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"SENSING OF LIVING CASUALTIES ON THE MODERN INTEGRATED BATTLEFIELD"

FINAL REPORT

L. A. Geddes, M.E., Ph.D., F.A.C.C.
and
W. A. Tacker, Jr., M.D., Ph.D.
Co-Principal Investigators

November 1983

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U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
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Purdue University Biomedical Engineering Center
Institute for Interdisciplinary Engineering Studies
West Lafayette, IN 47907

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This report describes the feasibility of a system for using sensors, artificial intelligence and robotics, imaging or other means to improve evacuation of soldiers from the battlefield. Possible approaches are based on either wearable individual sensors and/or proximate remote sensors (including radiant energy sensing). By far the most promising approach is one in which each soldier wears a small device for life-signs monitoring. The

DD FORM 1473 EDITION OF 1 NOV 65 IS OBSOLETE device would resemble a dogtag, wristwatch, or belt buckle (for example) and would acquire data such as pulse, respiration, and temperature. Upon electronic interrogation, the stored information could be broadcast to a central facility. Problems of security and acceptability to the soldier must be dealt with, but these problems seem amendable to reasonable solutions.

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I. CONTENTS

II. OBJECTIVES AND ASSUMPTIONS

It is the objective of this study to determine and report on the feasibility of using sensors, artificial intelligence, robots and/or other devices or technique to identify the presence, location, and medical status of casualties on the battlefield. The study will also asses the feasibility for developing the system to improve triage and subsequent medical care of casualties. Included is a concise report on the applicability of the spectrum of present-day sensing technologies with a technical description, discussion of strengths and weaknesses, evaluation of susceptibility to enemy induced countermeasures, and listing of current sources. A final objective is to recommend the most promising approaches for development of a sensing system which can be used in the immediate future to improve care of casualties, and which ultimately can be incorporated into a robot-based medical casualty-care system. The authors recognize the potential for non-military applications of the technologies reported herein. However, discussion of civilian applications is beyond the scope of work for this report, and therefore is not emphasized.

It is assumed that the battlefield environment will affect the soldier's vital signs. Exercise, fear and anxiety, etc. are known to alter the vital signs of the healthy individual. Blast or gunshot injuries on the conventional battlefield will produce vital signs indicative of trauma and shock including tachycardia, tachypnea, and decreased motion, the first two of which change to brachycardia and bradypnea shortly before death. On the contrary, on the chemical battlefield, early indications of exposure to chemical neurotoxins include slow heart rate and labored breathing. As a result, considerable expertise is required to interpret medical condition using only current heart and respiration rates. To distinguish chemical from non-chemical situations a built-in monitor and warning system (i.e., the Chemfet) would be of enormous value, particularly in the low exposure situation. Probably the greatest hazard to the soldier from organic phosphate agents is respiratory failure due to paralysis and fluid secretions in the lungs. The personal respiratory monitor, properly configured, could be of enormous value to the aidman, nurse or physician. It may well be that the proposed pressure sensor (see Ch IV) incorporated into the protective mask of the Chemical Defense Ensemble would be critical to care in the chemical warfare environment.

On the nuclear battlefield, exposure to high level ionizing radiation will not immediately be revealed in the vital signs. It could, however, be identified by a personal environmental radiation monitor. Of course blast injuries may be revealed in the vital signs.

The most difficult environment to deal with pertains to the use of biological agents. Despite their diversity and because of their slow and varied effects on vital signs, the biological agents can probably be grouped into families. It should therefore be possible to create detectors for such families, but it is not possible to do so at present.

Prediction of value for use of a personal monitor communicator (PMC) on the integrated battlefield is somewhat speculative. However, it should be noted that a monitor with considerable value in conventional or chemical environments, will be of some value in nuclear environments (limited mainly by the high likelihood of immediate death in the blast area, and low incidence of immediate death outside the blast zone).

III. CONCEPTS FOR FEASIBLE SYSTEMS

A number of systems and subsystems have been envisioned by the Purdue research group, or suggested by those with whom we have consulted within the Department of Defense, industry, and academic institutions. These will be described in brief and the advantages and disadvantages of each will be reviewed.

A. The Personal Monitor Communicator (PMC) System

This particular approach to sensing would use a personal medical monitor and communicator (PMC) worn by each soldier. Physically, it could resemble a wrist watch, a belt, or a dogtag. It would acquire vital signs, acquire environmental data, carry the soldier's medical history, and transmit information to command headquarters. The device could be used in the battlefield for triage by medics, for monitoring during evacuation, or at the battalion aid station and field hospital for monitoring. It could also be designed to measure chemical and radiation exposure. It could provide radiofrequency transmission of data and also be used to locate the wearers. This system is considered in detail in section V since it is the most promising of the possible approaches. The advantages envisioned are that it provides benefits to each individual soldier, it is technologically and medically feasible, it is achievable with present day technology, and its benefits are wide spread enough to offset the problems of security and enemy countermeasures.

The problems to be expected are in the areas of communications, security, acceptance, and practicality. Using radiofrequency for communication would be very difficult under battlefield conditions. However, we believe that this system could be readily implemented for use during periods of inactivity on the battlefield such as night time or between major engagements. Security problems are primarily those of the enemy use of radio frequency transmission signals for locating the soldier who is wearing the device. The problem cannot be fully solved, but application of standard army practices will minimize the risk. As the Army develops new approaches to these problems, the approaches should be applicable to the PMC.

With regard to the problem of acceptability of the PMC, it is clear that the soldier will not accept a very large or cumbersome or complex device and hence the monitor will have be truly miniaturized, and will have to be designed so that it does not impede the soldiers' carrying out his responsibilities. Also, the soldier will have to be educated about the benefits provided by the device. Likewise the value of this device must be clear to the commanders.

It has been suggested that the soldier should be able to manually control his personal medical monitor. This might increase acceptability, since he would be less concerned that the enemy could use the device for locating him. Also, only casualties would be put on the system for transmission and processing. There are some disadvantages. First, it requires another task of the soldier. Second, under conditions of anxiety and stress, he might not send accurate information. However, the advantages may outweigh the disadvantages. For these reasons, we recommend that this approach be further investigated.

Notwithstanding the problems that are identified, we believe this system will be of great value; that it is the leading candidate for application; and that its development should be pursued by the army.

B. Chemical Defense Ensemble System

Because of the unique characteristics of chemical defense ensembles it should be possible to add sensors to the standard PMC sensing system. For example, inside the mask for chemical defense ensembles there will be significant negative pressure inside the mask during inspiration, and this signal could be transduced by a miniaturized pressure transducer to monitor respiration. Likewise, monitoring electrodes for the electrocardiogram may be built into the chemical defense ensemble at points where elastic holds the ensemble tightly to the skin. In actuality the chemical defense ensemble would be a variation of the PMC system in which it would be easier to monitor life signs without constraining the soldier any more than already required by the chemical defense ensemble.

C. Imaging Systems

Imaging systems have proved to be useful in battle situations; the night-vision viewer is an example. With recent advances in microcomputers, fixed location sensors, and remote sensing devices, it is felt that combinations of these devices will be available for use in the future. The thematic maps provided by fixed location sensors will be coordinated with data from imaging devices to provide an integrated overview of the battlefield. It is likely that the data will be processed by human interpretation of enhanced images as well as by artificial intelligence.

We believe that imaging systems will have merit for application in medical monitoring in the foreseeable future. However, imaging systems involve different expertise and applications than the PMC. These systems are promising enough to warrant a section in this report (Section VI), in which details of the system will be reviewed.

Battlefield imaging to determine the medical condition of individual soldiers would have the advantage that the soldier would not be required to carry a sensor or sensors for that purpose. An example would be a handheld thermal scanner which would scan the facial region of the soldier to determine his physical condition. Based upon computer algorithms applied to the thermogram, the medical personnel using the device would quickly screen the personnel for treatment and transport.

Remote imaging of wide areas of a battlefield to determine the medical condition of personnel has a number of limitations. Practical limits on spatial resolution and interference by clouds, smoke, dust, and bad weather constitute basic restrictions. Deployment of platforms for imagers, data security, and detection of active imagers by enemy forces present challenging problems. If the soldier is wearing heavy or wet clothing, riding in a vehicle, or hiding under foliage, identification as a combatant (by remote sensing of a wide area) may be difficult or impossible. The use of sophisticated artificial intelligence algorithms to identify moving soldiers may prove to be practical in the future. However, there is no adequate system for recognition of the human body currently available. The flexibility of the body, the many views available (above, lateral, frontal, etc.) make this a major problem, further complicated by the possibility of limbs being distorted or absent due to trauma. We believe a major effort would be required to solve this problem.

The usefulness of such a system would depend upon the geographic area of conflict, including the location of the soldier under vegetation, in buildings or vehicles, etc. One major consideration in this area is the difficulty of using the imaging approach when the soldier is not exposed to aerial view. Since, in general, the soldier will avoid this condition, the imaging system approach is more difficult and less likely to be useful.

D. Voice System

A voice transmission system would be highly desirable from the standpoint of expanding the amount and variety of information to be transmitted. However, the overload of information would be tremendous unless special technologies were developed to reduce the information. Perhaps a voice system would be useful for a limited number of personnel, but this capability is already available, in great part, by present radio transmission capability. At the present time we do not recommend development of voice transmission for the first generation system.

E. Vehicle Mounted System

Since the Army has many soldiers in vehicles, and this trend is continuing, there is the possibility of developing a vehicle mounted system. This eliminates need for the soldier to carry the device, power is easier to obtain, and larger size is feasible. Only the sensors need be attached to the soldier. Data can be telemetered to the vehicle mounted system. The problem here is that the value is lost if the soldier is not near his vehicle. Therefore, we still see value for an autonomous personal monitor for all troops. There is indeed, a problem in that an additional vehicle-mounted adaption may be needed due to problems created by the vehicles. For example, the M-1 tank armor will prevent sending signals from the crew to the receiver, unless an external antennae is provided.

F. Robotics System

Of course the most desirable of the systems would be one in which a robot with a high degree of intelligence could go into a contaminated battlefield to locate, diagnose, and return soldiers for proper medical care. It might also provide some first aid capabilities or even carry out decontamination procedures in the field. At the present time we do not believe this is feasible with the present state of artificial intelligence and robotics, which are reviewed in more detail in Section VII. However, we do believe that successful development of the PMC would provide the foundation for later development of a robotics-based, artificial intelligence system. Given the complexity of the operations involved in evaluating the medical status of the wounded soldier, it is clear that effective use of robots must involve the use of personal medical sensors which communicate data to the robot.

G. Medical Records and Magnetic Data Storage

One of the advantages of the PMC system is that medical records could be stored in magnetic form or on a memory chip in order to carry permanent or semi-permanent records about the soldiers' medical history, blood type, etc. This medical records aspect actually has limited use in the battlefield but should prove to be useful for subsequent medical care of the casualties. It would be possible to develop a medical records system which works in concert with the PMC. This would need to be integrated with the development of the Soldier Support Card under testing at Fort Harrison, IN.

IV. PERSONAL SENSORS

A. Definitions

Individual sensors are devices that can be worn by a soldier. With current technology it is possible to design and deploy a miniature, personal medical device which would provide information on demand concerning the medical status of each soldier in the battlefield. Proper processing and data management would allow rapid decision making about the appropriate use of resources for evacuation and care. The personal device envisioned could take many forms, such as a wristwatch, dogtag, belt, or other wearable item. Such sensors, of course, must be comfortable and unobtrusive monitors of the soldier's vital signs and must be coupled to a transmitter so that the information can be obtained by medical personnel. Systems of the type described in this section will consist of a miniature personal monitor and communicator (PMC) and an intelligent interrogator. The PMC will contain sensors to measure vital signs, an interrogatable, short range transceiver to communicate the soldiers' physiologic status, and a microprocessor to concentrate the data and to control transmission. We will discuss such devices in terms of a watch or dogtag, but some other physical form may later prove more effective. The interrogator can be thought of as a portable transmitter/receiver, carried in an overflying helicopter or aircraft or on a truck or jeep. The interrogator will be able to query the PMC's of many soldiers to determine their physiologic status.

B. Potential Utility

One application of the PMC system is battlefield triage. Another use of the PMC would be to provide important monitoring information to a medic at the Battalion Aid Station. The system could also be used in a mass casualty situation, such as a field hospital, to assist in triage and to continuously monitor several patients. An important use of the PMC is to help allocate scarce medical resources in the field, in casualty evacuation and in medical treatment areas.

The capability of the PMC to provide continuous information regarding the approximate location and health status of the soldier would eliminate much of the risk now taken in sending medical personnel into hazardous areas. In addition, at least 2 other applications are envisioned. First, important medical history, such as blood type, allergies, medications, prescription for glasses, etc., could be stored in the PMC. Some of this information is of value in field medical care. Incorporation of important medical history into the PMC is merely an electronic adaptation of the Health Passport, advocated several decades ago by Paul Dudley White, the eminent cardiologist and physician to President Eisenhower. Second, the PMC could be used as a monitor in the field hospital. If appropriately designed, it could interface with a field "central" monitor to allow a single nurse or medic to continuously monitor many injured personnel.

C. Cost and Benefits

The use of high technology for military purposes is usually characterized by the creation of large, high-cost devices that are used by a few specially trained soldiers. The system discussed in this document employs high technology that is used by each and every soldier. However, this, like any other new system must compete with extant systems and its benefits must not be at the expense of reducing armament, ordnance, food, water, and medical supplies; nor must it compromise mobility. It also must not demand extensive training.

By virtue of its ability to provide vital-sign information, the system discussed in this document is designed to permit "quality-of-life" assessment. This information has value to the commander, as well as to the medical support personnel. For the latter, the system will allow a more effective triage function; the benefit here being an ability to return a soldier to combat duty sooner.

Perhaps one of the most important aspects of the system relates to morale value. When the indications and contra-indications for use have been worked out, the fact that an interrogable vital-sign monitor is being worn will assure the soldier that he can be found, diagnosed and treated more rapidly. The knowledge that survival rates are improved should raise morale.

Although the PMC does not require new technologies, some costs will accrue to several development tasks:

a) selection of the optimal vital signs to monitor
b) determination of the best electronic sensing techniques
c) design of sensing and signal processing circuitry
d) selection of best communications techniques
e) optimization of mechanical form of the system
f) design and development of prototype, and of field testable systems
g) software and algorithm development.

D. Availability of Sensors

Transmitted or transponded signals in the first-generation device could report skin temperature, heart rate, body motion, and possibly respiration, which are all signs of life when properly interpreted. Sensors for detecting these variables must be miniaturized adequately for incorporation into the PMC.

A first-generation system could combine a temperature sensor (thermistor) a heart rate sensor (electrocardiogram or pulse) a motion sensor (accelerometer) and possibly a respiration sensor

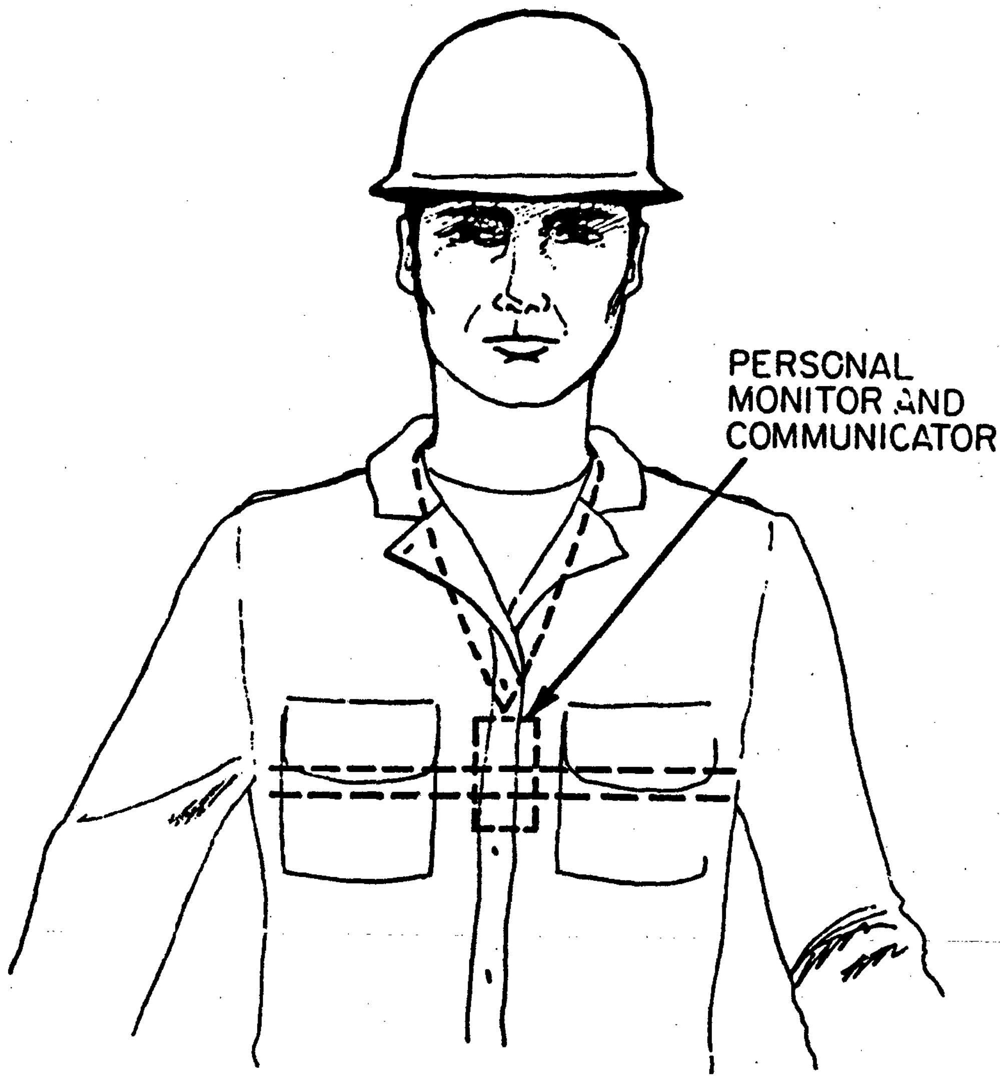


Figure 1. Frontal view showing the Personal Monitor and Communicator (PMC) in a dogtag format which could either be "free hanging" or held in place with an elastic chest band. See Figures 2 and 3 for other formats.

(impedance). Body temperature of a living soldier will be different than the temperature of the environmental objects under most field conditions; whereas a soldier killed in action would soon have body temperature near the environmental temperature. Determination of heart rate is of value for estimating effects of low-level organophosphate poisoning, since these agents will slow the heart rate dramatically. Hemorrhagic shock typically produces tachycardia. The accelerometer could be built with appropriate sensitivity and filtering to detect spontaneous motion of the soldier. The combination of these vital signs will be effective in estimating the physiologic condition of the soldier. A block diagram of a 3-sensor version is shown in Figure 2.

Later versions of the PMC could be capable of reporting exposure to toxic chemicals, radiation, and could perhaps provide voice communication. However, the analysis contained herein is limited to use of available technology. With proper design, it will be possible to add other sensing capabilities as they become available. For example, chemical sensing with field-effect transistors (CHEMFETS) is being developed for military use; but CHEMFETS are not yet small enough for use in the PMC, nor do they have adequate shelf life. Radiation detectors such as those under development in RADIAC at Fort Monmouth, might also be incorporated into these devices. It is important to note that from the onset, a modular design concept will be adopted. In essence, this means that the system will be designed to accept additions with minimal modification of previously developed hardware.

E. Acceptability to the Soldier

Sensors for the PMC must be contained in a comfortably wearable package of extremely low weight and attached in such a way that will not interfere with the soldier's normal duties. Several such arrangements have been considered and some are illustrated in Figure 3.

1. Wristband

There are several approaches using a wristband.

A. A single wristband-like device is capable of monitoring skin temperature, heart rate, motion, and responsiveness to an electric shock or other stimulus. This configuration of a PMC is likely to be most acceptable to the soldier. With two wristbands, one on each wrist, interconnected by a thin insulated elastic conductor, the electrocardiogram (ECG) and respiration (by electrical impedance change) can be acquired. The wristbands serve as dry electrodes for the ECG and respiration. Either or both wristbands can contain temperature sensors. The interconnecting insulated elastic conductor

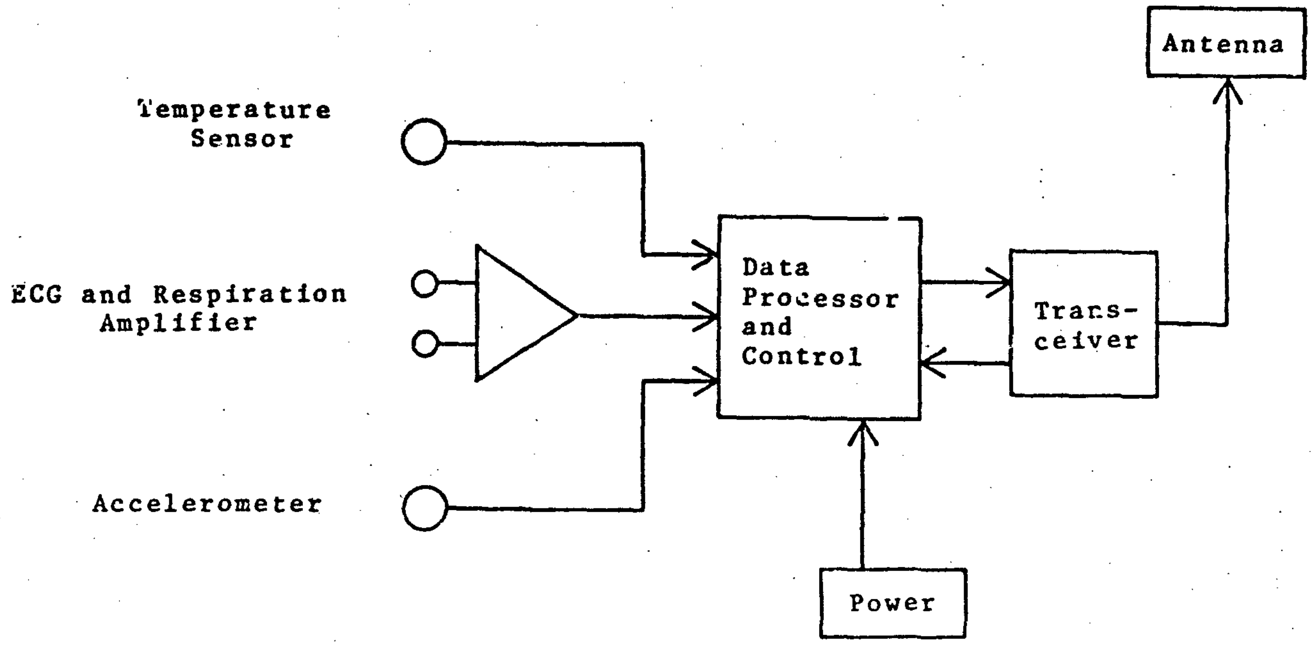


Figure 2. Block diagram of PMC.

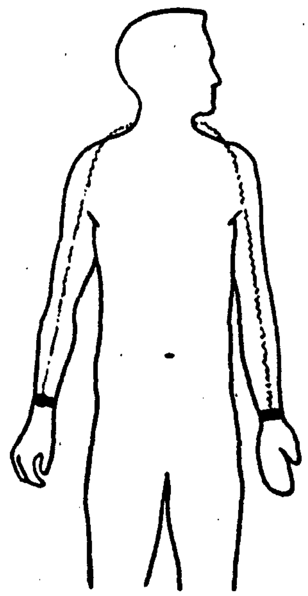


Figure 3a Two wrist band configuration

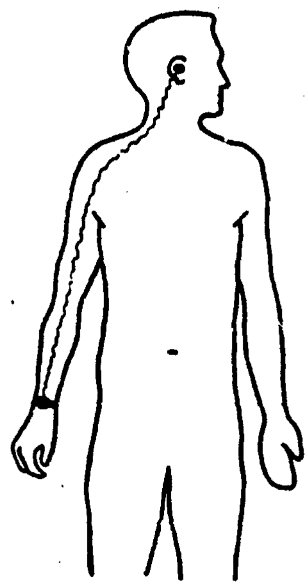


Figure 3b Wristband /earplug configuration

can serve as the receiving and transmitting antenna. Either wristband can be commanded to display heart and respiratory rate. The extra watch and connecting band, however, may prove a nuisance to the soldier, reducing acceptance of the device.

B. A wristband and an earplug electrode connected by a thin insulated elastic conductor, has been suggested. The electrocardiogram (ECG) and a reasonable estimate of core temperature can be obtained. The wristband and earplug can serve as dry electrodes for the ECG. A thermistor can be placed in the earplug to sense body temperature. In future versions of the PMC the earplug could also contain a miniature loudspeaker to provide voice communications, and a microphone for the soldier to reply, the earplug earphone/microphone already exists and is practical. However, we believe the earplug concept is impractical at the present time, as the soldier is unlikely to accept such a restriction.

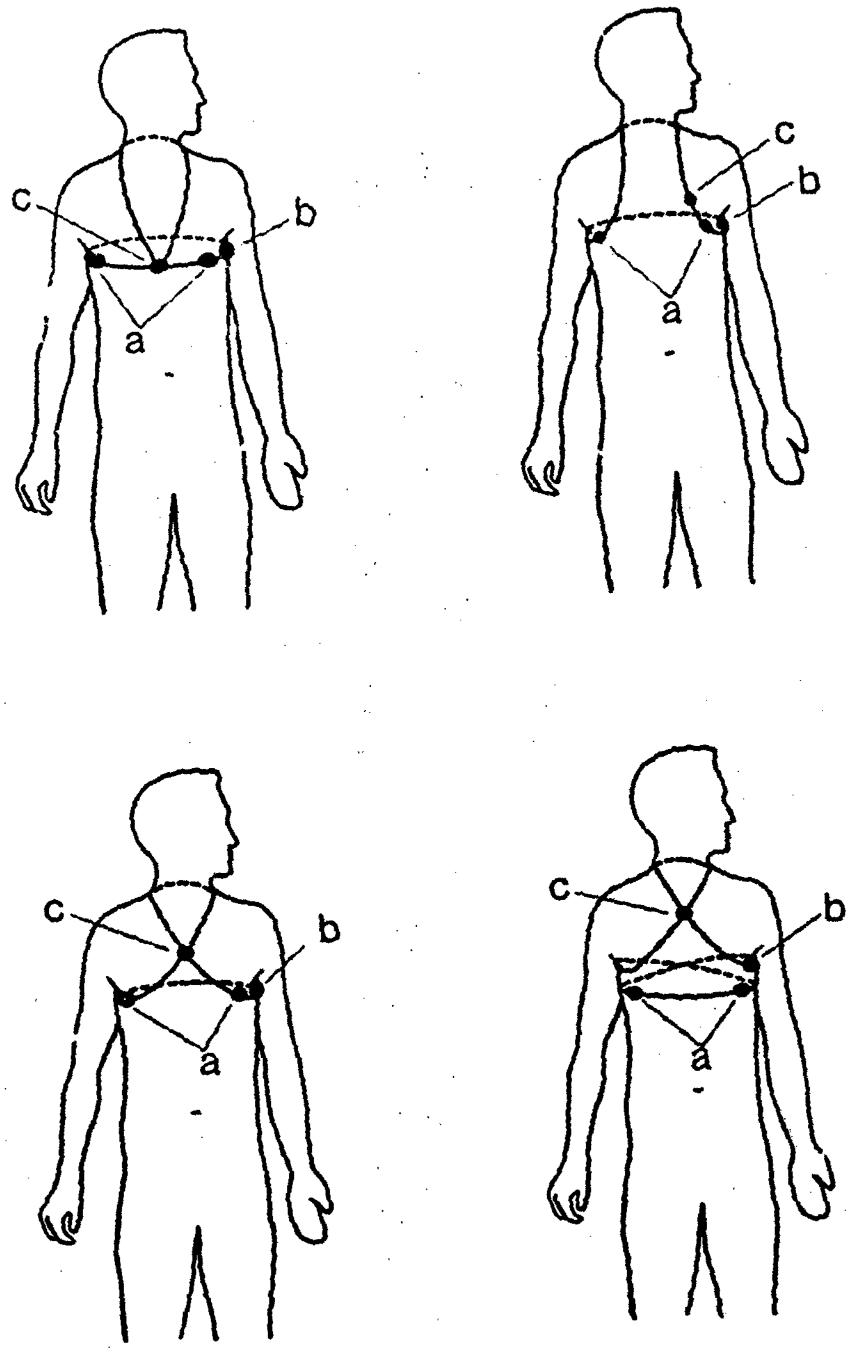
Figures 3a and 3b identify the configurations for the wristband concept of transducer placement.

2. **Chest sensors**

A number of different styles of chest bands might be used to acquire physiologic data. Figure 4 presents examples:

A. The chest band, with a loop around the neck (for stability and use as an antenna), permits acquisition of a large amount of physiologic information. From conducting silicone rubber electrodes in the chest band below the armpits, the ECG and respiration can be acquired. Likewise, a temperature sensor can be incorporated in the band. A chest-movement (accelerometer) detector can be included; this sensor can acquire respiration and cardiac vibrations, as well as motion associated with locomotion.

B. The axillary loops of conducting silicone rubber in the armpit area are connected by an extensible band containing a conductor which constitutes the antenna. From the armpit electrode, the ECG and respiration can be acquired. A temperature sensor and accelerometer can also be incorporated into this configuration. Mock-ups of both configurations would have to be field tested prior to development to be certain that the physical arrangement is comfortable, non-restraining, and acceptable to the soldier.



a- ECG and Respiration Electrodes
b- Temperature Sensor
c- Accelerometer

Figure 4 Chest band configurations

F. Communications Requirements

The PMC could be interrogated by a pulse-coded signal transmitted from a medic on the scene (short range interrogator. SRI) or an overflying helicopter or drone, a land vehicle such as a tank, personnel carrier or remote-controlled rover (long range interrogator, LRI). Using microsecond-duration pulses, hundreds of the PMC's could be interrogated within a second or less, giving information about a complete complement of men. Only codes corresponding to men known to be in the area need be transmitted. Pulse-coded replies would be transmitted over short distances from the PMC's to report the vital signs (e.g. temperature, heart rate, and motion) of each soldier.

These operations are compatible with existing Army doctrine of battlefield communications. Although it is theoretically possible to use millisecond duration transmission for target acquisition using electronic means, the practicability of the system is not contra-indicated at the present time. First, it is unlikely that the single soldier will be such a threat to the enemy that obtaining precise location is worth the effort. Second, voice communication by radio-frequency is acceptable, according to present doctrine, for periods of up to 20 seconds. The PMC signal, lasting much less than 1 second, is clearly within these guidelines.

G. Data Processing Requirements

A portable microcomputer would be required to collect data and provide a statistical profile of the status of the soldiers giving a distribution of the number of combat-capable soldiers and their locations. Such computers are readily available but must be made to conform to Army specifications. In particular, many of the currently available personal computers, have the processing and graphic display capability needed to compute the statistical profile.

The assembled information would eliminate the need for dangerous and futile rescue attempts and could indicate the geographic locations to which rescue personnel should be sent. This information would be of operational value, both to the field commander and to the field medical officer. Figure 5 graphically represents the PMC/Interrogator system. For simplicity, an airborne platform is shown carrying the interrogator.

H. Potential Problems with System Operation

A number of potential problems exist with regard to implementation of a PMC system. These problems include the areas of communications, security, acceptance, practicality, and cost. Most of these problems are not unique to this particular system; but are problems generic to applications of technology in the Army. In this section we will identify some of these problems,

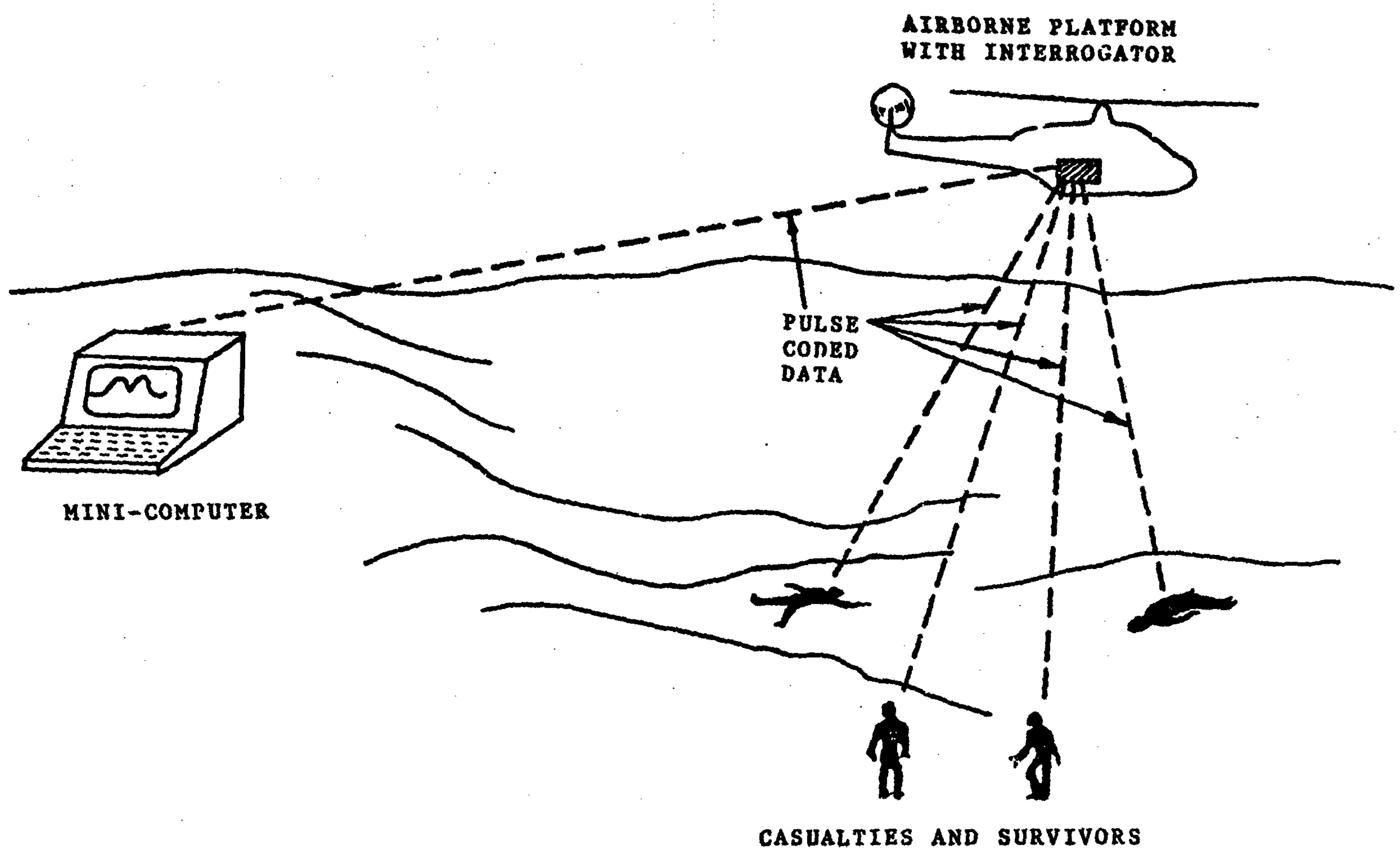


Figure 5: PMC/Interrogator system as envisioned for use in the field with a flying interrogator. See text for description of other interrogation approaches, such as in the Battalion Aid Station.

and will then show that despite these problems, the system has the potential for considerable benefit.

First, regarding problems in communication, it is clear that there would be several difficulties in using this device on the integrated battlefield. Problems also will exist with regard to using it during conventional combat, and it is unknown what effects jamming and counterjamming of electronic signals might produce. Another problem is the difficulty in getting information to the command in time for it to be of practical use. Under battlefield conditions it is unlikely that information from the PMC would have high enough priority to be channeled into command headquarters. Hence we have proposed that the original PMC system would not be designed for application during actual combat. Use of the system between battles will also be somewhat difficult, but we believe a practical and effective system can be developed. It should be pointed out that in addition to using radiofrequency transmission, ultrasound could be used for communication, depending upon the distance to be traversed and the environmental conditions.

A second set of problems relates to security. For example, the enemy might use radiofrequency transmission signals for finding a soldier who is wearing and using the PMC. Necessary security features will have to be designed so that this will be unlikely. Another possibility is that the enemy might be able to capture PMC's and use them to lure Army personnel to a particular location; or by developing electronic simulations of PMC activity, the enemy could affect command decisions. This problem is not unique to our device, but is a problem with most Army equipment that transmits and receives signals. As the Army develops solutions to cope with these problems, the solutions should be applicable to the PMC. However, as we will point out subsequently, many potential uses for the PMC do not require radio frequency transmission, and in fact the PMC may be useful in these supplementary operations. We would like to point out that in describing a coding/decoding system we are referring only to converting information to a form by which it can be transmitted. We do not view this first generation device as having encryption capability to avoid enemy acquisition of the information. We do not believe that would be cost-effective, nor would it be practical, before demonstration of the feasibility of acquiring vital signs from a soldier.

The third problem is acceptability of the PMC. In order for this system to operate it will be necessary for the soldier to recognize its benefit and to use the system properly. It is well known that the soldier will discard any items which prevent him from carrying out his duties and in fact under battlefield conditions he is frequently required to discard part of his equipment in order to fight effectively. It will be essential to develop a system which does not jeopardize the soldier in any way and which is clearly of benefit to him in the event that he becomes a casualty during battle. This will require good design and development as well as proper deployment and education. It is unlikely that the average soldier will accept the device which he has to wear either in the armpit, strapped to the chest, or in the ear, unless it has obvious value, and he is thoroughly educated about its benefit. In fact, some versions of the PMC may be used only under special conditions, such as with the chemical defense ensemble, where the PMC could be placed in a pocket in the headgear or other part of the ensemble. Moreover, there is some question as to whether or not the field commanders will accept the PMC as a useful device. It will be new, untested in its early form, and will undoubtedly take up a few resources which could be applied to other applications. For example training, education, and the requirement of having to carry additional equipment must be dealt with. Nonetheless, we believe that the device will be effective in decreasing casualties and fatalities, and if it will increase the rate of return of soldiers to active duty, the commanders will recognize its value.

Fourth, there is the question of cost. There is no doubt that the device must be relatively inexpensive and must show high benefit for it to be practical for implementation and deployment. The competition for scarce resources will require that the PMC compete with other demands, such as those of communications, transportation, and ordinance.

Notwithstanding the problems which we have identified, we believe that the PMC has potential value in a number of areas: 1) triage, 2) monitoring, 3) record keeping, and 4) evacuation of troops (identifying location and condition remotely). The problems of acceptability, practicality, medical need, and so forth can be determined early on at relatively low cost to the Army. The PMC system could be designated for a wide variety of uses initially, without requiring general-issue deployment through the entire Army.

V. REMOTE SENSING

A. Definitions

In this section, remote sensing is defined to include all sensors not worn on or carried by the individual soldier. The data from remote sensors fall into two categories: image data and point-data. The data contained in an image can be presented for human interpretation or automatically reduced to a few numbers which contain the information needed for manual or automatic decisions. The data from sensors located at fixed points can be interpreted individually or assembled to form thematic maps which provide an image-like overview of the battlefield.

A color television camera or a handheld thermal scanner can provide image data from the battlefield. When pointed directly at the soldier, this type of imager has potential as an aid in evaluation of his health status. This type of imaging will be termed "proximal". Other types of imaging will be referred to as "remote". Remote imagers have limited potential for health applications due to their wider fields of view and coarse spatial resolution. Orbiting satellites can provide images of the overall battlefield; however, due to their relatively poor spatial and energy resolution this technology is not considered to be appropriate to our task.

Acoustic sensors including infrasonic (seismic), sonic, and ultrasonic have found application in detecting vehicle and troop movements. This type of sensor may be a useful indicator of motion and, hence, a sign of life. However, deployment of these sensors to effectively determine reliable health parameters of individual soldiers seems unlikely. Other potential point-data sensors include those which measure a property of a region in their vicinity (permittivity, transmittance, etc) to infer the presence of metal, increased humidity, etc. These sensors can be quite effective in describing the soldier's environment (especially on the chemical or nuclear battlefield).

A georeferenced map with quantitative (and qualitative) indication of non-geographic phenomena (a thematic map) can be used to integrate the data from imagers and point sensors and present that data for interpretation.

The most effective use of remote sensing techniques is in conjunction with personal sensors which are worn on the soldier. A "handheld personnel scanner" which would be aimed at the face of the soldier and provide an image for interpretation by the corpsman (or relay the image to a central computer) is envisioned. The handheld personnel scanner could also interrogate the personal sensors worn on the soldier and provide immediate data to the medic and/or transmit the data to the central computer.

B. Potential Utility for Medical Applications

Triage:

Handheld personnel scanners could enable the corpsman to rapidly evaluate the condition of personnel based upon evaluation of images and data obtained from personal sensors worn by the soldier. Wide-area imagers could be used as an aid to triage (based on motion); to be used without human intervention, this capability requires the development of artificial intelligence algorithms for recognizing the human form.

Thematic Maps:

Data from handheld personnel scanners and wide-area imagers could be called for presentation in thematic maps of the battlefield. Information regarding the location of medical resources and the areas needing the resources could be superimposed on the map to aid in allocation.

Data from fixed-location sensors, such as chemical-agent detectors, could also provide information relevant to the soldier's environment and, therefore, serve as an aid in interpreting the data from personal imagers and sensors.

Rescue:

Based on terrain, data provided by fixed location sensors, and casualty distributions obtained from personal monitors and/or personal images-- optimum plans and routes for rescue can be determined.

C. Costs and Benefits

To the extent that handheld scanners would enable the corpsman to quickly evaluate the status of soldiers and relay that information to the appropriate HQ, the benefit of the scanner would seem to be significant. The benefit is enhanced by the option to use relatively short range communications to perform the basic triage objective while maintaining (in the handheld device) the capability for effective long-range communication of secure information to the HQ.

Since most of the data would be processed on-the-spot, the handheld personnel scanners would not load the central data system with image data and, therefore, the system could be low cost in that respect.

The battlefield of the future will probably have image and fixed-sensor data for purposes other than medical. The hardware would be in place. Therefore, use of the remotely sensed data by off-line computers for medical purposes would add little cost to the existing system and provide a great benefit to the soldier and, at the same time, provide the commander with casualty information.

The use of robots in the future battlefield (for whatever purpose) would provide potential platforms for imagers and "fixed location" sensors. Computers which handle and relay the information from the robots could be used to process the data before is integrated into the central system.

D. Availability of Technology

Optical radiation is presently used by industrial robots for positioning, recognizing, and handling of parts on assembly lines. Food quality, health parameters, blood quality, and many other quality parameters are routinely assessed by evaluation of the spectral optical properties of materials. Wide scale imaging is used (not in real time) for crop yield prediction and (real time) aircraft control in FLIR systems. Real time application of simplified versions of these pattern-recognition techniques to the interpretation of the combination of facial images and data from personal medical sensors is feasible.

Radar is presently used in military applications for weather maps, identification of nearby objects, and identification of distant objects (ships at sea). Soil maps indicating the type and moisture profiles are probable in the near future. Thematic mapping of geographic data, remotely sensed data, and other ancillary data is a routinely used tool for processing images of earth-resource data gathered from satellite and aircraft platforms. The technologies involved in creating and interpreting these thematic maps can be applied to the problem of providing an integrated overview of the medical situation on the battlefield.

Major Development Tasks Required: The tasks required to develop distant remote-sensing systems are monumental when compared to the tasks of the development of the handheld personnel scanner. Therefore, the following discussion will be limited to the development of handheld personnel scanner system.

Tasks required for the development of the handheld personnel scanner:

a) determine the vital information which can be obtained by

1) non-contact sensors: thermal and/or reflective infrared images, ultrasound, sound, and other sensible body signals such as subsonic vibrations and electrical signals.

2) scanning of personal sensors such as the PMC, chemfets,etc

b) development of techniques to obtain the vital information

1) research the imaging and other non-contact sensing techniques with respect to utility and reliability

2) based on success with human evaluation of images, develop artificial intelligence hardware and algorithms for automated evaluation

3) develop personal sensors (similar to PMC)

4) determine the appropriate algorithms for integrating the personal sensor data with the data gathered by imagers or other non-contacting techniques

c) development of hardware units which are suitable for integration into a handheld package for military usage

d) design communications and computer systems

1) determine the level of intelligence which should be present in the handheld scanner as opposed to the amount of processing which would be done at a central location

2) develop the communications system with appropriate security with respect to enemy interception of transmitted data and the use of the transmission as a target acquisition device

3) design the central information handling facilities and procedures for interface with a central battlefield imaging system.

e) integrate hardware into a package suitable for military operations

f) design, development, and testing of prototype systems

E. Acceptability to the Soldier

The use of handheld scanners by corpsman has advantages. The coordination of information regarding status and casualties into the overall battlefield information system should be perceived positively by the soldier as it will enhance his chances for rescue and survival. Acceptance problems for remote sensors are not seen to be great. There may be some reluctance to be scanned by a handheld scanner; however, this unit would typically be used on unconscious personnel.

F. Communications Requirements.

The communications requirements for the data from the personal sensors may be somewhat reduced in that relatively short range transmissions to the handheld personnel scanner are feasible. Data from the imager will probably be processed (manually or automatically) on-the-spot. This may reduce the communication to simple decisions, rather than images.

G. Data-Processing Requirements.

As discussed in Section V, the data from personal sensors would be processed by distributed processors to indicate the location and status of soldiers and the reduced information would be entered to the central databank for presentation on the central computer. Presentation in image and/or statistical form is envisioned. Historical data would be maintained at the appropriate computer.

Complete personal images could occasionally be relayed to an intermediate station for evaluation or human interpretation; however, the normal mode would be to transmit decisions only. The decisions and historical data would be handled in a manner similar to the data from the PMC.

H. Potential Problems with System Operation

There is some concern that the amount of radio-frequency transmission associated with the transfer of information to a central facility would allow enemy forces to aim missiles toward the corpsman in the triage operation or the computer center which is sending and receiving messages. In addition, the central computer would have high intelligence value and its capture, at any phase of the battle, might cause severe problems. The problems of data transmission and security will be encountered with any system involving central handling of data.

The localized use of a handheld personnel scanner (without transmission) is not without security problems; enemy capture of such a unit could lead to exposure of troops unaware of the capture.

Enemy alteration of sensor environment (e.g., a bag over a fixed location gas-sensing unit or electronic jamming of sensors or transmissions) is seen as a potential difficulty with all types of systems.

VI. COMPARATIVE EVALUATIONS OF TWO SYSTEMS

Outline

This section compares the potentials of the PMC (worn on the person) and proximate remote imagers (used without the PMC). Distant and wide-area remote sensors were rejected as potentially useful technologies in that they do not have adequate sensitivity or resolution to be effective in the determination of the medical condition of personnel under the wide variety of environments and situations encountered on the battlefield.

These technologies (discussed in Chapters V and VI) are compared with respect to

A. Quantity of Obtainable Information
B. Quality of Obtainable Information
C. Reliability of Obtainable Information
D. Susceptibility to Enemy Countermeasures
E. Complexity of Operation
F. Training and Personnel Requirements
G. Acceptability to the Individual Soldier
H. Durability and Ease of Service
I. Achievability with Present Technology
J. Conclusion

If one adopts the following rating system:

1 = Excellent
2 = Good
3 = Fair
4 = Poor

then PMC's can be compared to proximate imagers as indicated in Table VI-1 on the following page.

A. Quantity of Obtainable Information

The information obtained from distributed processing by the PMC's could be efficiently transmitted to a centralized database. It would be possible for dozens of data values to be gathered and stored for each of hundreds of troops. Of necessity, some sort of statistical evaluation and graphic display will be needed to make this information meaningful--for example a false color map of the terrain indicating distribution of soldiers in the area.

Remote sensing systems often deal with complex images, each comprised of tens of thousands of data values. Due to the large number of data points involved, routine transmission of digitized images to a control center is very unlikely. However, transmission of analog images in a television format is probably routine under secure conditions. The question of how and where to process the image requires careful consideration. Some image

Table VI-1: Summary comparison of individual and remote sensing systems

Attribute	Individual sensing (PMC)	Proximal Imaging
Quantity of obtainable information	1	1
Quality of obtainable information	1	3
Reliability of obtainable information	2	3
Susceptibility to enemy countermeasures*	2	2
Complexity of operation**	2	3
Training and personnel requirements	2	3
Acceptability to the individual soldier	2	1
Durability and ease of service	2	3
Achievability with present technology	1	2
Over-all rating	15	21

* 1 = least susceptible
** 1 = least complex

systems may yield the needed information with a minimum of electronic processing (particularly those utilizing human interpretation of the image). Whereas, fully automatic analysis of image data usually requires sophisticated information processing techniques and considerable computer resources. Therefore, it is likely that most images would be gathered by a scanner near the soldier and processed in-situ by manual or semi-automatic means. The extracted information would be of immediate use to the corpsman; however, the information or complete images could be optionally transmitted to a distant central facility.

In summary both types of system provide abundant data; the problem, in fact, is that of sorting out the wheat from the chaff. This problem leads one to consider the quality of information obtained by the two types of systems.

B. Quality of Obtainable Information

Medically relevant signals that can be acquired by the two types of systems are listed in Table VI-2.

Table VI-2: Physiologic data obtainable by PMC and Proximate Imager

Signal	PMC	Proximate Imager
Body temperature	yes	yes
Activity (motion)	yes	yes
Heart beat	yes	no
Respiration	yes	no
Voice	yes	no
Exhaled CO_2	?	unlikely
Chemical contaminant	yes	no
Response to circulatory shock	yes	?
Location of subject	yes	yes
Ability to monitor enemy troops	no	yes

Because the sensors for the PMC are in contact or very near to the subject, their potential to detect medically relevant information is great. Since a wide variety of sensors may be used with the PMC, a superior estimate of the soldier's condition is possible. Under some conditions, it may be possible to use the transponder feature of the PMC to locate an unconscious soldier. Furthermore, it may be possible to use directional stimulus signals or triangulation to remotely determine the approximate location of the soldier.

A particular disadvantage of the proximate imager is that it can't see through clothing and face masks and, usually, cannot be used (by itself) to locate a soldier obscured by ground cover. Unfortunately, for medical purposes, under field conditions, the imager will probably be limited to sensing the spatial distribution of facial temperature or infrared reflectance. This limitation obviates the use of the device on the chemical battlefield and in other situations where the face of the soldier must be covered. A more subtle, but very important, disadvantage is that the proximate imager will probably have, at most, two operant modes. This limits the kinds of relevant medical information which can be extracted from the electromagnetic data. A powerful advantage of the proximate imager is that it may be able to quickly determine the life status of the soldier from a reasonable distance without the use of radio or ultrasound communication. In some instances, the scanner may be able to see in the dark and this capability could be critical to effective triage and, perhaps, provide a means to locate enemy troops. Other advantages of a handheld imager are that it would have the means to transmit data over greater distances and provide more accurate location information than the small transponders.

In summary, the quality of medical information obtainable by the PMC is potentially much superior to that of the proximate imager. This is based on the wider range of medical data available from the PMC and the direct contact of the sensors. However, both techniques offer medical information potentially useful to the triage operation.

C. Reliability of Obtainable Information

Any sensor can pick up unwanted signals i.e. artifacts. Their frequency and severity depend upon the selectivity of the sensor and the way in which it is used. In general, each data channel of an individual sensing system will be plagued by particular artifacts under certain adverse conditions. For example, a motion detector will pick up vehicle movement, or exploding artillery; an electrocardiogram detector will pick up muscle and electrical noise; a body-temperature detector may be "fooled" in certain climates. Of course, false conclusions are less likely upon evaluation of data from a <u>multichannel</u> personal monitor. Furthermore, techniques can be developed to take into account the most common artifacts.

Many factors affect the electromagnetic radiation emitted from and reflected by surfaces. While many of the atmospheric transmission factors can be eliminated by proximate imaging, the image will still be modified by conditions of the skin which are not relevant to the medical condition of the soldier. For example, blood and mud containing different amounts of moisture will drastically affect the emissive and reflective properties of the skin. In addition, the natural variability from subject to subject will provide additional "noise". The reliable extraction of useful medical data from proximate images may be severely restricted by these factors. On the other hand, human interpretation of efficiently enhanced images may be able to extract the desired information from the image.

In summary, the reliability of the information from both systems may be less than ideal; however, the PMC will probably provide more reliable data than the proximate imager because it provides more kinds of information and the sensing arrangements are inherently more reliable.

D. Susceptibility to Enemy Countermeasures

Any military system created by man is susceptible to some sort of enemy countermeasure. PMC's can be sabotaged in a number of ways. The enemy could passively home in on signals from PMC's to learn the number of casualties after a battle or detect the existence of special forces on covert missions. The enemy could activate PMC's with a stolen or bootleg interrogator to learn which officers and men are in a given area, locate troop concentrations, or possibly locate key personnel. Similarly in peacetime, teams of enemy agents could use interrogators to size-up forces at a particular base.

All of the enemy countermeasures just identified are susceptible to counter-countermeasures. For example, if it is learned that the enemy is scouting a particular base with a bootleg interrogator, false information could be sent out from phantom PMC's. If the enemy suspects a covert mission is underway, phantom PMC's could be parachuted to a misleading location to draw the enemy away from the actual site of the mission.

There are also straightforward technological remedys. For example, lost or stolen PMC's, and PMC's of known dead can be locked out of future consideration by data analysis software. Encryption systems can be changed in order to make stolen interrogators obsolete. The interrogator, if interactive, must broadcast much longer than any single PMC, and will probably radiate more power. The enemy can probably learn most by monitoring interrogator queries. Limiting the range of the interrogator is an obvious solution.

An individual monitoring system, like any new weapons system, will require intelligent use. If properly used the system can be of benefit to the Army. If captured the system may also be of benefit to the enemy. However, the ability of an enemy to inflict serious damage upon alert friendly forces is amenable to a variety of countermeasures.

Proximate imaging systems are subject to the communications problems mentioned above. While relatively little information will normally be transmitted, the transmission of images to the HQ would probably be performed in secure situations. If captured, the imaging device could be used by enemy agents to allow them to appear to be friendly corpsmen. An active scanner will provide its own illumination and this may be sensed by enemy forces and used to direct sniper fire.

In summary, both types of system are susceptible to enemy countermeasures. Some knowledge is required in interpreting the received data, as is true for any battlefield information. There is little difference in the vulnerability of the proximate imager and a field interrogator for the PMC's. However, unlike the field interrogator, the proximate imager does pose some threat since it might be used to locate enemy soldiers. As a result, there would be more incentive to try to disable the imager. Furthermore, extended transmissions of images to the HQ would allow more accurate detection of the location of the imager. However, since the proximate imager would not be disabled from performing its basic function by communications jamming, it is felt that the effect of enemy counter- measures would be about equal for both types of system.

E. Complexity of Operation

Each individual PMC would contain sophisticated microelectronics, roughly an order of magnitude greater in complexity to that of a modern digital wristband. Once designed, debugged, and reduced to large-scale integrated circuits, however, such units would function as individual replaceable units and would not appear complex to the user. The interrogators would be simple to use.

The complexity of operation of proximate imagers is comparatively much greater than for the operation of the PMC system. The corpsman would be required to locate the soldier, properly operate the imager, and interpret the enhanced image. Any automatic evaluation of the image by the handheld device would require a rather complex algorithm and considerable expertise to interpret the result.

In summary, operation of the proximate imager is inherently more complex than the operation of the PMC system.

F. Training and Personnel Requirements

In the same vein, personnel operating the proximate imager would require more extensive education and technical training. Medical officers and commanders would need to understand the limitations and capabilities of the device and be able to interpret the images and derived data.

The digital image processing to provide useful information from the multispectral scanners requires very fast computers with large memory capacities. The task is not unlike analyzing meteorological and earth resources satellite data. Computer systems of this size would require maintenance personnel as well as specifically trained operators. However, should the military develop a battlefield imaging system for tactical purposes, the additional hardware, software and personnel training necessary for casualty location would not not be prohibitive if designed into the system from the outset.

Training for operation of the PMC system we see as being relatively less complex. However, a larger number of people will need to be trained. Individual soldiers must wear the PMC. Medical personnel and commanders or their assistants must learn to use the interrogators and computer programs for interpreting incoming data.

In summary, individual sensing systems will require minimal training for GI's and modest training for officers who will use the information generated. Proximate imager systems will require a small number of highly trained specialists.

G. Acceptability to the Individual Soldier

Whereas proximate imaging systems require little of the individual soldier, whether or not combat troops will wear individual sensors reliably is a very important concern. The device must be small enough to be of negligible weight, unobtrusive, comfortable, and non-confining. In practice, a PMC is almost certain to be larger than a conventional dogtag or watch (although exactly how much larger is difficult to predict, and will depend upon its capabilities and technical sophistication). Certain of its functions may require that it be secured to the skin surface more tightly than by a simple neck chain. Extra straps are unlikely to be accepted by soldiers, although a wristband-like device would probably be worn. More research is needed on the human factors engineering aspects of any system to ensure that the devices would not be discarded.

H. Durability and Ease of Service

Microelectronic systems share common features of durability and ease of service. Once manufactured and tested they are fairly reliable. Troubleshooting can be made relatively simple (replace whole chips) and can be supported by artificial intelligence (self testing programs).

Maintenance problems tend to increase with the physical scale of the system (i.e. with the number of memory units or logic gates), and service of imaging systems we see as being inherently more difficult than that of PMC's or interrogators. PMC's, if faulty, could be thrown away and replaced. Each new one, however, would require initialization for a given soldier--programming it with his name, rank, serial number, blood type, past medical history, etc. Ideally this job could be done using any interrogator unit. Servicing of the interrogators, in turn, would be equivalent to servicing any microcomputer.

I. Achievability with Present Technology

A first-generation PMC system seems achievable with present technology. Indeed a primitive type of personal heartbeat monitor was developed for commercial use by Texas Instruments, Inc. ECG-based pulse monitors are sold by Seiko; Casio has developed a temperature sensing watch for divers and sportsmen. Adequate telemetry systems already exist in military, space, and commercial applications, and could probably be included into a PMC without excessive size or weight. First-generation portable imaging systems for determining medical information will require the development of additional technology.

J. Conclusion

Both individual and remote-sensing systems could be developed by the Army for casualty identification and triage on the battlefield. Individually worn sensors provide higher quality information, but only if they are worn reliably by individual soldiers. Hence human engineering must accompany electrical and biomedical engineering in the design of such systems. Provided that human factors are taken into account, the PMC system seems to offer the preponderance of advantages.

VII. FURTHER APPLICATIONS OF ARTIFICIAL INTELLIGENCE/ROBOTICS

A. Artificial Intelligence

In general, artificial intelligence (AI) is a term that is applied to a computer program that exhibits some of the characteristics of human reasoning. When computer scientists refer to artificial intelligence they usually mean a set of specific programming techniques. These techniques are applied in similar ways to different problems. State-of-the-art applications using AI techniques have a similar structure, whether referring to signal-processing, image-understanding, expert or knowledge-based systems, or intelligent sensors.

Current systems are structured of three main components, as shown in Figure 6. For purposes of illustration we can use a fire allocation system for an artillery battalion to demonstrate how the three components work. First there is a set of input data. These data can be pieces of information from electronic sensors, scouting reports and pertinent facts about the weapons available (such as number and types of artillery as well as ordinance supplies). Second, there is the "knowledge base". This "knowledge base" is a set of rules that have been defined previously by computer programmers working with human artillery experts. These rules have been coded such that the computer program can access them. Lastly there is the "inference engine". The "inference engine" is a computer program that uses the input data in conjunction with the knowledge base to form and test a set of hypotheses and then make deductions and recommendations. In this example some recommendations could be:

- Fire 3 weapons (8 rounds each) at coordinates x,y. Positive tank column.

- Fire 2 weapons at coordinates x,y. Probable artillery command post.

- Probably outnumbered. Send for reinforcements or pull back.

Recent systems have the ability to trace through the reasoning for the user. This feature is very helpful while developing the knowledge base and also increases user confidence. In theory, with a careful design the inference engine will not need to know about the nature of the inputs or the knowledge base. Consequently, the same program could be used for a different application merely by changing the knowledge base and adjusting the input interface for the different input data.

Following is a list of some of the "expert systems" that have been developed or are nearing completion. Several of these are in areas of medical application, emphasizing the potential for AI in battlefield casualty care.

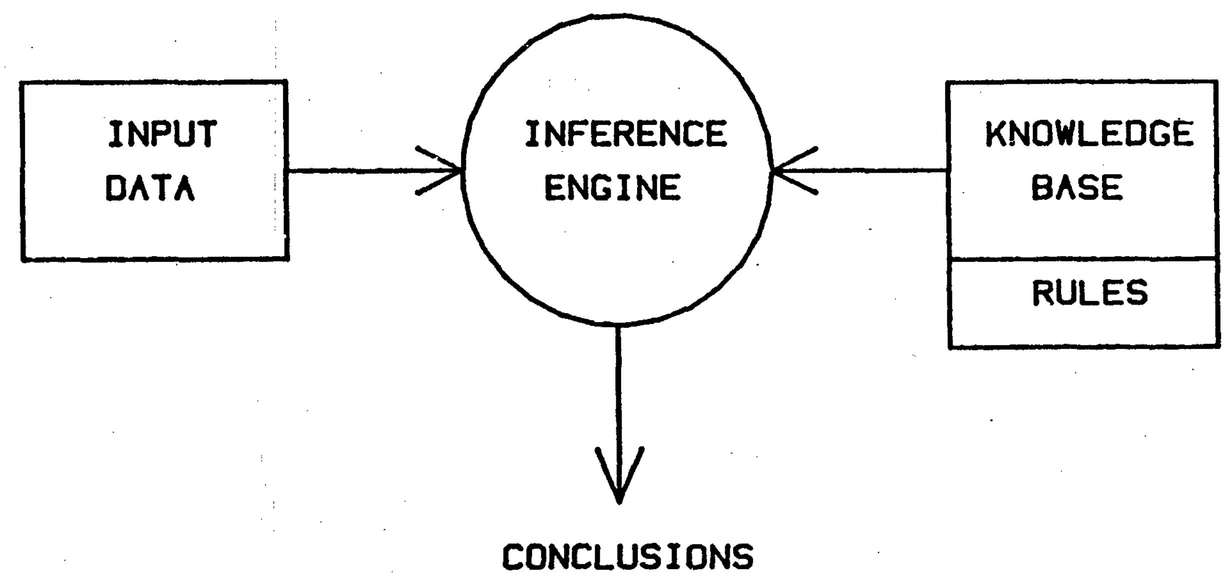


FIGURE 6
EXPERT SYSTEM

• MYCIN

MYCIN is an expert system, developed in the mid 1970s, to diagnose infectious diseases. The system was successful in that its diagnoses compared favorably with those of practicing physicians. It was unsuccessful in that it has never really been used extensively. MYCIN is a relatively primitive system when compared to systems under development today.

• R1

R1 is an expert system developed by Carnagie-Melon University for Digital Equipment Corporation (DEC). This system is used to configure VAX-11 computer systems. VAX systems can only be ordered in individual pieces, of which there are over 1000. In the past, DEC had people look over the orders and decide whether they represented a working system. If they decided that it was a complete system and it later turned out that it wasn't, then DEC would supply the missing pieces at no charge to the customer. R1 has been used to test the orders for complete system criteria for two years with a savings to the company of approximately ten million dollars per year. Monetarily, this makes R1 the most successful expert system to date.

• CADUCEOUS

CADUCEOUS is an expert system for medical diagnosis. In some ways it is similar to MYCIN. However its scope is much larger. CADUCEOUS attempts to include the whole of internal medicine in its knowledge base. In that respect it is at least an order of magnitude more complex then MYCIN. It also differs in that the mechanisms used for reasoning are much more highly developed. At the present time approximately 80% of the designers goal has been implemented.

The existence of such systems today indicates that computer aided triage by the central computer assigned to monitor PMC's of many soldiers is distinctly possible with present technology.

B. Robotics

• Industrial Machines

A good way to evaluate the state of the art in industrial robotics is to examine the industries' current definition of a robot. "A robot is a manipulator (mechanical hand) mounted on an arm (with several degrees of freedom) attached to a fixed base". This is a far cry from the concept seen in science fiction and from that required to meet military objectives (except in manufacture). Industrial robots are very good at repetitive tasks such as spot welding, spray painting and machining. Sophisticated system combine low resolution video cameras and computers to do things like positioning an unsymmetric part correctly so that it can be placed in a jig. There are some systems that are mobile, such as a lift truck that follows a cable buried in the floor, but there is presently nothing approaching a fully autonomous vehicle.

- Autonomous vehicles

Research is underway to solve problems using fully autonomous vehicles. Some of these will be reviewed.

Prof. Rodney Brooks of the MIT Artificial Intelligence Lab is developing AI techniques to analyze the scene from a camera to navigate a robot around obstacles and placing payloads. He has developed a new symbolic representation of space that shows promise for autonomous robots. Dr. David Tseng of Hughes Research Laboratories is conducting research on using an AI approach to real-time control systems for autonomous vehicles. He has developed a test bed and has had good results in the laboratory. Honeywell Inc. has an autonomous roving land-mine under development. This is a tracked device that uses multiple sensors to navigate and locate an enemy tank which can be identified by several techniques. The primary one is pattern matching of a seismic signature. In general, autonomous vehicles are probably not sufficiently developed to be of use in Army medicine in the next 10 years.

Although practical field autonomous vehicles appear to be several years in future, some of the applications seen for them can be realized in the interim by remotely piloted vehicles.

- Remotely Piloted Vehicles (RPV's)

Both NASA and the Army have remotely piloted vehicle development programs underway. These RPV's are intended to fill a variety of needs, but the primary use is for a platform on which to mount sensors for gathering intelligence information. The NASA device and one of the Army devices are small fixed-wing aircraft. Another Army RPV is a land-based vehicle intended to carry sensors or weapons systems. Also, the Marine Corps is developing a small (3ft. diam.) lightweight (under 60 lbs) flying disc that uses a fan type rotor.

C. Future Applications of AI and Robotics to the Medical Mission

- Robot Medic

It is theoretically possible to build a robotic device that can independently locate a wounded soldier, evaluate his condition, give first aid, and move him to a medical care facility. Such a device would essentially be a replacement for the medical corpsman. However, even superficial examination of the state of the art of artificial intelligence and robotics will show such a device is not feasible at the present time. Most of the work in this area involves the design of autonomous weapons delivery systems. Some of these systems are in place and many more of them are a few years away from practicality. However, with robots, as with the humans they model, it is an order of magnitude more difficult to effectively treat a dying man than to locate and fire at a target.

- Resource Allocation

Another future application of AI is the allocation and management of medical resources. The logistics of wartime medicine has always been a large problem and the threat of fighting future battles with highly mobile forces over large fronts greatly complicates resource management. Work is underway to provide the Armed Forces with an overall information and resource management network. The Medical Command must make sure that medical resources and information are included in the system.

VIII. CONCLUSION

A feasible system for automated vital-sign monitoring and triage on the battlefield can be developed with present technology. The most straightforward approach would include wearable personal sensors, similar to a wristwatch, worn by a soldier and capable of short-range communication with interrogator devices. Effective remote-sensing systems that do not rely on wearable sensors are also possible but the fundamental technical problems to be overcome are very much greater than those of systems using wearable sensors. Aside from technical problems in areas of physiology and electronics, problems of security and soldier acceptability must be addressed and solved for any such systems.

As the final draft of this report was written, rescue attempts were underway for more than 200 marines who were in the rubble of a bombed building in Beruit, Lebanon. Although this condition was not considered by us in preparation of this report, the value of a personal monitor on each soldier which enables precise location of that soldier is obvious. The living, but injured soldiers could have been pinpointed under the wreckage, and rescue teams would have known where to dig.

IX. RESOURCE DOCUMENTATION

NAME, ADDRESS, AND TELEPHONE	SUBJECT
HERMAN MADNICH U. S. Army Natick Research & Development Laboratories Attn: DRDNA-ICCC Kansas Street Natick, MA 01760 (617) 651-5431	Combat clothing for the soldier
KARL D. BZIK, M.D., F.A.C.S. (Colonel) U. S. Army Medical Corps for Medical Research Combat Casualty Care Letterman Army Institute Presidio San Francisco, CA 94129 (415) 561-5818	Surgical combat casualty care and triage
JAMES TYLER (Major) Academy of Health Sciences Fort Sam Houston San Antonio, TX 78234 (512) 221-5371	Organization and procedure for medical care on the battlefield
RICHARD MILLER, PH.D. School of Aerospace Medicine Brooks Air Force Base, TX 78235	Chemical field-effecter development for chemical defense
A. L. KUEHN (Captain) DRDAR-CLE Chemical Systems Laboratory Building 3330 Aberdeen Proving Ground, MD 21010	Artificial intelligence/robotics

NAME, ADDRESS, AND TELEPHONE	SUBJECT
MATT HUTTON Chief Threal Evaluation Group Systems Development Division Chemical Systems Laboratory Building 3330 Aberdeen Proving Ground, MD 21019	Artificial intelligence/robotics
BERNARD FROMM DRD AR CLC-CK Chemical Systems Laboratory Building 3330 Aberdeen Proving Ground, MD 21010	Artificial intelligence/robotics
HENRY WATSON Naval Research Laboratories Washington, DC 20390 (202) 767-2622	Artificial intelligence/robotics
E. L. QUARANTELLI, PH.D. Department of Sociology Disaster Research Center Ohio State University 1659 North High Street Columbus, OH 43210	Dynamics of handling large groups of casualties
DAVE NORDIN Resuscitation Products Manager McMinnville Division Hewlett-Packard 1700 South Baker Street McMinnville, OR 97128 (503) 472-5101	Monitoring of CO_2, Blood pressure, pH, ultrasound, infra-red fiberoptics
KEN PATTON General Manager Hewlett-Packard McMinnville Division 1700 South Baker Street McMinnville, OR 97128 (503) 472-5101	Monitoring of CO_2, Blood pressure, pH, ultrasound, infra-red fiberoptics

NAME, ADDRESS, AND TELEPHONE	SUBJECT
WILLIE JOHNSON CSTA Laboratories Attn: DELCS-R Fort Monmouth, NJ 07703 (201) 544-5723	PLARS tactical data system, electronic signal detection, RADIAC system
BOB TORREGROSSA CSTA Laboratories Attn: DELCS-R Fort Monmouth, NJ 07703 (201) 544-5723	PLARS tactical data system, electronic signal detection, RADIAC system
EDWARD GROEBER Branch Chief Radiac Division CSTA Laboratories Attn: DELCS-K Fort Monmouth, NJ 07703 (201) 544-5723	PLARS tactical data system, electronic signal detection, RADIAC system
BILL MURPHY (Major) CACDA Fort Leavenworth, KS 66027 (913) 684-2886	Battlefield scenarios
CLIF ALFERNESS Physio Control Corporation Redmond, WA 98052 (206) 881-4000	Life-signs monitoring, emergency medical care
MEL BARNEY Texas Instrument Company Dallas, TX 75221 (214) 995-2011	Temperature and heart rate monitoring from wristband-like devices
SHAWKI IBRAHIM CTS Corporation 1201 Cumberland Avenue West Lafayette, IN 47906 (317) 463-2565	Multi channel miniature transceivers

NAME, ADDRESS, AND TELEPHONE	SUBJECT
HOWARD HEALY Honeywell Defense Systems Division 600 Second Street NE Hopkins, MN 55343 (612) 378-4000	Research and available technology in sensors, communications, military applications
JOHN CICERELLO Honeywell Defense Systems Division 600 Second Street NE Hopkins, MN 55343 (612) 931-7094	Research and available technology in sensors, communications, military applications
RAYMOND R. RAGOUSKAS (Major) 1149 Dorthy Lane Harber Heights, TX 76543 (Fort Hood, TX)	Observe field maneuvers of 2nd Armored Division; briefing with 1st Cavalry Division
GARY CARLTON (Lieutenant) Brooks Air Force Base, TX 78235 (817) 685-5132	Air Force vital signs monitor
C. OCCHIALINI Department of the Army U. S. Army Soldier Support Center Fort Benjamin Harrison, IN 46216 (317) 542-3782	Soldier Support Tag
ANTHONY SANCES, JR. Professor and Chairman Biomedical Engineering Department of Neurosurgery The Medical College of Wisconsin 8700 West Wisconsin Avenue Milwaukee, WI 53226 (414) 257-5307	Bioelectric event sensors

NAME, ADDRESS, AND TELEPHONE	SUBJECT
JAMES R. BUCK Professor and Chairman Program in Industrial and Management Engineering College of Engineering The University of Iowa Iowa City, IA 52242 (319) 353-6083	Human factors analysis
RICHARD S. C. COBBOLD, PH.D., F.R.S.C. Institute of Biomedical Engineering University of Toronto Toronto, Canada M5S 1A4	Solid state biomedical transducers
THEO C. PILKINGTON Professor of Biomedical Engineering and Electrical Engineering Department of Biomedical Engineering Duke University Durham, NC 27706 (919) 684-6185	Signal analysis of biological signals
JANUSZ BRYZEK I.C. Sensors Inc. Sunnyvale, CA 94088	Piezoresistive IC pressure sensors
ALFRED DUMBS Fraunhofer-Institut fur Physikalische Messtechnik Freiberg Germany	Sensors for robots
A. L. HAMER Battelle Switzerland	Fiberoptic sensors

NAME, ADDRESS, AND TELEPHONE	SUBJECT
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D. W. LUBBERS Max-Planck-Institut Germany	Biological and chemical sensing with optical techniques
K. D. WISE University of Michigan 3505 East Engineering Building Ann Arbor, MI 48109	Distribution of intelligence in integrated sensing systems
WEN H. KO Case Western Research University Cleveland, OH 44106	Pressure transducers for medical use Case Western Reserve
TOM COOK P.O. Box 997 N.O.S.C. Kailua, HI 96734	Cognitive Psychology / Human Factors (NAVY)
JOHN MCCARTHY Department of Computer Science Stanford University. Stanford, Br. Palo Alto, CA 94305	Artificial Intelligence
DR. RAJ AGGARWAL Honeywell Systems Research Center 600 Second Street NE Hopkins, MN 55343 (612) 378-4000	Image Understanding

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