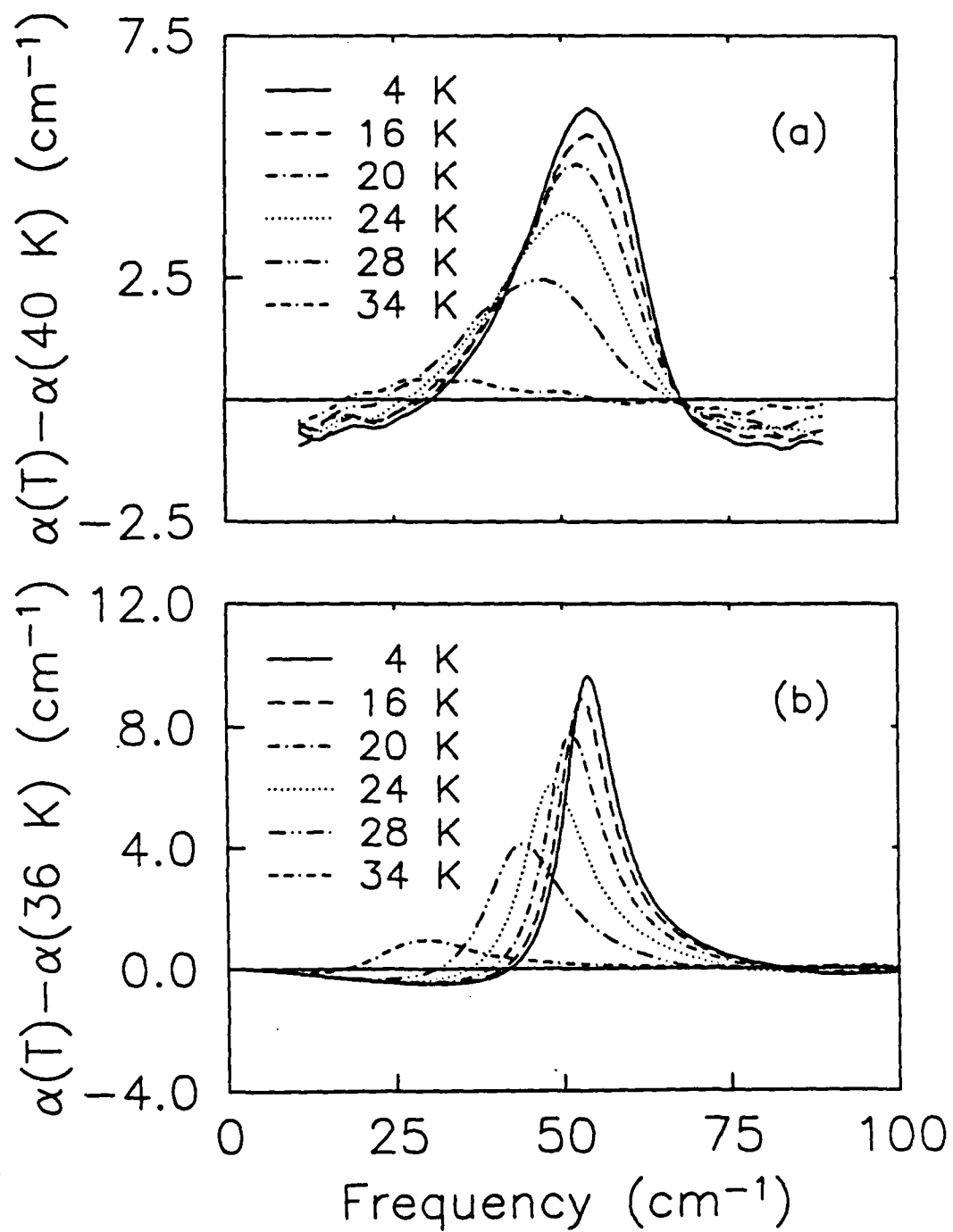


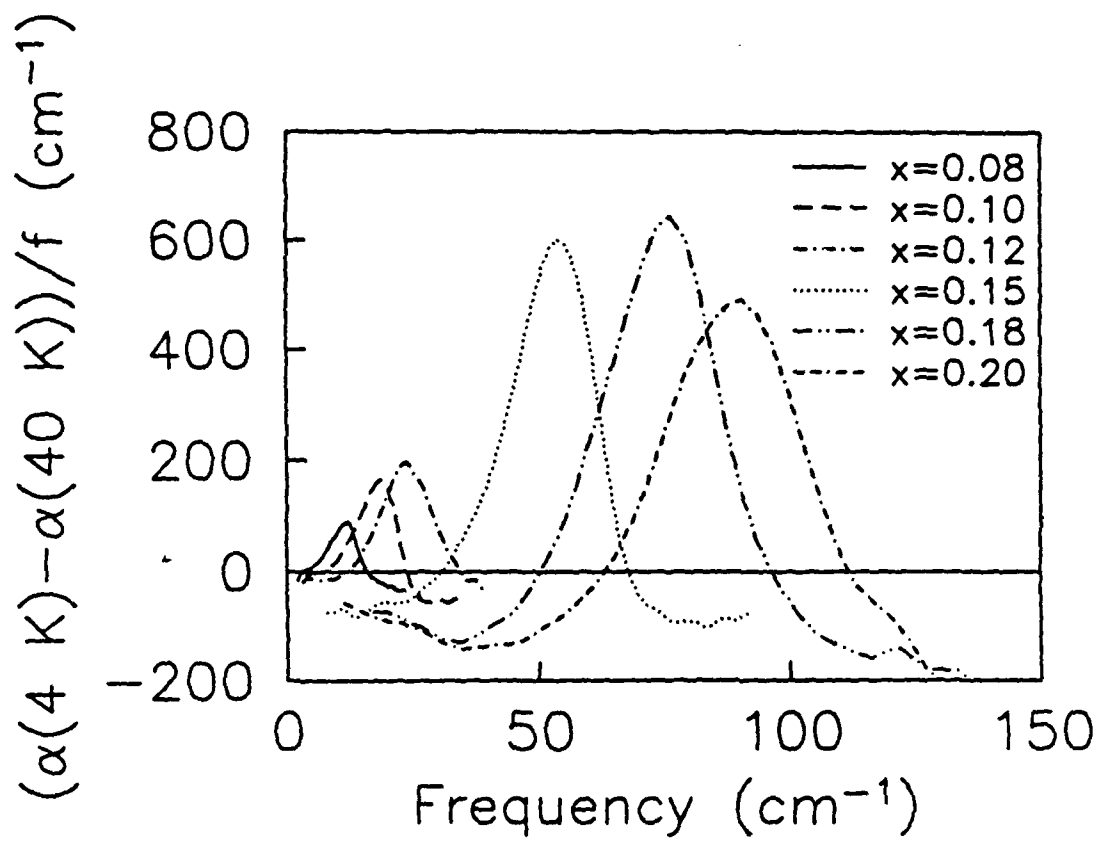












To Preserve and Defend: The Tech Base

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Keynote Address presented at the 16th Army Science
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Fort Monroe, Virginia

To Preserve and Defend: The Tech Base

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The title of my talk was chosen because I believe that it is no less than the sworn duty of every Army employee to preserve and defend the Tech Base. That is not, as we all know, an easy task. There are problems with getting an adequate budget, allocating it within the Army R&D community, and there are problems in defending the pace and the quality of the R&D work. Myths abound as to just what is the health of the Army's Tech Base—and the Nation's. We ought to look at some of these myths, because their currency has led some to advocate short term, "quick fixes". Some of these solutions are not only inappropriate, they are likely to exacerbate the real problems. Fortunately, the actual situation is definable and there are actions that you—among others—can take that will restore and strengthen the Tech Base. The cures will not be swift nor without some pain.

To begin, my choice of title: To Preserve and Defend, comes from the oaths we take on entering government service. These oaths recognize that the Constitution is the heart of the United States.

And let us recall the emphasis that those at the Constitutional Convention placed on technology. It was so important that it can be found in the First Article, along with the defense of the Nation.

In Article 1, Section 8, the Constitution speaks to "promote the Progress of Science and Useful Arts...". And a few lines later, the Congress is empowered

to "raise and support Armies¹", and after that, "to provide and maintain a Navy".

In reading the Constitution and recalling the history of the times, it is likely that the framers of the Constitution recognized the time to create and the capital investment needed to have a national Naval force, but probably did not think overly long about the technology involved. They certainly did not recognize any problem with calling forth an Army. After all, in those times the average citizen possessed or could quickly learn to use a level of firepower close to that enjoyed by professional troops. All that was needed, they must have felt, was a little time in which to arm the militia and give them a bit of close order drill.

Times change.

Outside this community, there is a perception that the Army's missions are static. But they are, in reality, ever changing and ever more complex. To maintain a credible deterrent to possible foes and to win swiftly and decisively any conflicts that may arise despite that deterrence, the Army must be maintained at an appropriate level. To do that, a dynamic Tech Base must exist, a Tech Base consistent, not only with the present but more importantly, with the future missions of the Army.

Since World War II, the United States has chosen to substitute technology for people in terms of its national defense programs. It has stressed strategic forces at the expense of tactical; nuclear over conventional.

¹It is interesting that the Army was treated to "two year money" from its very inception. It was much later that Congress decided that even research functions would be paid for with "one year money", thus handicapping long range research.

The emphasis on strategic and nuclear forces follows from the fact that while nuclear weapons and their delivery systems are expensive, the cost is nowhere near that of a comparably capable deterrent that consists solely of standing conventional forces. While the public perception is that the emphasis has been entirely on strategic technologies at the expense of tactical, we know that not to be entirely true. The level of technology found in the present Army is comparable to that found in the Navy and Air Force. If Divisions were as discrete, as concentrated as aircraft carrier groups, say, it would be easier for the public to recognize how technology intensive is their Army.

Thus the DOD, including the Army have come to depend upon a dynamic technology base. Were it necessary today to rewrite Article 1, the words ought to be to empower Congress to "raise and maintain" all branches of the defense establishment. And there would continue to be that juxtaposition of technology and national defense.

Hence, my thesis that all of us are obligated to work to preserve and defend the Tech Base.

The first battle for the Tech Base is the budget battle.

The large and recurring national investment in the Defense budget has led some to look at the funds spent in the DOD as a part of simply too much government spending. They argue that the fact that no major war is going on or has occurred means that we have at least a sufficient or overly large defense establishment. A more realistic attitude might be to consider the defense appropriation as though it were an insurance premium. If there are no conflicts in a year, then on September 30, at midnight, the protection afforded by the DOD premium has gone and it's time to renew that protection. While people gripe about the size of their auto insurance, they generally recognize that the potential liability of an accident is many times larger than

the premium. So they pay the bill. It is a pleasant thought, but the sums are too large for anyone to think of the military budget in the same class as liability or auto insurance.

So we have and always will have generic attacks on the DOD budget, simply because of its size. But there are also those with more specific complaints.

There are the anti-defense interests, and nothing short of pacifism and outright disarmament will satisfy them, so let's not worry about them any more—do the job and do it well and try to satisfy the rest of the people.

There are those who attack the budget because they want those sums for other purposes. They mount arguments that seem plausible on the evening news. The usual charge is that "if we do away with two Divisions, we will be able to take care of the research needs of a new air transportation system," or other comparisons. Statements like that ignore the reality of the way the budget is developed.

While we do start with a large pool of money, it is artfully divided in the Congress¹ in Authorization Hearings designed to implement various aspects of public policy. The environment, say, is accorded so many dollars and so many people to accomplish specific ends. Transportation similarly receives its share. And so on and so on, down to the DOD and, within it, the Army. Given that EPA, say, gets a certain number of dollars and a certain FTE, Congress determines through the authorization and appropriation process that a portion of the

¹I say, Congress, but we all recognize that the budget process is interactive between the legislative and executive branches. However, in recent times, the initial budget of the President has been so cheerfully ignored, my feeling is that we can credit (blame) Congress as the generator of the Federal Budget.

money given an Agency for its mission ought to go for a research and development function. And so on with the other departments, agencies, commissions, and administrations.

For those who believe that the Federal Research Budget gives too much to defense in general or the Army in particular, there is a problem: there is no such thing as a Federal Research Budget!

What is called the Federal Research Budget is the summation of all the myriad of Congressional/individual Agency decisions as to how to divide the resources given each agency into the functions that must be done, including research.

Thus it makes little sense to speak about raiding one Agency or Department's research funds for the benefit of another's. Only someone who does not understand how Congress sets policy can pretend to think that a reasonable trade. In truth, money that vanishes from an Agency's research budget is most likely to wind up as a middle class transfer payment—because that's the largest single item in the Federal Budget.

There are some who attack the military Tech Base because they do not like science or technology. While such have always existed, no doubt, it was not until the nineteenth century that they became very vocal, as the pace of technological change picked up. In the days of the Industrial Revolution, such people became known as "Luddites". Today Neo-Luddites oppose research and the development of new technology—any technology—on the grounds that such inventions produce new, bigger problems.

In response to that, let me note that a new technology does not enter the market unless it is the solution to a perceived problem. There is, unfortunately, no such thing as an absolutely benign innovation. Because of

that, any new process, gadget, product—what have you—increases the number of solutions , but at the same time it may also pose new problems.¹

Refusing to recognize their own responsibility to understand all the implications of new technology, the Neo-Luddites frequently join others in attacking military research and development.

Then there are those who appreciate new technology, even military, but feel that it is not the government's role to develop it. They say that such activities ought to be left to the private sector. While these people, usually in business, most frequently rail against the National Laboratories, they spare some time for the DOD research establishment.

As a part of this last, some observers have claimed that the DOD has inflicted a "double whammy" on the total U.S. technology base—that not only has the DOD attracted more than its share of scientists and engineers, thus depriving the rest of the economy of that talent, but also that defense R&D has little application to non-defense needs. Unfortunately for conventional wisdom, a recent report by the National Academy of Engineering² concludes that even during the Korean War (when the increase in defense expenditures was seven times larger than in the period 1980-85) and during the Vietnam buildup (when the increase was twice that in the early 1980s), defense and

¹Chlorine in drinking water acts on humus and other contaminants to produce chlorinated organics that can pose problems of cancer years hence. But the chlorine is put in the water to prevent immediate problems with diseases.

²**The Impact of Defense Spending on Nondefense Engineering Labor Markets**, Panel on Engineering Labor Markets, Office of Scientific and Engineering Personnel, National Research Council, National Academy Press, Washington,- DC (1986)

non-defense industries adjusted to the defense expansions with little or no major dislocations. This amazing resiliency is partly due to the the ability of our tech base to substitute between engineering and nonengineering labor and partly due to the fact that only about half the people trained in science and technology in the U.S. find employment in science or engineering.

As for the second point—that R&D in the defense sector has little chance of meeting non-defense needs—there may be more merit—but if so, it does not reflect well on U.S. non-defense industry.

With the possible exception of some battlefield-specific systems, defense R&D does produce scientific discoveries and technologies that could be useful outside the defense community. But U.S. industry's ability to carry any and all such work to the marketplace has declined, relative to its overseas competition. It is easier to blame the DOD for using resources to produce "inappropriate" results than to admit domestic business' failure to capitalize on those results for profit.

The R&D budget battle has tacticians within the DOD. As is the case with every other federal agency, there are those who offer up R&D as the sacrificial goat in the budget process. These people are well-intentioned; they know how important the R&D function is the the future ability of the agency to discharge its missions. But they believe that the Congress knows, too. So they propose cuts in 6.1, say, trusting that the sacrifice will not be accepted, thus leading to less severe cuts overall. Every so often, Congress does take the bait. R&D is such a tempting target. Because procurement expenditures are more spread out in time than those of R&D, there is a greater budgetary savings in chopping 6.1. And the harmful effects are not going to be obvious until far beyond the current budget year.

We turn now to the problems of a successful conclusion of the budget wars, successful in terms of the size of the pot given the Army for R&D. But that isn't the end. Our friends on the Hill, having specified the tasks, having allocated the resources (and one-year-money, at that), now proceed to micromanage the R&D process. Any engineer worth his or her salt knows how efficient is an over-constrained system.

Or they may insert control language in the Appropriations Bill.

By the way, sometimes the control language inserted in the budget process has far reaching, unintended effects. The Mansfield Amendment applied in only one year, 1971, and only to the Defense appropriation. Yet 12 years later, I was told by an Assistant Secretary at HUD that he could not fund that sort of a research program because of the "Mansfield Amendment!"

Once the money has reached the Army, it can be subjected to other flaws in the system.

Not peculiar to the Army, there is always the matter of the pacing of research, of how aggressively research ought to be pursued. There are research programs that are too timid. These are the ones that always succeed. The steps taken are small, small enough that success is assured. But they are so small that the progress is painfully slow, wasting time as well as money.

Then there are the research programs that are too bold, shortening the research phase to step into development. These are the "plan for success" programs as was the case with the Space Shuttle program. The often encountered flaw is that when success does not occur, research is done in the development phase at enormous increases in dollars and in overall time.

There are questions as to personnel.

Research and development is best done by those most competent. And they should be guided by those who understand the research and development

process. We have passed out of the era in which business believed that "a good manager can manage anything" into an understanding that it may be worth the loss of a good researcher if that is the only way to get a technically literate manager.¹ The late Nobel Laureate, Luis Alvarez, once remarked that "All new discoveries are made with marginal equipment by people working at the limits of their abilities."

The rewards and incentives accorded researchers within the Army are inadequate. That the Army does retain competent individuals is remarkable. The problem is not exclusively the Army's and is recognized. In response, Congress permitted an experiment in Science and Engineering Manpower within the past few years. The Navy's China Lake lab was one such. It has been cited as proof that that set of reforms ought to be adopted wholesale. A few observers have noted some flaws with the experiment, however. For instance in the so-called Merit Salary portion, the general satisfaction with raises based on merit and not time-in-grade may have been due to the fact that 95% of the researchers were found to be above average!

Currently, there is an understanding that taking twenty years for the fielding of a major new system may not be in the best interests of the Army. And there are attempts to shorten that development time.

By the way, there is a tendency to feel that our own problems are unique; that no one else has ever had these troubles and thus cannot understand them. Be of good cheer! The inability to get technology off the shelf and into the field is neither a new problem nor one restricted to the military!

¹Of course, if the result is not only the loss of a good researcher but also the creation of a bad manager, then one should rethink the transformation.

First, there were no "good old days". For example, during the Second World War, when the country was as fully mobilized to pursue a war as was possible, 59 distinct models of warplanes saw service. But what is seldom mentioned is that 54 of those models began their development before December 7, 1941!¹

And the problem exists in the private sector. Despite the advantages to the bottom line associated with new products, with the outstanding exception of the electronics industry, American businesses take their time in introducing new technology. For example, a typical lifetime for auto engines is 15 years. (That allows not only time for RDT&E, but also time to recapture the retooling and other capital costs associated with a radical new engine.)²

Teflon hit the market in a big way in the mid 1950s. But it was invented in 1938.

¹American Warplanes, Bill Gunston, Crescent Books, NY, NY (1986)

²Thus we can see the problems associated with Congressionally mandated marginal improvements in auto emissions—improvements every two years or so. The changes needed to meet the new standards are minimal, when considered each in isolation, and cannot justify a major change in the internal combustion engine (ICE). So the industry meets the standards by "Rube Goldberg", bucket-at-the-end-of-the-pipe modifications: PCV, spark and timing adjustment, catalytic converters, and the like. Of course, the problem with the ICE is that it is an intermittent combustion device and such systems are inherently dirty. The net effect of all the add-ons is to turn the intermittent combustion process into a continuous combustion system—but the continuity takes place outside the power chamber, adding not one Btu of efficiency.

Super conducting stator windings on large generators would increase efficiency an additional two or three percent—a large enough amount that the system is economic even with the present super conducting materials that require liquid helium cooling. None have been installed anywhere.

In an effort to resolve the lengthy process of R, D, T & E, and fielding, there has been an emphasis on NDI. The reasoning is that the technology is "there," "there" being the non-DOD side of our society. While I applaud the shifts in emphasis that now favor NDI in the ARs, I have two cautions. The first is that it is not sufficient to rely on the Regs; the people involved must feel that it is to their benefit to implement them. The second is that once that millennium has arrived, and NDI procurement is routine, it is likely to be revealed as a short term solution.

An analogy might be found by looking at a natural gas field, the pipeline from there to the city, and the city filled with consumers of natural gas. Faced with a shortage of natural gas at the load end, solution is to increase production to match the increased rate of flow and consumption. And so it is with technology. NDI can give us needed help now, but in the long term we must count on the total Tech Base.

Before we discuss ways to improve the Tech Base, let us not forget that the Army's Technology Base resides within a broad range of institutions.¹ Any proposals aimed at strengthening the Tech Base must not do so by bolstering some of the institutions at the expense of others.

Some resources may always have to be used only indirectly by the Army, forever denied to direct control by the internal research managers. For

¹The Defense Technology Base, Office of Technology Assessment, United States Congress, (March, 1988)

instance, more than half of the graduate students at UC-Berkeley in Electrical Engineering and Computer Science are non-US citizens. Thus they are unlikely to be able to enter directly the military-housed Tech Base centers, but they may be capable contributors to Army Tech Base needs through the civilian sectors. The situation at Berkeley is representative of the nation as a whole, and unlikely to improve any time soon.¹

We do have problems with the Tech Base.

So what is to be done?

The first is that you have a firm understanding that the Tech Base is of absolute importance for the continuing function of the United States Army and that you communicate that understanding.

And a part of that is the critical need for military R&D to bolster the military Tech Base.

There is no harm in the admission that good DOD basic research may not yield a technology harvest for military needs for years or may even benefit the non-military Tech Base. It is true and it is nothing to be ashamed of.

But don't allow that fact to lead to another Mansfield Amendment. Resist all efforts to blame the Army and the DOD for the ills that have beset American industry and its laggard performance as compared to some other countries.

¹ And how did it come about that so few US citizens stay on for graduate degrees? One answer is the salary compaction that now exists for PhDs versus Bachelors. But another is the shrinking of direct Federal support for graduate students: In 1966 there were over 50,000 graduate students supported by Federal Fellowships and Traineeships, not counting the NIH Traineeships. Today there are barely 2,000 so supported.

Relieve the acquisition pipeline problem by being smart buyers of off the shelf technology. That includes avoidance of the bells and whistles, the full MilSpec, or unneeded ruggedizing where the civilian product can be purchased in enough quantities that redundancy can substitute for survivability.

Seek stability in the budget process. Lean periods followed by crisis-generated booms wreak havoc with long term research. The best situation may well be a monatonic, gradual growth. But if you can't get that, try to even out the bumps for your extramural programs. Such programs should never be used as the dead man to balance things for the inhouse programs. To do so risks turning off the outside community so that they won't be interested in working on the Army's problems—and they are a potential constituency in the budget wars, as the USDA discovered long ago.

Finally, take care of yourselves.

Seek the best use of dollars and people. You won't always be rewarded for being good managers of resources, but you will certainly suffer for bad management.

Do not hold up China Lake as the only solution to the S&E manpower problem. Get permission to redo the experiment at several locations with variations. Report honestly on the failures and combine the features that seem to work best. Face the fact that there may be no generally applicable S&E personnel rules. If so, seek the best ones for specific locations. We have attempted to retain good researchers far too long by using a combination of giving them work on interesting problems and by appeals to their patriotism.

Of course, the reason for restructuring S&E personnel policies is to seek and maintain competent technical people. There must be resident competence throughout the Army's R&D establishment. That includes career officers who

TALLEY

have had bench experience. And by career, I mean ultimately seeing Army Generals with PhDs in engineering and science.

To conclude, your role in taking care of the Tech Base goes beyond scratching an intellectual itch. We ought to view it as an obligation, a discharge of the oath that we take when we join government service.

An Overview of Biotechnology

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Theme Presentation presented at the 16th Army
Science Conference 26 October 1988, 1100 hours,
Fort Monroe, Virginia.

AN OVERVIEW OF BIOTECHNOLOGY

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This paper reviews major methodological advances in molecular biology and immunology and cites examples of their current and future applications. Beginning with recombinant DNA in the early 1970's (1), monoclonal antibodies in 1975 (2) transgenic animals in the early 1980's (3) and the polymerase chain reaction in 1985 (4) these methods have had a profound impact on basic research in biology and are having an increasing role in the development of new products in the pharmaceutical, diagnostic and agricultural industries.

Figure 1 illustrates the basic concept underlying recombinant DNA (rDNA). Such techniques are in common use in university, government and private laboratories and have already led to a variety of drugs and vaccines which have been approved for medical use by the Food and Drug Administration (Table I). Although some of the earliest applications of rDNA were to make the human equivalents of some drugs previously isolated from animal tissues or bacteria (e.g. insulin, streptokinase) more recent efforts have been directed toward making components of the human immune system to test as potential new therapeutics. Figure 2 is a simple scheme showing the origin of the white blood cells in the immune system and lists some of the proteins which either regulate aspects of immunity (e.g. interleukin-2) or are responsible for resistance to disease (e.g. antibodies or interferons). This approach has identified several potentially useful new drugs which are currently undergoing clinical testing for safety and efficacy (Table II).

The second method to have a substantial impact on medicine was the discovery of a way to produce a purified antibody having a unique specificity. These monoclonal antibodies are made as shown in Figure 3, and have been used to suppress organ rejection following transplantation (Table 1) and for the treatment of septic shock (Table II; see also work done by Jerry Sadoff elsewhere in this volume). Another medical application of monoclonal antibodies is based on using their exquisite specificity to target a potent cellular toxin to kill cancer cells (5). Figure 4 illustrates this approach which has shown promise in the treatment of melanoma and certain leukemias. Monoclonal antibodies have also been widely used as reagents in sensitive diagnostic tests such as those which can directly detect pathogens (chlamydia, gonorrhea, and herpes viruses) in clinical specimens.

Transgenic animals are a more recent technique that allow scientists to put foreign genes into the germ line of an animal (Figure 5). It's most dramatic illustration resulted from the transfer of a gene for growth hormone into a mouse (6) and its subsequent abnormal growth (Figure 6). Potential medical applications include the development of better animal models for cancer or AIDS. For basic studies of developmental biology, it is possible to put

the gene for a cellular toxin into an embryo where it is under the control of a regulatory element that turns it on at a specific stage in the development of a tissue (7). This facilitates the study of certain cell lineages. Transgenic animals include cows, which can produce the drug Factor IX for hemophilia in their milk, and chickens which can be made resistant to infection by certain viruses. An analogous technique in plants (8) confers resistance to insect predation by producing a species-specific insect toxin in the plant leaves (Figure 7).

In 1985 a new method was described, the polymerase chain reaction (PCR), which has had a revolutionary impact on molecular biology and disease diagnosis. The method permits the in vitro amplification of a specific DNA fragment or gene in a few hours, thus producing millions of copies of it for further analysis (Figure 8). The technique can amplify a single molecule of a gene in a complex mixture of total human DNA and is being widely used for the diagnosis of genetic diseases (Table III). It is also finding increasing use for the diagnosis of cancer and for the forensic identification of individuals in criminal and autopsy cases (9). Because of its sensitivity, PCR can be used with degraded DNA from minute samples of bone, blood or single hairs and will find increasing application in situations requiring identification of missing persons, e.g. the children of "disappeared" parents in Argentina.

The various applications of the methods described above will also have medical, diagnostic, prophylactic and forensic value to the defensive role of the military services (Table V). Others have proposed or opposed potential defensive and offensive applications of these technologies (10,11,12). In my experience, molecular biologists don't talk much about biological warfare. It is a taboo subject; genetic engineers don't like to imagine themselves as contributing to a new arms race. But more than that, they rarely think about BW; the subject has not been of fundamental scientific interest. Both proponents and opponents of military uses of biotechnology have argued that biological weapons could be the preferred choice over other relatively more effective weapons such as explosives or even outlawed chemical weapons because biological weapons can't be detected. Both sides have also contended that advances in biotechnology have made the 1972 BW Convention obsolete. A contrary notion is that germ warfare is ineffective relative to other ways of killing people or destroying economies and that while recombinant DNA conceivably could make "better" bugs or toxins or make them more efficiently, it really doesn't alter the strategic and technical reasons for not using them.

In my opinion the recently published book Gene Wars gives a realistic assessment of BW and of biotechnology's potential impact - both technical and perceived. Pillar and Yamamoto have done a superb job of researching the history and use BW with natural pathogens and of speculating on the feasibility and likelihood of biotechnological improvements. For this reason alone, the book is worthwhile reading for any scientist who might wish to assess the potential contribution of recombinant DNA to another arms race. The authors encourage molecular biologists to oppose government efforts to restrict the transfer of plasmids, reagents and equipment, to classify certain research and to portray the BW Convention as obsolete in order to justify a biological weapons program. On these topics Gene Wars intelligently derives and then destroys conventional wisdom about the utility of BW and offers a realistic appraisal of the allegation of a new BW threat to national security.

Gene Wars nonetheless contains significant flaws. It exaggerates the difficulty of detecting BW agents by emphasizing the ease of manipulating antigenic variability. There are several obvious, simple and practical approaches to overcoming this obstacle based on targeting a limited number of conserved or essential segments of genes, toxins or virulence factors. Unfortunately, the authors give unnecessary credence to undetectability as a rationale for developing BW.

The book also overstates the argument that the only difference between defensive and offensive BW research is intent. Thus, they imply there is no credible reason for supporting the development of vaccines or therapies for exotic diseases. But many scientists would maintain that there's a considerable difference between experiments designed to eliminate virulence genes from a pathogenic virus in order to make an attenuated vaccine and experiments which might enhance virulence. Furthermore, Pillar & Yamamoto's argument could be extended to prohibit work on an AIDS vaccine or cancer therapy, since both could conceivably make HIV or cancer viruses potential weapons. The authors' point about defensive research is more compellingly stated in the context of their proposal that there's no reason for the military to fund such vaccine work.

Another weakness is that the book mythologizes the bogeyman of the small biotechnology company that sells itself to BW in order to keep afloat financially. The authors go out of their way to maintain this sinister contrivance; after a long list of academic violations or avoidance of NIH guidelines for rDNA (UCLA, UCSD, Wistar, Oregon State University) they quote David Kingsbury "we must be overregulating and pushing companies to test their

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products overseas"

No book on the government-military-corporate-academic complex is complete without a good conspiracy theory. But Gene Wars confuses examples of potential economic conflict of interest with actual wrong-doings. The book's low point is reached when the authors state that any scientist who does basic vaccine or therapeutic research with military funding is intentionally ignorant or naive. Despite these weaknesses Gene Wars is well written and many of its recommendations should be actively supported by scientists and their societies, institutions and companies.

In this short article I have tried to summarize some of the recent advances in biotechnology which are having a profound impact on basic research and its applications in medicine, agriculture and the military. The opinions expressed herein are my own and do not reflect the opinion on policies of Cetus Corporation or any other individual or institution cited in the article.

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FIGURE LEGENDS

- Fig. 1. The cloning of DNA in a plasmid (with permission from reference 13).
- Fig. 2. The cells of the immune system. TNF: tumor necrosis factor; CSF-1: macrophage colony stimulating factor; IL-2; interleukin-2.
- Fig. 3. The production of monoclonal antibodies.
- Fig. 4. The action of an immunotoxin.
- Fig. 5. The introduction of foreign genes into fertilized mouse eggs (with permission from reference 13)
- Fig. 6. A normal mouse and a transgenic mouse which overexpresses a gene for growth hormone (with permission from reference 13)
- Fig. 7 Transgenic cotton plant leaves which express B+ toxin (left) and cotton loopers (with permission from Winston Brill, Agracetus)
- Fig. 8 The polymerase chain reaction
- Fig. 9 Military applications of biotechnology

APPROVED THERAPEUTICS

AND VACCINES

<u>Drug</u>	<u>Disease</u>
Human Insulin	Diabetes
Growth Hormone	GH Deficiency
Tissue Plasminogen Activator	Acute Myocardial Infarction
Interferon	Hairy Cell Leukemia
Erythropoietin	Anemia, Renal Failure
KT3 Monoclonal Antibody	Kidney Transplant Rejection
Hepatitis B Vaccine	Hepatitis B

DRUGS IN CLINICAL TRIALS

<u>Drug</u>	<u>Disease</u>
TPA	Stroke, Pulmonary Embolism
G-CSF	Aplastic Anemia
GM-CSF	Chemotherapy-Toxicity
Superoxide Dismutase	Reperfusion Injury
Interferon Gamma	Venereal Warts, SCLC
Interleukin-2	Renal Cell Carcinoma, Malignant Melanoma
	SCIDS
Anti-LPS Monoclonal	Septic Shock
Malaria Vaccine	Malaria
Factor VIII C	Hemophilia
Epidermal Growth Factor	Eye Surgery, Wound Healing

TABLE II

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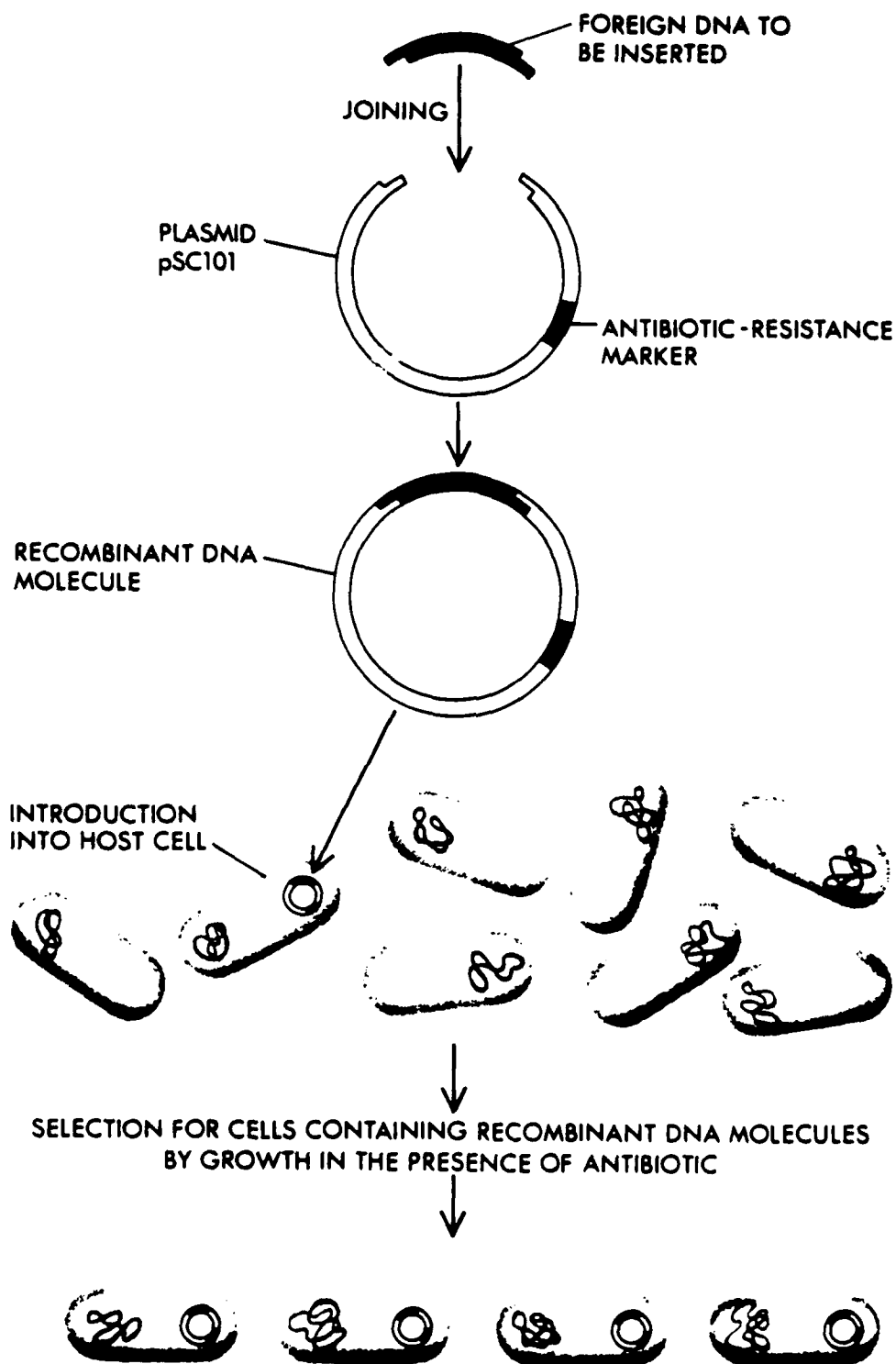


Figure 1
The cloning of DNA in a plasmid.

FIGURE 2

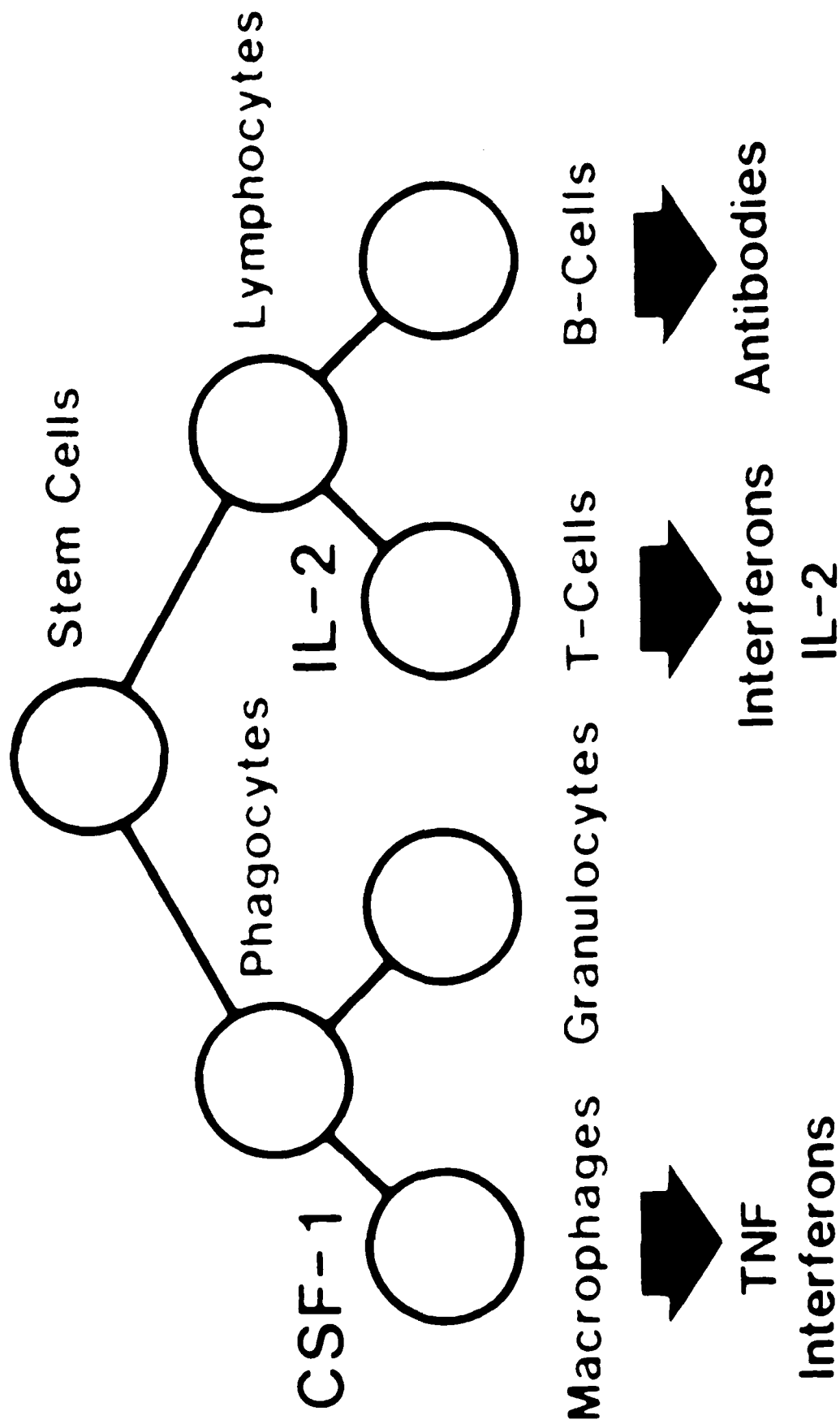


FIGURE 3
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**Tissue or Cells with Specific
Antigenic Determinant(s)**

Crude Antigen Prep

Inject Mouse

Remove Spleen and Disaggregate

**Add TK⁻ Myeloma and
Hybridize (PEG)**

Clone in HAT

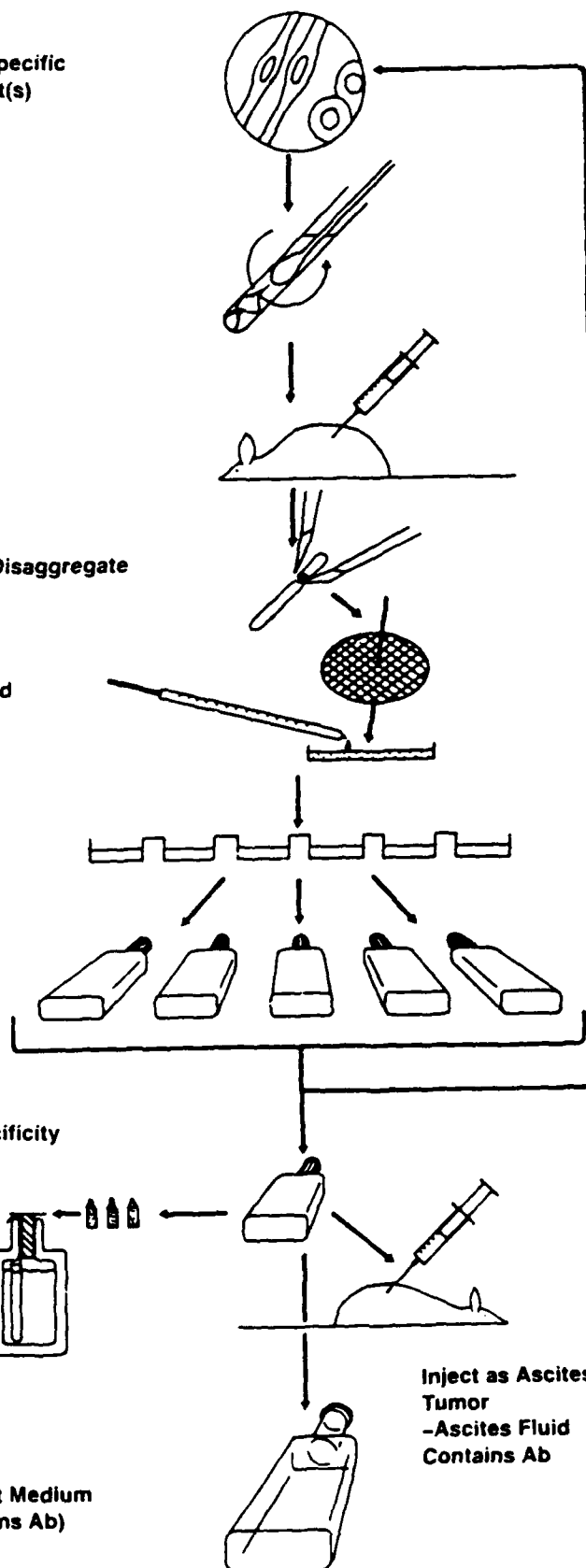
**Isolate Clones and
Grow Up**

**Test for Antibody
Production and Specificity**

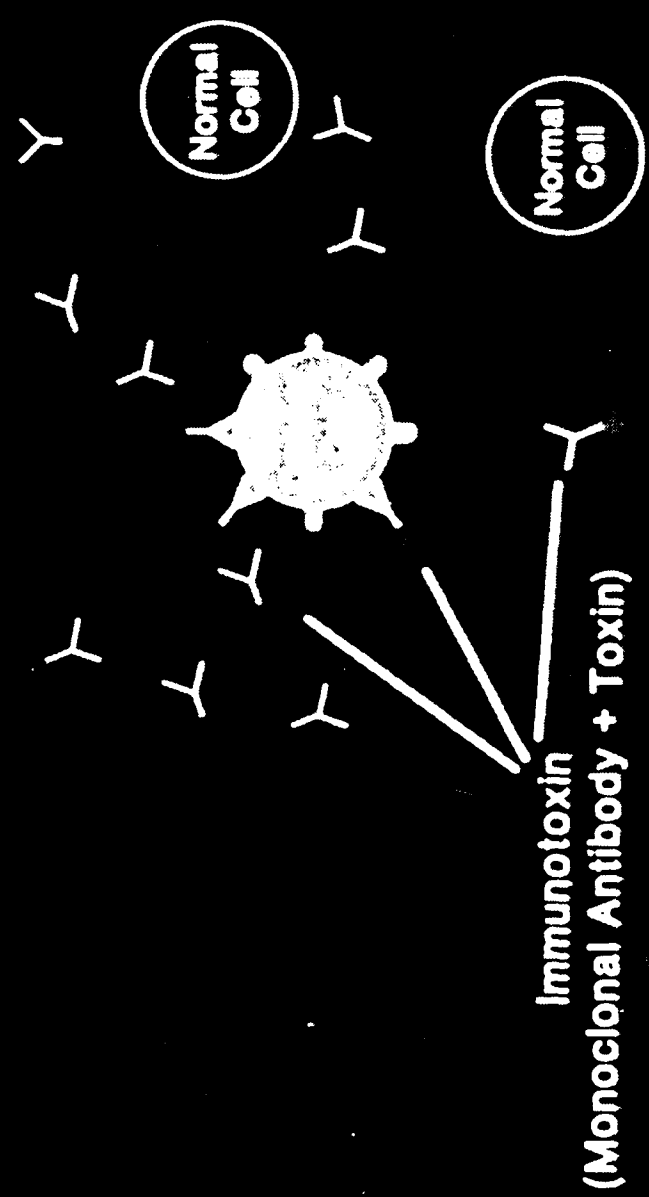
**Select Clones
Grow Up and
Freeze**

**Grow Up and Collect Medium
Supernatant (Contains Ab)**

**Inject as Ascites
Tumor
-Ascites Fluid
Contains Ab**



ACTION OF IMMUNOTOXIN



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FIGURE 4

FIGURE 5

THE INTRODUCTION OF FOREIGN GENES INTO FERTILIZED MOUSE EGGS

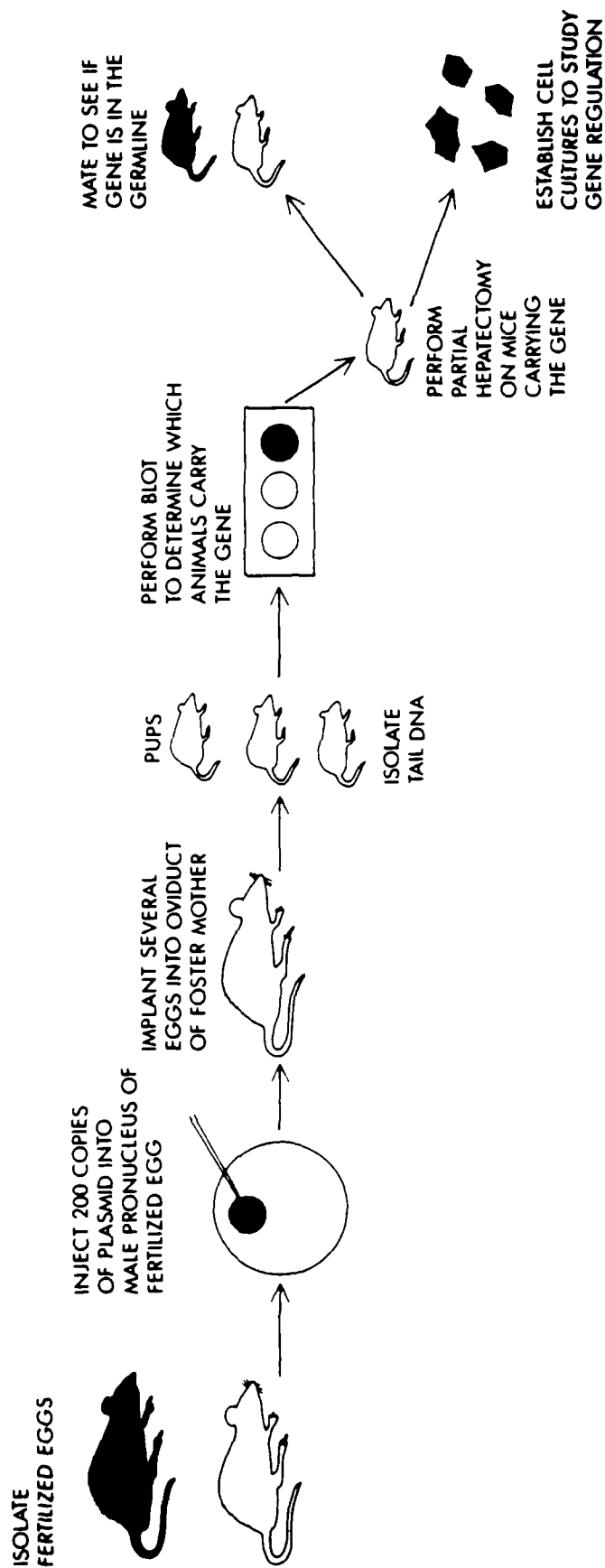


Figure 16-1
Microinjection of cloned genes into mouse embryos.

Recombinant DNA

A Short Course

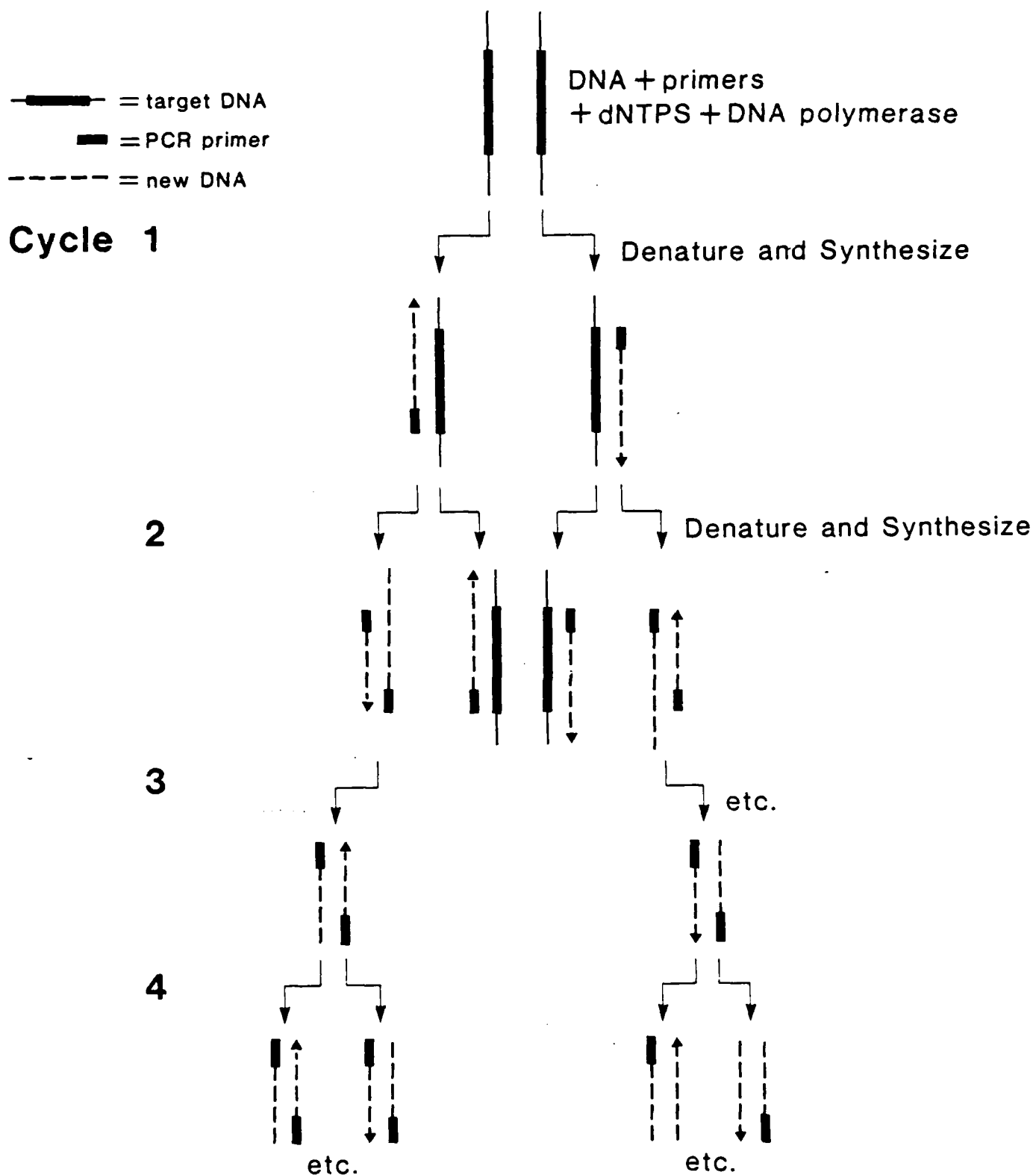
James D. Watson

John Tooze

David T. Kurtz

FIGURE 7
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MILITARY APPLICATIONS

Defensive

Therapy

Vaccines

Rapid Diagnosis

Forensics

Examples

Anti-sepsis Monoclonal

Malaria

Infectious Agents

Individual Identification

Offensive

"Improved" Pathogens?

Toxin Production

Honorable Jay R. Sculley

Assistant Secretary of the Army
(Research, Development and Acquisition)

Banquet Address prepared for presentation for the 16th
Army Science Conference 27 October 1988, 1900 hours,
Fort Monroe Virginia.

REMARKS

BY THE

HONORABLE JAY R. SCULLEY

ASSISTANT SECRETARY OF THE ARMY

(RESEARCH, DEVELOPMENT AND ACQUISITION)

AT THE

ARMY SCIENCE CONFERENCE

U. S. ARMY TRAINING AND DOCTRINE COMMAND

FORT MONROE, VIRGINIA

(THURSDAY, 27 OCTOBER 1988)

SCULLEY

GOOD EVENING, LADIES AND GENTLEMEN.

IT IS A PLEASURE TO BE WITH YOU ON THIS OCCASION. THIS IS MY FOURTH BANQUET AT THE ARMY SCIENCE CONFERENCE. THE THEME, "SCIENCE - THE COMPETITIVE EDGE" COULDN'T BE MORE APPROPRIATE OR MORE TIMELY. AS THE PROSPECT OF GLOBAL PEACE AND NUCLEAR DISARMAMENT LOOKS THE STRONGEST IT HAS EVER BEEN, THE EMPHASIS ON DETERRENCE THROUGH TECHNOLOGY SUPERIORITY BECOMES PARAMOUNT. SUPERIOR TECHNOLOGY, APPROPRIATELY EMBEDDED IN OUR WAR FIGHTING SYSTEMS, IS THE CORNERSTONE OF OUR NATIONAL SECURITY, THROUGH STRONG DETERRENCE ON ALL POTENTIAL FRONTS AND FORMS OF CONFLICT. IT IS THROUGH THE DECISIVE EDGE OF OUR SCIENTIFIC KNOWLEDGE THROUGH BASIC RESEARCH THAT SUCH A SUPERIOR TECHNOLOGY BASE IS FIRMLY ASSURED AND EFFECTIVELY APPLIED. IN PURSUING THE TECHNOLOGICAL COMPETITIVE EDGE, IT IS IMPORTANT THAT I, AS THE ARMY ADVOCATE, AND YOU AS CONTRIBUTORS REMAIN AWARE THAT THERE ARE LARGE ISSUES INFLUENCING FORWARD MOMENTUM.

ONE MAJOR ISSUE IS THAT ARMY AND DOD SENIOR OFFICIALS ARE OFTEN PREOCCUPIED WITH MAJOR SYSTEM ACQUISITION DECISIONS. THIS FOCUS IS UNDERSTANDABLE IN LIGHT OF THE HIGH COST AND VISIBILITY OF MAJOR SYSTEMS. THE OTHER MAJOR ISSUE IS THAT THE DECISION MAKERS AND OTHER INFLUENTIAL PEOPLE ARE NOT ADEQUATELY EXPOSED TO OR KNOWLEDGEABLE ENOUGH OF THE NATURE AND PROCESSES OF SCIENCE AND TECHNOLOGY TO FULLY APPRECIATE THEIR IMPACT ON THE AVAILABILITY AND RELIABILITY OF THOSE HIGHLY VISIBLE SYSTEMS.

ESSENTIAL TO MY ADVOCACY ROLE IS ENLIGHTENING THE ARMY COMMUNITY AND RECOGNIZING THE CENTRAL ROLE YOU HAVE PLAYED. TONIGHT, I'D LIKE TO RECALL A FEW EXAMPLES OF THE MANY IMPORTANT CONTRIBUTIONS YOU HAVE MADE DURING THE LAST DECADE. THE 1980'S HAVE SEEN SCIENTIFIC ADVANCES ON ALL FRONTS FROM IMPROVEMENTS IN SURVIVABILITY, HEALTH AND WELL BEING OF THE SOLDIER, TO SIGNIFICANT ENHANCEMENTS TO OUR WARFIGHTING SYSTEMS.

IN THE BIOMEDICAL ARENA:

OUTSIDE INFLUENCES HAVE SERVED AS THE STIMULUS FOR MANY OF THE ACCOMPLISHMENTS AND PRODUCTS OF ARMY MEDICAL RESEARCHERS OVER THE LAST DECADE. SUCH A STIMULUS WAS THE ACCIDENTAL RELEASE OF ANTHRAX SPORES FROM A SOVIET BIOLOGICAL LABORATORY IN 1979; ANOTHER WAS THE EMPLOYMENT OF TACTICAL TOXIN WEAPONS IN SOUTHEAST ASIA AND AFGHANISTAN IN THE LATE 70'S AND EARLY 80'S. THESE SUBSTANCES HAVE HELPED US ANTICIPATE AND DEFINE THE BIOLOGICAL THREATS OF THE FUTURE.

IN THE LABORATORY, UNPRECEDENTED PROGRESS IN THE UNDERSTANDING OF THE INTERNAL FUNCTIONS OF LIVING CELLS, THE MOLECULAR BIO-MECHANISMS AND THE DEVELOPMENT AND USE OF MICROPROCESSOR-CONTROLLED INSTRUMENTS, SIGNALLED THE BEGINNING OF WHAT SOME HAVE CALLED THE BIOTECHNOLOGY REVOLUTION. HOWEVER, THIS KNOWLEDGE HAS AGGRAVATED AND CONFUSED THE THREAT PICTURE BY ENABLING THE CONCEPT OF DESIGNER BIOLOGICAL WARFARE (BW) AGENTS. THE GOOD NEWS IS THAT THEY ALSO

SCULLEY

POINTED THE WAY TO DRAMATIC NEW PROGRESS IN THE EFFORT TO PROTECT AGAINST NATURALLY OCCURRING INFECTIOUS DISEASES THAT CAN INCAPACITATE OUR SOLDIERS.

ON AVERAGE IN WORLD WAR II, KOREA, AND VIET NAM, CASUALTIES DUE TO DISEASE OUTNUMBERED BATTLE INJURIES TEN TO ONE. THESE CASUALTIES CAN BE REDUCED WITH THE DEVELOPMENT OF NEW VACCINES AND CHEMOPROPHYLAXIS.

PROGRESS IN DEFENSE AGAINST THOSE NATURALLY OCCURRING INFECTIOUS DISEASES HAS BEEN DRAMATICALLY IMPROVED BY THE NEW METHODS. GENETIC ENGINEERING, FOR EXAMPLE, ALLOWS ISOLATION OF THE GENE OR GENES THAT CODE FOR PRODUCTION OF THE IDEAL IMMUNIZING COMPONENTS, AND THE TRANSFER OF THESE GENES INTO ORGANISMS THAT CAN BE EASILY, SAFELY AND CHEAPLY GROWN IN LARGE QUANTITIES. IN 1984, ARMY RESEARCHERS REPORTED ON AN ORAL VACCINE THAT PROTECTED AGAINST TWO COMMON FORMS OF DYSENTERY. OUTBREAKS OF DYSENTERY CAN RAPIDLY INCAPACITATE ENTIRE BATTALION SIZE UNITS. DYSENTERY ACCOUNTED FOR

FORTY PER CENT OF ALL DIARRHEAL DISEASE IN VIET NAM. IT IS CONSIDERED ONE OF THE TWO MOST SERIOUS INFECTIOUS DISEASES THREATENING OUR OUR SOLDIERS. THE OTHER MAJOR DISEASE THREAT IS MALARIA. CHEMOTHERAPY AGAINST MALARIA HAS PROVEN A LOSING GAME DUE TO EVOLUTION OF NEW RESISTANT STRAINS OF THE MALARIA PLASMODIUM. THE DISEASE IS TYPICAL OF MOSQUITO INFESTED ENVIRONMENTS WORLDWIDE. IT ACCOUNTED FOR 44,000 HOSPITAL ADMISSIONS OF SOLDIERS DURING THE VIET NAM CONFLICT. IN 1986, MEDICAL RESEARCHERS REPORTED THAT A RECOMBINANT VACCINE AGAINST MALARIA WAS POSSIBLE. AT THIS TIME THE WORLD'S FIRST MALARIA VACCINE HAS PROVED TO BE ANTIGENIC IN ITS EARLY CLINICAL TRIALS, AND IS CURRENTLY UNDERGOING FURTHER REFINEMENT.

OTHER ACHIEVEMENTS IN VACCINE DEVELOPMENT IN THE 80'S INCLUDE VACCINES AGAINST DENGUE FEVER, TULAREMIA, HEPATITIS "A", "Q" FEVER, RIFT VALLEY FEVER, JAPANESE ENCEPHALITIS, AND SEVERAL OTHERS. THESE ACHIEVEMENTS NOT ONLY ENHANCE THE GLOBAL PROTECTION OF OUR SOLDIERS, BUT ALSO REPRESENT A GREAT HUMANITARIAN CONTRIBUTION. FOR EXAMPLE,

THERE ARE YEARLY EPIDEMICS OF JAPANESE ENCEPHALITIS IN THAILAND, THE PHILIPPINES AND OTHER PARTS OF SOUTH EAST ASIA. THERE ARE 2,000 CASES IN THAILAND ANNUALLY AND AS MANY AS 400 DEATHS.

IN OUR DEFENSE AGAINST THE CHEMICAL THREAT, AN IMPRESSIVE DATA BASE DOCUMENTING BOTH THE PHYSIOLOGICAL EFFECTS OF CHEMICAL WARFARE (CW) AGENTS AND THE METHODS OF PREVENTING SUCH EFFECTS HAS BEEN ACCUMULATED OVER THE LAST DECADE. EFFECTIVE AUTO-INJECTOR KITS AND SKIN DECONTAMINATION KITS HAVE BEEN DEVELOPED AND FIELDDED.

WHEN THESE MEDICAL RESEARCH ACHIEVEMENTS ARE COMBINED WITH THE IMPROVEMENTS OF PROTECTIVE CLOTHING, NOTABLY THE NEW CLASSES OF MATERIALS TO IMPROVE SOLDIER COMFORT IN HEAT-COLD-RAIN AND CONTAMINATED ENVIRONMENTS. THESE SCIENTIFIC ACHIEVEMENTS WILL ENHANCE THE SURVIVAL RATES OF OUR SOLDIERS. IN FACT, THE SCIENTIFIC PROGRESS IN THESE AREAS HAS ALLOWED THE ARMY TO UPGRADE OUR GOAL

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FROM SURVIVABILITY - JUST KEEPING SOLDIERS ALIVE - TO SUSTAINABILITY
- KEEPING THEM FIGHTING. THE FOCUS IN THE 90'S WILL BE COMBAT
EFFECTIVENESS.

THE ARMY IS FORTUNATE TO HAVE A WORLD-CLASS, IN-HOUSE
BIOMEDICAL RESEARCH CAPABILITY, AUGMENTED BY A STRONG INTERFACE WITH
LEADING ACADEMIC INSTITUTIONS, INCLUDING THE BIOTECHNOLOGY RESEARCH
CENTER THE ARMY SPONSORED RECENTLY AT CORNELL UNIVERSITY UNDER THE
UNIVERSITY RESEARCH INITIATIVE (URI) PROGRAM. I RECENTLY RECOGNIZED
WALTER REED ARMY INSTITUTE OF RESEARCH, THE 1988 RECIPIENT OF THE
PRESTIGIOUS ARMY LAB-OF-THE-YEAR AWARD, FOR ITS WORK IN VACCINES AND
AIDS QUALITY ASSURANCE TESTING, AMONG MANY OTHER ONGOING PROJECTS.

IN THE LETHALITY ARENA:

FIRST, THE EVER-SHIFTING BALANCE BETWEEN ARMOR PROTECTION AND
ANTI-ARMOR MUNITIONS. IN THE LATE 1960'S IT WAS CONSIDERED
IMPOSSIBLE TO DEVELOP TANK ARMOR TO DEFEAT SHAPED-CHARGE WARHEADS --

THE ARMOR WEIGHT AND VOLUME BURDENS WERE SIMPLY UNACCEPTABLE. BUT THAT THINKING, WHICH WAS FOCUSED ON CONVENTIONAL ROLLED HOMOGENEOUS STEEL ARMORS, PROVED SHORT-SIGHTED. ARMY SCIENTISTS STEPPED IN WITH NEW CONCEPTS FOR ARMOR MATERIALS, GEOMETRIES, AND MECHANISMS TO DEFEAT SHAPED CHARGE WARHEADS. EXPLOITING CONCEPTS OF MATERIAL MISMATCHING, AND ARMOR DYNAMICS, U.S. ARMORS LEAPED AHEAD. ARMOR TECHNOLOGY HAS SINCE SUPPLIED APPLIQUE ARMOR, AND SPECIFICALLY, REACTIVE ARMOR, TO PROTECT ARMORED FIGHTING VEHICLES FROM SHAPED-CHARGE AND KINETIC ENERGY PENETRATOR THREATS. WE ARE SHARING INFORMATION WITH OUR NATO ALLIES TO ADVANCE THIS CAPABILITY.

IN VEHICLE DESIGN, WHOLE NEW MATERIAL CONCEPTS HAVE EVOLVED. TODAY, ADVANCED THICK COMPOSITE TECHNOLOGY IS CONSIDERED A REVOLUTIONARY SYSTEMS DESIGN OPTION. ARMY MATERIALS RESEARCHERS DETERMINED THAT RESINS, FIBERS, AND PROCESS TECHNOLOGY WERE READY TO ATTEMPT A MAJOR STRUCTURAL ARMOR DEMONSTRATION - THE BUILDING OF GROUND COMBAT VEHICLES FROM MOLDED, THICK-SECTION COMPOSITES INSTEAD OF THE TRADITIONAL WELDED METAL PLATES. AN ENTIRE HULL WAS DESIGNED

AND WILL SOON BE READY FOR BALLISTIC AND ROAD TESTING. THIS MATERIALS DEMONSTRATION IS SHOWING A 25 PERCENT REDUCTION IN WEIGHT COMPARED TO THE STANDARD METAL COMPONENTS. THE INITIAL WEIGHT SAVINGS CAN BE FURTHER MULTIPLIED BY SYSTEMS SAVINGS IN ENGINE SIZE, FUEL CONSUMPTION, LOGISTIC TRAINS, ETC. FOR THESE REASONS AND MORE, THERE IS A GREAT INCENTIVE TO PROVE AND TRANSFER ADVANCED THICK COMPOSITES TECHNOLOGY INTO ARMY SYSTEMS.

AUGMENTING OUR OWN EXCELLENT IN-HOUSE BALLISTIC RESEARCH CAPABILITY AT BRL AND OUR COMPOSITE RESEARCH CAPABILITY AT WATERTOWN, WE HAVE RECENTLY INAUGURATED A COMPOSITE RESEARCH CENTER AT THE UNIVERSITY OF DELAWARE, CO-SPONSORED BY THE ARMY UNDER THE URI PROGRAM AND OTHER LARGE CHEMICAL CORPORATIONS IN THE AREA.

WHILE THE ARMOR SCIENTISTS WERE MAKING SUCH IMPRESSIVE ADVANCED IN PROTECTION TECHNOLOGY, YOU MAY BE ASSURED THAT THE ANTI-ARMOR SCIENTISTS WERE NO LESS INNOVATIVE AND DILIGENT. THE SUCCESS OF REACTIVE ARMOR TILES IN PROTECTING THE BRADLEY LED TO A NEW WARHEAD

CONCEPT - THE TANDEM WARHEAD, A PROJECTILE OR MISSILE CONTAINING TWO WARHEADS, ONE IN FRONT OF THE OTHER. IN THIS DESIGN THE FIRST WARHEAD FRACTURES THE REACTIVE ARMOR AND THE SECOND HAS ONLY DEBRIS TO PENETRATE. THE IMPLEMENTATION OF THIS CONCEPT IN THE ALTERNATE ANTI-TANK AIRFRAME CONFIGURATION (AATAC) TECHNOLOGY DEMONSTRATION IS AN EFFORT TO DEMONSTRATE THE FEASIBILITY OF NOT ONLY HEAVY TANDEM WARHEADS BUT TWO OTHER TECHNOLOGIES FOR ANTI-ARMOR MISSILE USE AS WELL - FLEX WINGS AND OPTICAL/MAGNETIC STANDOFF SENSORS. THE WARHEAD LETHALITY HAS BEEN DEMONSTRATED, AS HAS THE FLEXWING CONCEPT. THE INTEGRATION OF THE SEVERAL TECHNOLOGIES IS NEXT TO BE DEMONSTRATED.

THE SCIENTIFIC TUG-OF-WAR IN ARMOR AND ANTI-ARMOR RESEARCH EFFORTS IS PROVIDING A STIMULUS FROM WHICH ALL ARMORED FIGHTING VEHICLES ARE BENEFITING. HERE, ARDEC AND BRL, COLLABORATING WITH DARPA, LIVERMORE AND SANDIA, OFFER THE BEST HOPE FOR KEEPING US AHEAD IN THIS RELENTLESS BATTLE.

LOOKING FARTHER AHEAD IN GUN PROPULSION OPTIONS, WE HAVE REASON TO BE EXCITED ABOUT ELECTRIC GUN OPTIONS.

SINCE THE DISCOVERY OF THE LORENTZ FORCE IN THE 19TH CENTURY, A GREAT MANY ELECTRIC PROPULSION CONCEPTS HAVE BEEN INVESTIGATED. MANY OF THESE CONCEPTS ARE BASED ON VERY HIGH POWER ELECTRICAL PULSES THAT HAVE THE POTENTIAL FOR ACCELERATING ORDNANCE-SIZED PROJECTILES TO EXTREMELY HIGH VELOCITIES. DESPITE PAST CYCLES OF RISING AND FALLING INTEREST IN ELECTRIC GUNS, CURRENT EFFORTS APPEAR MUCH CLOSER TO ACHIEVING APPLICABLE CONCEPTS THAN EVER BEFORE. THE PROPULSION MODES BEING CONSIDERED INCLUDE THE ELECTROTHERMAL (ET) AND THE COMBUSTION AUGMENTED PLASMA (CAP) CONCEPTS WHICH DEVELOP THE DRIVING FORCE BY ELECTRICALLY HEATING GAS CONTAINED IN THE BARREL AND BREECH AREAS. THE ELECTROMAGNETIC (EM) GUN UTILIZES THE LORENTZ FORCE TO ACCELERATE THE PROJECTILE.

IN THE ET CASE, PRESENT RESEARCH IS CONCENTRATING ON REPLACING THE HUGE CAPACITORS IN THE LABORATORY WITH MUCH SMALLER AND LIGHTER FIELD BATTERY-INDUCTOR POWER SUPPLIES.

THE STRONGEST SELLING POINT OF THE EM PROPULSION CONCEPT IS ITS POTENTIAL IN THE LONGER TERM FOR OUTPERFORMING "EXPANDING GAS" GUNS IN VELOCITY AND CONTROL OF ACCELERATION. ALTHOUGH THE APPLICATION OF LARGE PULSED ELECTRICAL CURRENTS AND HIGH VOLTAGES SEEMS FAR FROM THE REALITIES OF TODAY'S BATTLEFIELD, THE EXTREMELY LARGE EXPANDING MAGNETIC FIELD PRESSURES AVAILABLE MUST SURELY BE EXPLOITED IN A WEAPON AT THE TURN OF THIS CENTURY.

TWO URI CENTERS HAVE BEEN SPONSORED TO ACCELERATE PROGRESS IN THE PROPULSION ARENA -- THE ULTRA-FAST REACTION KINETICS CENTER AT THE UNIVERSITY OF SOUTHERN CALIFORNIA, AND THE ELECTRO-MECHANICAL CENTER AT THE UNIVERSITY OF TEXAS AT AUSTIN.

IN THE THE DIRECTED ENERGY WEAPONS AREA, RESEARCH EFFORTS INCLUDE BOTH DEVELOPMENT OF WEAPONS AND PROTECTION OF U.S. SYSTEMS AND SOLDIERS AGAINST ENEMY WEAPONS. IN THE RELATIVELY NEAR TERM, LASER WEAPON SYSTEMS SHOULD BE ABLE TO DESTROY OR PERMANENTLY DAMAGE ELECTRO-OPTIC SENSORS AND THUS, AFFORD A MEASURE OF SELF-PROTECTION FROM ENEMY FIRE. TODAY, HIGHER POWER LASERS ARE CAPABLE OF DAMAGING LIGHTLY ARMORED SYSTEMS, ESPECIALLY HELICOPTERS. HIGH POWER MICROWAVES CAN BURN OUT OR UPSET ELECTRONIC SYSTEMS AND DESTROY OR NEUTRALIZE THREATENING MISSILES OR MINES. FOR THE SURFACE ARMY, PARTICLE BEAMS OFFER POTENTIALLY GREAT IMPACT IN THE FUTURE, AS SCIENCE HELPS EXTEND THEIR EFFECTIVE PROPAGATION RANGE THROUGH THE ATMOSPHERE. THE MAJOR DIRECTED ENERGY EFFORTS IN SUPPORT OF STRATEGIC DEFENSE WILL ALSO PROVIDE IMPORTANT SPINOFF IN TACTICAL APPLICATIONS. HERE, ARMY SCIENTISTS ARE PRESSING FORWARD ON BROAD FRONTS -- TO ADVANCE AND ADVISE WEAPON TECHNOLOGISTS ON THEIR WEAPONS INVESTMENT OPTIONS -- AND WE'RE ALL WATCHING CLOSELY.

IN THE MICRO-ELECTRONICS AREA, RECENT EFFORTS HAVE FOCUSED ON GALLIUM ARSENIDE TECHNOLOGY TO PRODUCE PIONEERING CONCEPTS FOR VERY AND ULTRA HIGH SPEED SWITCHING AND MILLIMETER WAVE SIGNAL PROCESSING. AN IMPORTANT FEATURE OF THIS EFFORT HAS BEEN ITS MULTIFACETED APPROACH TO LEVERAGING COOPERATIVE EFFORTS WITH INDUSTRY AND OTHER GOVERNMENT AGENCIES. THE VERY HIGH SPEED INTEGRATED CIRCUITS PROGRAM (VHSIC) IS NOW IN ITS EIGHTH YEAR IN THE DEVELOPMENT OF ADVANCED INTEGRATED CIRCUITS FOR MILITARY SYSTEMS. MAJOR REDUCTIONS IN LIFE CYCLE COST HAVE BEEN ACHIEVED THROUGH THE DEVELOPMENT AND INSERTION OF THIS STATE-OF-THE-ART MICROELECTRONICS TECHNOLOGY INTO MILITARY SYSTEMS.

TODAY THE TRI-SERVICE MICROWAVE/MILLIMETER WAVE MONOLITHIC INTEGRATED CIRCUITS (MIMIC) PROGRAM IS UNDERWAY AND IS EXPECTED TO DEVELOP AFFORDABLE AND REPRODUCIBLE MONOLITHIC INTEGRATED CIRCUIT COMPONENTS FOR SMART MUNITIONS, RADAR, ELECTRONIC WARFARE (EW) AND

COMMUNICATIONS SYSTEMS SUCH AS THE MULTILAUNCH ROCKET SYSTEM (MLRS)
- TERMINALLY GUIDED WARHEADS, SENSE AND DESTROY ARMOR, MULTI OPTION
FUSE FOR ARTILLERY, PHASED ARRAY RADARS AND WIDEBAND EW SYSTEMS.

COMPUTERS:

TOOLS OF SCIENCE ASSUME MANY FORMS, BUT CERTAINLY IN TODAY'S
WORLD THE COMPUTER OFTEN BECOMES THE CENTERPIECE IN THE FORMULATION
OF THEORY AND ANALYSIS OF EXPERIMENTS. HIGH PERFORMANCE COMPUTING
IS BECOMING A LIFE NECESSITY IN OUR LABS AND MANY OF OUR FUTURE
COMBAT SYSTEMS. ACCORDINGLY, WE ARE FORTUNATE TO HAVE ACQUIRED,
INSTALLED, AND PLACED IN OPERATION THE ARMY'S FIRST THREE
SUPERCOMPUTERS -- TWO AT THE BALLISTIC RESEARCH LABORATORY (BRL) AND
ONE AT THE TANK AUTOMOTIVE COMMAND (TACOM). WHAT AN APPROPRIATE WAY
TO CELEBRATE THE 40TH ANNIVERSARY OF THE DELIVERY OF THE WORLD'S
FIRST ELECTRONIC, DIGITAL COMPUTER, THE ENIAC, TO THE BRL. AND WHAT
A LONG WAY COMPUTERS HAVE COME! THESE CRAY SUPERCOMPUTERS HAVE
OPERATIONAL SPEEDS WHICH ARE SIX ORDERS OF MAGNITUDE GREATER THAN

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THE ENIAC, TO SAY NOTHING OF THE SOPHISTICATED SOFTWARE WHICH WAS NON-EXISTENT TWENTY OR EVEN TEN YEARS AGO. THESE SUPERCOMPUTERS ARE PROVIDING THE COMPUTATIONAL SPEED AND STORAGE SPACE TO ADDRESS, FOR THE FIRST TIME, REALISTIC THREE-DIMENSIONAL SIMULATIONS.

SOPHISTICATED, ANALYTICAL DESIGN TOOLS COMPLEMENT EXPENSIVE, BUT ABSOLUTELY NECESSARY, WELL-ORGANIZED TESTING PROGRAMS TO INCLUDE THE LIVE-FIRE PROGRAMS.

PRESENTLY UNDER CONSIDERATION IS THE INITIATION OF A UNIVERSITY HIGH PERFORMANCE COMPUTING RESEARCH CENTER TO ADVANCE AND BROADEN THE APPLICATION OF THIS INCREDIBLE TECHNOLOGY THROUGHOUT THE ARMY, R&D AND USER COMMUNITY.

MANPRINT

LAST, BUT NOT LEAST, MANPRINT - TODAY'S ARMY LEADERSHIP'S HIGHEST PRIORITY INITIATIVE - THE HUMAN LINK. SINCE THE 1970'S, THE ARMY HAS BEEN INVOLVED IN A MASSIVE MODERNIZATION PROGRAM. TO

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ENSURE THAT THE EXPLOITATION OF ADVANCED TECHNOLOGIES IN THE DESIGN OF THESE SYSTEMS IS RESPONSIVE TO THE SOLDIER, THE ARMY CREATED WHAT IS KNOWN AS "MANPRINT". "MANPOWER AND PERSONNEL INTEGRATION" IS THE FOCUSED EFFORT OF IMPOSING THE FULL RANGE OF HUMAN FACTORS ENGINEERING, MANPOWER, PERSONNEL TRAINING, MEDICAL AND SAFETY CONSIDERATIONS ON THE MATERIEL ACQUISITION PROCESS. WITH MANPRINT HAS COME A SHIFT IN EMPHASIS FROM "MANNING EQUIPMENT" TO "EQUIPPING THE MAN". THE CHALLENGE IS TO DESIGN SYSTEMS WHICH HAVE SUPERIOR OPERATIONAL PERFORMANCE AS WELL AS SIMPLICITY OF OPERATION AND EASE OF MAINTENANCE, GIVEN OUR EVER DIMINISHING RESOURCES IN PERSONNEL AND TRAINING. WITH THE MANPRINT FOCUS, THE ARMY HAS CHOSEN TO TEAM OUR TECH BASE, MATERIEL DEVELOPMENT, AND INDUSTRY RESOURCES INTO A PARTNERSHIP WHICH LEVERAGES OUR TECHNOLOGY TO BENEFIT OUR MOST IMPORTANT ARMY ASSET -THE SOLDIER - AND SIGNIFICANTLY MULTIPLY HIS COMBAT EFFECTIVENESS.

IN CONCLUSION...

ALTHOUGH I HAVE LIMITED MY CITATION TO A FEW EXAMPLES, THE FOUR RESEARCH ARMS OF THE ARMY: THE ARMY MATERIEL COMMAND, THE CORPS OF ENGINEERS, THE SURGEON GENERAL, THE ARMY RESEARCH INSTITUTE AND THE MORE RECENT ARMY STRATEGIC DEFENSE COMMAND HAVE IMPRESSIVE RECORDS OF ACCOMPLISHMENT, OF WHICH WE MAY ALL BE VERY PROUD.

IN OUR TECHNOLOGY PULL TO SATISFY TODAY'S CRITICAL BARRIERS, WE CANNOT OVERLOOK WITH THE SAME LEVEL OF INTENSITY AND DETERMINATION, THE TECHNOLOGY PUSH THROUGH NEW SCIENTIFIC DISCOVERIES, BREAKTHROUGHS AND OPPORTUNITIES. I HAVE RECENTLY COMMISSIONED BAST TO CONDUCT A VERY COSTLY AND EXTENSIVE LONG RANGE TECHNOLOGY FORECAST THAT WOULD ASSIST US IN PLANNING WISELY AND PRODUCTIVELY FOR THE FUTURE.

OUR SCIENCE AND TECHNOLOGY INVESTMENT STRATEGY AND TECHNOLOGY MASTER PLAN ARE COMMITTED TO PROVIDING THE REQUISITE ARMY WAR FIGHTING CAPABILITY ACROSS THE FULL SPECTRUM OF POTENTIAL GLOBAL CONFLICTS, AT ANY PLACE AND ANY TIME IN THE NEAR AND FAR TERM. IN ACHIEVING AND SUSTAINING THAT GOAL, WE SHALL STRIVE TO BALANCE OUT

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OUR INVESTMENT ACROSS SEVERAL DIMENSIONS: NEAR VERSUS FAR TERM NEEDS; SCIENTIFIC PUSH VERSUS TECHNOLOGY PULL; MODERNIZATION OF WEAPON SYSTEMS VERSUS PROTECTING AND SUSTAINING THE SOLDIER ON THE MODERN BATTLEFIELD OF THE FUTURE.

AS FOR MY PERSONAL COMMITMENT - AS LONG AS I REMAIN IN MY OFFICE, YOU SHALL CONTINUE TO HAVE MY FULL, ENTHUSIASTIC AND UNWAVERING SUPPORT - SO THAT WE MAY MARCH FORWARD, SHOULDER TO SHOULDER, ONE TEAM, SPIRITED AND DETERMINED TO KEEP THIS GREAT ARMY THE STRONGEST, AND THIS GREAT NATION THE MOST SECURE, THROUGH DECISIVE DETERENCE, BASED ON OVERWHELMING TECHNOLOGICAL AND SOLDIER SUPERIORITY, DERIVED FROM THE CUTTING AND COMPETITIVE EDGE OF YOUR SCIENTIFIC ACHIEVEMENTS.