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**EXECUTIVE OFFICE
OF THE PRESIDENT**

OFFICE OF TELECOMMUNICATIONS POLICY

✓
SECOND REPORT ON

**"PROGRAM FOR CONTROL OF ELECTROMAGNETIC POLLUTION
OF THE ENVIRONMENT: THE ASSESSMENT OF BIOLOGICAL
HAZARDS OF NONIONIZING ELECTROMAGNETIC RADIATION"**



MAY 1974



FOREWORD

This report summarizes activities over the past year (1973) associated with the Federal Government's multiagency program, being coordinated by the Office of Telecommunications Policy (OTP), to assess the biological effects of nonionizing electromagnetic radiation. It covers the period following that reported by OTP in March 1973.*

This program was recommended by the Electromagnetic Radiation Management Advisory Council (ERMAC) which was established in 1968-69 to advise the Director, Telecommunications Policy, on possible side effects and the adequacy of control of electromagnetic radiations associated with the use of the spectrum.

The purpose of this cooperative undertaking is to ensure the well being of man and his environment without unnecessarily restricting his use of the electromagnetic spectrum and the many benefits it provides.

* Office of Telecommunications Policy Report, "Report on 'Program for Control of Electromagnetic Pollution of the Environment: The Assessment of Biological Hazards of Nonionizing Electromagnetic Radiation'", March 1973.

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I. INTRODUCTION AND SUMMARY

This document summarizes activities pertaining to the multiagency Federal Government program, being coordinated by the Office of Telecommunications Policy (OTP), to evaluate the biological effects of nonionizing electromagnetic radiation (EMR), with emphasis on the portion of the spectrum between 0 and 3000 GHz. It covers activities and progress in Calendar Year 1973, and is intended to present an overall picture of the Program. Facets of the Program activities are also reported by individual agencies.

This program, consisting of individually funded agency undertakings, was recommended by the Electromagnetic Radiation Management Advisory Council (ERMAC) to the OTP in 1971, following a review of the subject and associated activities within the Federal Government. Their report, "Program for Control of Electromagnetic Pollution of the Environment: The Assessment of Biological Hazards of Nonionizing Electromagnetic Radiation," December 1971, outlined the need for such a program, its objectives, priorities and general framework, including recommended roles of individual agencies and departments, consistent with their missions and responsibilities.

In January 1972 the program was approved and coordinated by OTP with cognizant agencies for implementation in Fiscal Year 1974, and earlier insofar as practicable.

The objectives are:

- o To determine what effects these radiations have on living organisms under different conditions of exposure--that is, the effects of various frequencies, waveforms, energy levels, and exposure durations, as well as biological considerations of age, sex, health, etc.
- o To determine the clinical significance and assess the hazard, if any, associated with any observed effects with reference to realistic exposure environments.
- o To establish a rational scientific basis and guidelines for developing appropriate remedial and/or control measures which may appear warranted.

While it is known that some of these radiations at sufficiently high energy levels can have adverse effects due to heating, this program emphasizes the study of exposures at lower power density levels, particularly over extended periods of time.

Activities during 1972 centered on fiscal planning and establishing mechanisms to ensure adequate coordination of this multiagency undertaking.

Principal activities during 1973 were concerned with establishing a soundly based research activity of reasonable volume, appropriately oriented toward the program objectives, to serve as a foundation for future efforts. A considerable portion of the effort went into the development of exposure facilities and associated instrumentation and techniques for dosimetry and electromagnetic field measurements needed for this research. Additionally, some of the agency programs progressed to a stage where it is possible to review and assess preliminary results which will enable future efforts to be focused in more specific areas.

During the year, work was conducted in the principal program areas reported last year. Review of these activities indicates that the relative distribution of effort generally corresponds to the recommended program priorities as regards areas of biological effects research and frequency spectrum. At this early stage there are no definitive, scientifically confirmed results to report, however the work performed thus far has indicated the possibility of effects requiring further study.

Internationally, progress was made in establishing cooperative activities and technical exchange in this area. For example, an international symposium was held in Warsaw and a collaborative activity is being developed with the U.S.S.R.

II. THE RESEARCH PROGRAM

Our previous report indicated the program was to comprise some 112 projects concerned with the following principal areas wherein most of the past year's effort has been concentrated (Ref. Figs. 1 and 2):

- Genetic, hereditary and developmental studies
- Nervous system
- Behavioral studies
- General health
- Mechanisms of EMR interaction with living organisms
- Ocular effects
- Metabolism, endocrinology and biochemical studies
- Cytology/histology/morphology
- Instrumentation, measurement techniques, and facilities
- Absorption/dosimetric studies
- Environmental and safety studies

During the year, several of the 112 projects planned were modified or consolidated and new projects were undertaken. In some cases, research commenced somewhat later than originally anticipated for various reasons, e.g., unavailability of funds and exposure facilities, and efforts required to resolve problems associated with experimental setup. Other projects were completed or terminated during the course of the year.

In general, effort follows the recommended guidelines in terms of frequency and biological priorities, practical and operational needs, and the basic program objectives.

Figure 3 illustrates the distribution of project efforts in key areas of investigation by frequency spectrum and has been used in overviewing the program effort. This distribution reflects the recommended spectrum priorities with concentration of effort at microwave frequencies. It should be noted that attempts to obtain absolute totals from this presentation can be misleading because individual projects are often concerned with several related areas. Consequently, a given project may appear in more than one category.

At this stage, effort is somewhat dispersed in a multiplicity of projects which are generally smaller and are not as readily relatable to one another as might be desired. This is typical of the formative stage of a coordinated undertaking among different organizations. In view of the multifaceted questions to be answered, a certain amount of diversity is helpful in uncovering effects over a wide range of possibilities. The point is being reached however, where better focusing and close interactions among individual efforts are necessary to resolve the questions raised in preliminary research; but this should not be at the expense of those intellectual "outriggers" which can provide additional insights.

Although progress is being made, there is a continuing need for better standardization of terminology, electromagnetic (EM) field measurement protocols, instrumentation and dosimetry.

More work is needed involving chronic exposures over extended periods of time, as well as observations for possible delayed effects following exposure. Most of the present studies involve exposures over relatively short periods of time. Observations in the short-term studies can provide guidelines for the design of long-term studies, however both are needed in each of the program research areas.

Long-term (chronic) studies involving periods up to the life span of the animal and studies of successive generations, involve considerable cost and dedicated exposure facilities. Such studies are not now underway. Short of this, however, and particularly important at present, is the need for more work with exposure durations of at least several months. This is compatible with existing resources. This point was emphasized in recent discussions between U.S. and Eastern European and U.S.S.R. scientists, where it was again stated that the reported effects at low power densities in the foreign literature frequently do not occur until several months of exposure have elapsed.

No firm conclusions can be made, nor should they be expected at this early stage in the research activity. There are a few tentative and preliminary indications, however, which at present suggest that effects may occur -- in the nervous system and behavior, normal developmental and growth processes, and possibly in some metabolic and biochemical parameters -- at lower levels than anticipated in the past. It is emphasized, however, that these are preliminary observations and not scientifically validated results. In many cases they are based on single experiments in a particular laboratory involving small numbers of subjects and causal relationships between the EM fields and the observations are not yet clearly established.

In overview, the activity in several key areas is briefly summarized below. Additional information, including details of specific experiments and resultant observations, is contained in agency reports on facets of the program and various other publications resulting from the research efforts. Some of these are referenced in Appendix B.

Nervous System and Behavioral Studies

Study of possible effects in these areas was strongly emphasized as a research priority by the ERMAC.

A substantial number of individual projects included studies of nervous system and/or behavioral effects. Approximately half of these were concerned with both. Some nervous system studies were also oriented so

as to investigate mechanisms of interaction, neuroendocrine/biochemical interactions and other related considerations -- i.e. energy absorption, thermal/thermoregulatory responses, and instrumentation problems, including suitable field measurement probes and electrodes for use in radio frequency (RF) fields.

This work was supported primarily by the Department of Defense (DOD) and Health, Education and Welfare (HEW), with the Environmental Protection Agency (EPA), National Science Foundation (NSF), and Veterans Administration (VA) each supporting a project.

As Figure 3 illustrates, most of these studies are at microwave frequencies and ELF, because of the Navy's studies associated with their project SANGUINE which would operate at ELF frequencies. There are also a few studies in the HF and VHF region. This distribution is reasonable at present. The microwave frequencies are of considerable interest because: they are widely used for a variety of purposes and therefore involve exposures of substantial populations; they involve directed power; the probabilities for interactions are greater than in other spectrum regions; molecular and rotational couplings are possible; and modulations can introduce additional possibilities of interactions. In future studies, the low and medium frequency ranges should not be overlooked since some high powered systems which expose the public operate here, as does AM broadcasting.

Most of the current studies involve relatively low power levels. However, the need to establish upper and lower thresholds for any observed effect may require varying power density over a considerable range. It is quite conceivable that an effect may be observed at a rather high level which disappears or becomes insignificant with decreasing energy deposition. Such information is helpful in establishing levels of confidence with respect to possible hazards associated with a given observation, particularly when it relates favorably to realistic levels of operation.

Both continuous and modulated waveforms are being employed in these studies. It is important that the role of various modulations be emphasized. In this connection, a somewhat greater effect has been attributed to pulsed vs continuous wave (CW) radiations in some of the research literature.

Preliminary observations in several current studies suggest that under certain conditions effects may occur -- in the form of changes in certain behavior and electrophysiological activity (electroencephalographic (EEG) recordings) which appears to be associated. It is emphasized that the validity, biological significance, necessary exposure conditions, and underlying mechanisms are at present unclear. However, work to date, and Eastern European reports stressing the significance of such effects for which we lack confirmatory evidence, provide important impetus for additional work to resolve these questions.

There remains a need for studies designed to investigate possible chronic effects associated with lower exposure levels over relatively long periods of time, i.e., months to years. It is necessary to continue investigations of acute effects of shorter and, perhaps, higher levels

of exposure since this can provide bench marks and guidelines as to biological variables of interest for longer term studies.

Genetic, Hereditary and Developmental Studies

During 1973, a fairly large number of projects dealt with this general area of research. Some of these were also concerned with micro-mechanisms or biochemical/biophysical interactions.

Investigations of possible chromosomal and mitotic effects and disturbances in the normal growth and development processes predominated. The former included studies of both somatic and germinal tissues, with perhaps a slightly greater emphasis on mutagenesis and potential hereditary effects. A few studies dealt with fertility and reproduction and some were also concerned with possible endocrine/biochemical effects, e.g. nucleic acids.

The principal animal subjects were small rodents. Several studies employed microorganisms, bacterial systems and cell cultures. A few used insects and avian eggs. Studies in the ELF region associated with the Navy's Project SANGUINE employ a wide variety of organisms including plants. This reflects a broad approach to answer environmentally oriented questions associated with this proposed communication system.

As in most areas, the majority of these projects are at microwave frequencies, with a substantial number in the ELF region. Frequencies in and around the microwave region are an appropriate primary direction, particularly in this area of investigation, in view of the greater possibility of interactions occurring at the molecular level with higher quantum energies.

At present there is no clear evidence of effects at low power levels, while there clearly can be effects at sufficiently high levels (e.g., considerably in excess of current U.S. safety levels). This requires a careful "backing down" from levels at which effects can be observed. Some early studies have suggested the possibility of effects on the normal growth and development processes and an experiment with mice, although at relatively high levels, raised the possibility that teratogenic effects may occur. Again, it should be emphasized that these are very preliminary and inconclusive observations at this stage. Work will continue in these areas.

Mechanisms of EM Interaction With Living Organisms

This is an important area of study concerned with determining how energy in the EM field is transferred to the organism--and relating different modes of "coupling" to effects.

A primary direction in these studies is to determine whether there are biologically significant mechanisms of interaction other than gross or microheating or to prove that none exist. This is needed to: guide the design of experiments looking for functional effects; shed light on the question of possible effects from long term, low-level exposures and any delayed effects; and establish the validity of possible "nonthermal" effects. It is also important for hazard assessment -- to enable the prediction or extrapolation of hazards.

These studies of interaction processes make use of a variety of biological, clinical and physical techniques and involve investigations at different levels of biological organization, i.e., molecular, membrane, cellular, tissue, etc. Thus they include studies at both macro- and microscopic levels.

At present, the macroscopic electrical properties of tissues are better understood and work in this area is further advanced than is the case at the microscopic level.

Computer and phantom (synthetic) models are being developed and refined to enable more precise determination of local energy deposition under various exposure conditions.

Local concentrations of energy deposition could affect certain body chemicals which could, in turn, become manifest in more readily observable behavioral or functional changes such as alterations in the normal growth and development processes, etc. The complexity of interrelationships, biological redundancy, and the existence of numerous "alternatives" or compensatory mechanisms makes observations of subtle chemical changes quite difficult.

Studies of effects involving cell membranes and their properties, particularly neuronal, are important here and require more emphasis in future studies.

While there are currently only a few studies primarily investigating mechanisms of EM interactions, a number of studies in other program areas (e.g., nervous system, metabolic/biochemical, etc.) include a substantial effort directed toward uncovering pertinent mechanisms.

The study of mechanisms is a difficult area of basic research with very few hypotheses at the present time. These studies need to be conducted in parallel, and to be reciprocally interactive, with more phenomenologically oriented studies -- both providing and taking guidelines from findings in other areas.

Ocular Effects

Studies of ocular effects have been predominantly concerned with cataractogenesis and lenticular changes.

Almost all of the current studies are at microwave frequencies and most involve acute exposures (over relatively short periods) at relatively high power densities (e.g. well above 10 mw/cm^2). While it is known that EMR around and above 100 mw/cm^2 can produce ocular changes in laboratory animals, the effects of various EMR exposure conditions are not yet sufficiently understood -- e.g., dose dependance for various

frequency ranges and effects of various waveforms -- nor is the relationship of laboratory observations to man.

Studies of ocular effects are being conducted by the Army, Navy, Bureau of Radiological Health (BRH), and VA. There is a reasonable amount of work in this area and considerable interagency collaboration, including an ad hoc committee on microwave ocular effects (BRH and DOD) as well as several jointly funded projects.

In addition to establishing thresholds and relationships of electromagnetic variables to ocular effects in more acute, higher dose experiments, there is an outstanding need to determine whether effects of repeated exposures to relatively low level ("subthreshold doses") over extended periods of time can produce ocular effects, and whether there are delayed or late-occurring effects--long after either acute or chronic exposures.

Metabolic, Endocrinology and Biochemical Studies

This is a large composite area of activity involving many seemingly diverse studies in several different technical fields and disciplines. However, these areas are related in that they involve processes fundamental to the proper functioning of the organism and are indicators of its condition and response to the external environment. Changes in levels or activity of enzymes, hormones, or other basic body chemistries and their impact on metabolic processes are of interest here. Some of the studies are strongly oriented toward investigating possible mechanisms of EMR interactions.

Careful experimental design and hypotheses are critical because of difficulties in detecting very subtle changes in view of the body's efficient homeostatic and compensatory mechanisms. Disruption of a specific enzyme, for example, may be extraordinarily difficult to detect when several others can "do its job" such that the effect of its loss is not readily discernable in observable and measurable metabolic function.

Although there is little to report at this time in the way of research observations, a few studies have suggested the possibility of variations in oxygen metabolism and other biochemical parameters.

The ELF studies in this area employ a wide variety of organisms, including plants and soil microorganisms, consistent with the ecological focus of studies associated with SANGUINE.

Epidemiology, Clinical Studies and General Health

These areas are discussed together because there frequently tends to be a commonality of approach--namely, the integrated study of effects on the organism as a whole v.s. a specific subsystem or parameter. Of course, this is not always the case since an epidemiological or clinical study can be designed to examine a particular phenomenon, e.g., ocular effects, cancer, etc. However, most typically, these studies afford a broad overview, "screening" kind of approach which has the potential of detecting subtle effects on general health and well being. Thus, they can be an effective part of an overall

effort to identify effects. At a later stage these studies may be designed to look for specific effects based on laboratory observations; thereby helping to establish relevance to man in actual exposure situations.

Epidemiological and clinical studies are primarily concerned with man whereas both human and animal studies, involving multiple parameters indicative of general physical condition, are included in the general health category. At present, there are few studies in these areas.

Meaningful epidemiological studies can be difficult to design and, in some cases, require a considerable commitment of resources for extended periods of time. In general, the prospect of specific, definitive findings from studies of retrospective data is not optimistic because of difficulties in establishing exposure histories and the variability of available medical records. Prospective studies with well defined populations and suitably matched controls appear more promising.

Most of the epidemiological studies (noted in Figure 2) were not implemented beyond the planning stage for a variety of reasons including difficulties in establishing appropriate populations, control groups and/or protocols, problems with availability or quality of records, funding, and other difficulties. In essence, beyond one almost completed and rather specific study of a possible relationship between paternal exposures and the incidence of Down's Syndrome in children, for which data is being statistically analyzed, there is only one ongoing study. This involves the collection, monitoring and evaluation of health records of people working with electromagnetic pulse (EMP) sources (a very specialized situation involving multiple frequency bursts of very narrow pulse widths with rapid rise time). Additional studies, one involving naval personnel and another involving a particular military base, are being contemplated.

Studies involving clinical examinations include one concerned with eye examinations for possible ocular changes and another involving annual physical examinations of a small number of people working at an ELF test site. Clinical data have been taken in the course of another Navy study of ELF fields.

Other studies of general health involving multiple parameters, include ELF frequencies and an EMP study with daily exposures of rodents over a relatively long period (e.g., one year).

Current Status

As mentioned previously, during 1973 some changes occurred in terms of specific projects, as would be expected in the development and evolution of a research program. New projects were undertaken, some were completed, and other efforts were revised to pursue directions suggested by the ongoing research. This does not represent a substantive change in the

overall program directions, priorities, or in the proportional distribution of activities in terms of spectrum or areas of investigation (program areas) as can be seen in Figures 4 and 5 which indicate the structure and nature of current program activities (for Fiscal Year 1974).

The program currently consists of approximately 114 projects, the majority represent continuing efforts and approximately 40 new projects are included. Individual agency's undertakings and the distribution of effort in key program areas are illustrated in Figure 4.

Figure 5 illustrates the areas of the spectrum in which these studies are being conducted. As can be seen, the major concentration of this work continues to be at microwave frequencies. Particular regions of emphasis of individual agencies' efforts are also apparent. These reflect those agencies' responsibilities and concern with existing and planned equipments/systems.

III. AGENCY ACTIVITIES AND PROGRAM SUMMARIES

The level of activity related to this Program effort within most of the agencies increased somewhat in 1973. It is also encouraging that, in most cases, despite budgetary decreases in other and related areas, agency funding for this effort has shown some gains. However, overall funding has been lower than desirable with respect to the development of sufficient new approaches, facility requirements, and attracting new investigators. This area is not yet a well recognized, established scientific field or discipline and interdisciplinary capabilities are required to solve problems of considerable technical complexity in a realistic time frame.

Funding for Fiscal Year 1973 was approximately \$6 million and the current estimate for Fiscal Year 1974 is approximately \$7 million. By comparison, recommended levels were \$10.6 million for the first full year of coordinated effort (FY 74) and \$15.2 million for the second (FY 75).

The program is based on independently funded efforts by participating agencies. Current pressures in the economy have caused FY 1974 to be a year of tight budgets with extreme competition for priorities and funds among even established, higher-priority programs. As a result, it has been a difficult time in which to initiate or even amplify this program activity in terms of the full resources required. Accordingly, while efforts to obtain increased budgetary resources continue, it may be necessary to accommodate a more graduated buildup of funding to the requisite levels. This emphasizes the need to maximize the effectiveness of efforts undertaken—including better focusing of activities and closer coordination of individual projects within given areas of research. Even so, the unavoidable effect will be that work will have to be conducted over a more protracted period of time.

Activities, accomplishments and principal directions of some of the major agency programs are illustrated in their summaries, as follows.

HEW/Bureau of Radiological Health (BRH)

The Food and Drug Administration (FDA) has responsibility to develop and enforce equipment performance standards which limit emissions (including nonionizing and ionizing radiations) from devices used in the practice of medicine, by industry, and by consumers. Its BRH has been delegated this responsibility since the passage of the Radiation Control for Health and Safety Act of 1968. As a result, research efforts in nonionizing radiation (radio spectrum) have been concentrated on instrumentation development for both dosimetry and field measurements and on investigating biological effects, particularly at low levels.

Most of the biological research was at 2450 MHz, used in most microwave ovens, with a few studies involving lower frequencies. This work includes

investigations of possible effects on fetal development, genetic studies, ocular effects (cataractogenesis), behavior and electrophysiological activity in the central nervous system, and associated problems of developing better dosimetric methods. Additionally, efforts have been made to develop a suitable epidemiological study. Additional information, including some preliminary research observations, is summarized in the FDA submission, "Justification of Appropriation Estimates for the Committee on Appropriations - FY 1975,* the 1974 Annual Report on the Administration of the Radiation Control for Health and Safety Act of 1968, issued July 19, 1973, and is reported in other research publications.

In 1973, progress was made in expanding laboratory instrumentation to conduct biological effects studies utilizing some of the more recent BRH advances in measurement and control of exposure sources. Work also continued on instrumentation development for field measurements and dosimetry at additional (lower) frequencies used in diathermy.

A number of additional studies utilizing research grants, interagency agreements and negotiated contracts are planned for initiation in 1974.

HEW/National Institute of Environmental Health Sciences (NIEHS)

The research program of NIEHS on the health effects of nonionizing radiation is concentrated in the areas of neurological effects, developmental effects and dosimetry, at the microwave frequencies of 1-10 GHz. The neurological studies are at the neuronal level, with primary emphasis on the interaction of the electromagnetic field with neural activity. The developmental studies are concerned with the effects of microwaves on the normal development of embryos during the early stages of embryogenesis. Of particular concern are differentiating cell systems, which have been shown to be particularly sensitive to the influence of imposed factors. The study of dosimetry is a necessary part of these activities. Accurate measurement techniques and mathematical modelling of the systems to determine the energy absorption without artifacts are, of necessity, a major part of the research effort.

Environmental Protection Agency (EPA)

the EPA's nonionizing radiation program gained momentum during 1973. The program consists of two basic parts: environmental measurement studies carried out by the Office of Radiation Programs (ORP), and biological research conducted by the Office of Research and Management (ORM). The environmental measurement function became operational during the year and the health effects research program recovered from the disruption caused by the transfer of EPA's Twinbrook Research Laboratory studies to Research Triangle Park, North Carolina.

Activities in the environmental measurement area included the establishment of a facility to support the development of a mobile monitoring capability. An interagency agreement was initiated with the Army to provide space for the support facility which is located at the Walter Reed Army Institute of Research, Forest Glen Annex, in Maryland. Instrumentation efforts started by preparing for measurements of both high intensity

*to be published by the Congress

field levels near specific types of sources and the lower, ambient radiation levels typical of locations where exposures are the result of many sources. Development was begun for a semi-automated system for measuring environmental levels of radio frequency and microwave radiation. The principle components of the system are a spectrum analyzer, a minicomputer system to control the spectrum analyzer and to acquire and reduce data, and an omni-directional antenna system. The spectrum analyzer, with a frequency range of 1 kHz to 18 GHz was used to characterize the environment of the facility site and to do a field study on large, ground based air-traffic-control radars. A microwave hazard survey of several airborne radar units was accomplished in the fall. Environmental levels of radiation in the near vicinity of a high power UHF broadcast installation were calculated on a computer available through the Army interagency agreement. Another interagency agreement was established with the Department of Commerce, Office of Telecommunications, ITS, for antenna development and calibration. Contracts were awarded for the minicomputer system (scheduled for arrival during January 1974) and a mobile monitoring van to house the measurement system. Plans were made late in the year for conducting measurements at several satellite communications system installations in collaboration with the Army's Environmental Hygiene Agency and for a series of high intensity field measurements around AM standard broadcast stations. A spectral activity study of the high frequency band (3-30 MHz) was completed during the summer to gain an insight to optimum sampling times for environmental RF exposure in this frequency range. Information on transmitter locations and source parameters, e.g., transmitter power, effective radiated power, frequency, and pulse repetitions rates, continued to be generated through an interagency agreement with the DOD Electromagnetic Compatibility Analysis Center.

With regard to studies of possible hazards to biological systems, a 2.45 GHz exposure chamber and ancillary equipment became operational and a microwave calibration program was instituted. The major parts of an X-band exposure system were acquired and design of the related chamber begun. Two-model computer programs for RF cross section and field strength distribution in multilayered dielectric spheres were set up and operated.

Biological studies concentrated on mechanisms of EM interaction. Efforts to confirm Canadian reports that microwave radiation can inhibit growth of bacteria (E. coli) were unsuccessful. Exposure of various strains at frequencies of 1.7, 2.45, and 68-74 GHz failed to elicit any response. No effect was observed in isolated rat liver mitochondria exposed to 2.45 GHz radiation with respect to rate of respiration, respiratory control, ADP/O² ratio, and energy-linked transport of calcium. Initial observations of effects of 1.7 and 2.45 GHz upon quaternary structure of bovine serum albumin were later shown to be artifacts. Chromosome aberrations were observed in lung, kidney, and thyroid cells from hamsters irradiated at 2.45 GHz at power densities down to 15 mW/cm². Neurobiological studies remained in abeyance during the greater part of 1973, but successful recruitment allowed planning of new studies at the end of the year. In the latter part of 1973, teratological studies were also initiated.

DOD/Army

Initial studies of behavioral effects at five microwave frequencies between 0.75 and 3 GHz on fixed ratio performance of rats were completed. Results showed a definite frequency dependence of time to work stoppage of exposed animals. Further work is planned to examine possible species specificity of results. Development of prototype electrodes and thermistor probes for use in microwave fields has been completed. Evaluation of these devices is in process and indications are that they are superior in performance to any such devices currently available. Studies of ocular effects of microwave radiation are continuing with both single and chronic high-level exposures. Contract effort is being utilized to compile all available world literature on biological effects of nonionizing electromagnetic radiation. A contractual study of effects of microwave radiation on mammalian serum protein is continuing with indications of changes which at present cannot be definitely linked to microwave exposure.

It is planned to continue work in the areas noted above. In addition, work will be done on attempting to better control and measure the microwave field in which experimental animals are exposed. Specifically, problems of perturbation of the field by exposure cages, absorption of energy in relation to complex geometrical shapes, and dielectric constants of biological materials are to be studied.

DOD/Navy

Navy personnel can be exposed to nonionizing radiation from radar, communications equipment, and other electronic gear. A principal objective of the Navy program is to establish safe exposure levels and tolerance times, and to define the nature of possible biological effects of exposures to microwave and other radio frequency and magnetic fields.

It has been suggested that microwave radiations at levels of exposure which are less than required for thermal injury may produce psychomotor disturbances. For this reason, microwave studies will emphasize neurophysiological and psychological studies. Other areas of study include: endocrinology and metabolism, multiple stresses, embryology, development, and sensory systems -- particularly the evaluation of cataractogenesis. In support of Project SANGUINE, effects of extremely low frequency (ELF) electric and magnetic fields on man and other ecologically representative organisms are being investigated. Possible effects of electromagnetic pulses (EMP) of very short duration but very high peak power are being evaluated.

The Navy program consists of both intramural and extramural activities. Approximately 39 projects are underway at four naval laboratories and 23 civilian institutions, as well as several joint efforts with other agencies.

The current program emphasizes low-level exposures. Because the nervous system, both central and autonomic, is believed to be the most sensitive to microwave radiation, effort is concentrated in behavioral, neurophysiological, neurochemical, and neurohistological studies. Efforts are also being made to establish thresholds for ocular effects in terms of dose regimen, frequency and power. Biochemical and histological studies of lens tissue cultures are being conducted together with electronmicroscopy of exposed lenses. ELF electric and magnetic fields exposures over several weeks are being studied. Rats and monkeys are trained with complex operant conditioning techniques and exposed to low levels of microwave irradiation to evaluate the combined effect of psychological stress and microwave radiation.

Some preliminary observations in these early studies are noted as follows. It is emphasized that these observations have not been independently reproduced or verified and are largely based on single experiments. CW, S Band (3000 MHz) irradiations at levels as low as 5 mw/cm^2 for 30 minutes have indicated alterations in behavioral baselines in rats trained to a very demanding paradigm. Similar changes are not observed in animals trained to simpler tasks. Possible decreases in brain oxygen consumption were observed following microwave irradiation of cats' heads. Mongolian gerbils exposed to ELF magnetic fields for long periods of time appear to exhibit a two-fold increase in the stored lipid in the liver parenchymal cells. Other observations with ELF exposures include the following: metabolic activity in chicken eggs appears to be depressed although no apparent effect was observed on hatchability or the resulting chick; possible delays in the onset of mitosis and a decrease in the streaming activity in slime mold; and a possible delay in the onset of metamorphosis in tadpoles raised in ELF fields. Work is continuing to establish the validity and significance of these observations.

DOD/Air Force

A power absorption meter was developed which allows accurate determination of energy deposition versus frequency. Power absorption measurements were made in the HF band. Absorption was determined to be only 10 percent or less, which suggests it may be possible to relax exposure safety criteria in this frequency range. Cardiac pacemaker EM interference studies were completed. Test reports were prepared and provided to the FDA. A multiple frequency exposure facility was completed which has the capability of producing simultaneous exposure to three frequency ranges (3-30 MHz, 40-400 MHz, and 1-10 GHz). Primate exposure studies were initiated using parameters appropriate for multiple frequency Airborne and Warning and Control System (AWACS) environment. A "near field" synthesizer developed by the National Bureau of Standards was delivered and installed.

Preliminary studies indicate that for frequencies of 50 MHz and below, the H field magnetic vector is more biologically significant than the E field electric vector, contrary to the belief of some investigators. Additional studies are under way to validate this finding.

A contract was let to determine the biological effects of very low frequency (VLF) radiation from the frequency range utilized by Strategic Air Command Control Communications Net. Preliminary data indicate that very little of this VLF radiation couples to the biological target.

IV. ASSOCIATED ACTIVITIES

ERMAC

During the year, the ERMAC continued to follow and overview activities in the Program, providing advice and recommendations to OTP on program needs, strengths and weaknesses, research directions, as well as standards and other related matters. A major activity was reviewing and evaluating the status of the program as a whole, which was completed in September. A summary of their comments is included as Appendix A. Additionally, the ERMAC was consulted throughout the year on various matters pertaining to biological effects, particularly on several proposed standards.

Side Effects Working Group

The interagency Side Effects Working Group continued to meet regularly and to function as the principal intragovernmental coordinating mechanism for the Program effort. This group is organized within the structure of the Interdepartment Radio Advisory Committee (IRAC) which advises OTP on the use of the radio spectrum within the Federal Government. The working group provides a forum for the exchange of information pertaining to the Program activities and treats related matters of common concern and interest.

Activities in 1973 included the following:

- o Revised and updated project resumes covering specific research activities in each agency to reflect FY 74 undertakings.
- o The Ad Hoc Technical Subcommittee, formed in 1972, organizes informal discussion/seminars among investigators in various program research areas to promote the exchange of ideas and discuss common problems. Two such meetings were held in 1973, addressing the areas of (1) behavioral studies and (2) biophysical/biochemical mechanisms of EM interaction with living organisms.
- o Reviewed various safety standards proposed during 1973 and provided comments to the proposing agency.
- o Completed a survey and documented EM field measurement facilities and capabilities within the Government, which could be made available on an interagency basis to determine EM fields in situations involving exposures or suspected hazards. Procedures were established for accessing and maintaining the resultant information, with EPA serving as the focal point. This information has been referenced in the OTP Manual of regulations and

pertinent information relating to Government use of the spectrum.

- o Initiated a similar effort to identify and document exposure facilities and their capabilities. This can provide a basis for determining additional facility requirements as well as ensuring optimum utilization of existing resources.

Pertinent Legislation and Standards

Interest and concern in the Government, scientific community, and public continued to be evidenced in 1973 by new and carried-over proposed legislation, activity vis-a-vis safety standards, and by numerous inquiries pertaining to biological effects, potential hazards, and the Program.

As discussed in the previous summary report, existing legislation and orders with relevance include the following:

- o The "Radiation Control of Health and Safety Act of 1968", (PL 90-602), administered by HEW.
- o The "National Environmental Policy Act of 1969" (NEPA), (PL 91-190).
- o Reorganization Plan No. 3 of 1970, which established the Environmental Protection Agency (EPA) which has authority to establish environmental standards.
- o The "Occupational Safety and Health Act of 1970", (PL 91-596), administered by the Department of Labor.

Two pieces of proposed legislation mentioned in last year's report were not acted upon. One, "The Radiation Protection Act of 1972" (Schweiker Bill), has been reintroduced as the "Radiation Protection Act of 1973" - S.2724. The second, the "Amendment to the Radiation Control for Health and Safety Act" (Tunney Bill) - S.3487, may be reintroduced in 1974.

On November 27, 1973 Senator Ribicoff introduced the Energy Reorganization Act of 1973" - S.2744. This bill and its companion bill in the House (Hollified Bill) include provisions pertaining to environmental protection in general, transmission of energy, biomedical research, and research in underground electric power transmission and could, therefore, have relevance in this area.

Standards activities during 1973 included the following:

- o DOL/OSHA-The Occupational Safety and Health Administration (OSHA) of the Department of Labor published a proposed standard for "Telecommunications" (29 CFR 1910, new subpart T) in the Federal Register in August 1973. Included were safety criteria for exposures associated with "Microwave Transmission" (Section 1910.345), which represented a significant departure (lowering permissible exposure levels) for this occupational group from the existing OSHA standard (29 CFR 1910.97) applicable to all occupational exposures. After careful review OTP and several other agencies submitted comments to OSHA which, for the most part, recommended modifying this portion of the proposed standard to adhere to OSHA's existing exposure safety standards for these EM radiations. Final OSHA action on this standard was pending at the close of 1973.

- o ANSI-As noted in last year's report, the American National Standards Institute (ANSI), C95.1, 1966 safety standard (based on 10 mw/cm^2) was due for reaffirmation, revision or withdrawal during 1973 under ANSI protocol. It being the general feeling of the cognizant subcommittee that there was insufficient new evidence to warrant a change, a draft incorporating some minor modifications, was circulated to the ANSI members for their vote. Final action was still pending at the close of 1973.

- o NATO-The matter of safety standards for nonionizing EMR has been under consideration by several different subgroups within the NATO organization. During the past year several different exposure limits were proposed including the recommendation that adoption of a uniform NATO standard at the present time would be premature until a better understanding of biological effects is available. This matter remains under consideration.

International

There was notable growth in the area of international exchange during 1973, both in terms of actual interchange, and planning for future cooperative activities.

An International Symposium on Biological Effects and Health Hazards of Microwave Radiation was held in Warsaw, Poland in October. This symposium, co-sponsored by the World Health Organization, U.S. Department of Health, Education and Welfare (BRH) and Polish Ministry of Health, included approximately 50 invited participants from various countries, and afforded a first substantial opportunity for contact and exchange between Eastern and Western investigators. The resultant dialogue and rapport should enhance international cooperation in the future.

Progress was made in efforts to develop a collaborative activity with the U.S.S.R. under the U.S.S.R./U.S. agreement to cooperate in the area of environmental health, for which Dr. Rall of NIEHS is the U.S. coordinator. Preliminary discussions and technical information exchange took place as a basis for developing a collaborative agreement. Further meetings to develop specific undertakings are planned for 1974-75.

Additionally, the matter of biological effects and potential hazards of nonionizing EMR, particularly associated standards, has been the subject of discussion in a number of international forums, i.e., the International Radio Consultative Committee (CCIR) of the International Telecommunications Union (ITU), the International Radio Scientific Union (URSI), and the World Health Organization (WHO), as well as in individual contacts with administrations of various countries.

Other

- o In addition to the aforementioned, a number of other organizations and professional groups have activities in this area -- i.e., the National Council on Radiation Protection and Measurement (NCRP) which, until recently, has been primarily concerned with ionizing radiation has established a subcommittee on nonionizing radiation which has been reviewing the matter of standardization of terminology and units of measurement.
- o Preliminary discussions were held with representatives of the electrical power industry to discuss research needs and activities pertaining to possible biological effects from EM fields such as are associated with electrical power generation and transmission.

- o Meetings - Several meetings, symposia and conferences in 1973 which treated the subject of biological effects of nonionizing radiation include the following:

Symposium and Workshop on the Effects of Low Frequency Magnetic and Electric Fields on Biological Communication Processes, Snowmass-at-Aspen, Colorado, co-sponsored by the NSF, Neuro-Electric Society, International Institute for Medical Electronics and Biological Engineering, Marquette University, and the Medical College of Wisconsin, February 18 - 24, 1973.

Society of Automotive Engineers (SAE) Workshop on EM Pollution, Rockville, Maryland, co-sponsored with BRH and EPA, May 7 - 8, 1973.

The IEEE International Microwave Symposium, Boulder, Colorado, June 4 - 6, 1973.

The IEEE International Electromagnetic Compatibility Symposium, New York City, N.Y., June 20 - 22, 1973.

Symposium on Biomedical Aspects of Nonionizing Radiation and Facility Dedication, Naval Ordnance Laboratory, Dahlgren, Va., July 10, 1973.

Third International Congress of the International Radiation Protection Association, Washington, D.C., September 9 - 14, 1973.

The Symposium on Microwave Power, Loughborough University of Technology, U.K., sponsored by the International Microwave Power Institute, September 10 - 13, 1973.

Conference on Electrically Mediated Growth Processes, New York Academy of Sciences, New York City, N.Y., September 19 - 21, 1973.

International Symposium on Biologic Effects and Health Hazards of Microwave Radiation, Warsaw, Poland, co-sponsored by HEW/BRH, the Polish Ministry of Health and the World Health Organization, October 15 - 18, 1973.

IEEE National Telecommunications Conference, Atlanta, Georgia, November 26 - 28, 1973.

FIGURES

FIGURE 1. PROGRAM AREAS: AREAS OF INVESTIGATION

No.

1. Genetic/Hereditary/Developmental

Chromosomal
Mitotic
Reproduction/Fertility
Embryology
pre- and postnatal development, etc.

2. Nervous System

CNS
Sensory
Neurochemical-Neuroendocrine
Single cell - membrane phenomena

3. Behavioral/Psychological

4. Gross Physical Condition/General Health

(specifics, as appropriate)

5. Epidemiology

(specifics, as appropriate)
pro- and retrospective

6. Clinical Examinations

(specifics, as appropriate)

7. Mechanisms of EM Interaction (with molecules, tissues, body systems, etc.)

micro-
macro-

8. Other Areas

- A. Ocular
- B. Cardiovascular
- C. Metabolism/Endocrinology/Biochemical
- D. Thermal/Thermoregulatory/Lethality
- E. Cytological/Histological/Morphological
- F. Other Effects: Blood, GI, Respiratory, Motor, Physical
Endurance, Stress, Biological Clocks/
Rhythms, Disease, etc...

9. Instrumentation/Techniques/Calibration

- A. Bioresearch: EM measurement, special biomedical instrumentation, exposure and calibration facilities
- B. Field Measurements: equipment, methodology, etc.

10. Absorption/Dose

- A. Analytical/Mathematic/Theoretical
- B. Experimental: animal, phantom, model

11. Environmental and Safety Studies

- A. Environmental Surveys
- B. Population Studies
- C. Hazard Assessment/Safety Standards

12. Special Features

Specifics, such as:

- Multiple Frequencies
- RF with other stressors and environmental factors (e.g. drugs, ionizing radiation, disease, etc.)
- RF heating vs. other heat sources
- Chronic vs. short term effects studies
- Compare differences due to sex, age, and other biological factors
- Literature Studies
- Therapy

FIGURE 2. EMR/BIOEFFECTS PROGRAM - FY 73
(Summary Data)

PROGRAM AREAS (See Figure 1 & Key Below)

AGENCY	#PRO-JECTS	I/O - Inhouse/Out	1 G/H/D	2 NS	3 BEHAV/ PSYCH	4 GROSS COND	5 EPIDEM	6 CLIN EXAM	7 MECH	8A EYE (LJ)	8B C-V	8C MET/END/ BIOCHEM	8D T/T, REG	8E CYT/HIST /MORPH	8F OTHER	9 INST	10 ABSORP	11 ENVIR/ SAFETY	12 SPECIAL FEATURE
DOD	(54)	I = 29 O = 25	15-2,10 (LJ)	15-15	11-2,9	7-1,6	2-2 (LJ)	2-2	3-3	7-3,4 (LJ)	1-1	16-2,14	5-5	1-1	9-9	4-4	10-2,8	-	6-1,5
ARMY	8 (1w/BRH)	I = 5 O = 3	2-2 (LJ)	1-1	1-1	-	1-1 (LJ)	1-1	1-1	2-1	-	3-1,2	2-2	-	-	1-1	-	-	1-1
NAVY	36 (2w/BRH)	I = 19 O = 17	9-5,4	12-12	10-2,8	5-1,4	-	1-1	2-2	5-2,3 (LJ)	1-1	10-1,9	2-2	1-1	7-7	3-3	6-1,5	-	4-4
AF	8	I = 4 O = 4	3-3	2-2	-	-	-	-	-	-	-	3-3	1-1	-	1-1	2-1,1	4-1,3	-	1-1
DNA	2	I = 1 O = 1	1-1	-	-	2-2	1-1	-	-	-	-	-	-	-	1-1	-	-	-	-
HEW	(39)	I = 28 O = 11	12-5,7 (LJ)	4-2	1-1	-	4-2,1 (LJ)	-	5-5	6-3,3 (LJ)	-	6-1,5	2-2	2-1,1	1-1	7-3,4	8-1,7	2-2	6-1,5
BRH	31 (3w/DOD)	I = 23 O = 8	10-3,7 (LJ)	2-2	1-1	-	3-2,1 (LJ)	-	3-3	6-3,3 (LJ)	-	6-1,5	2-2	2-1,1	1-1	5-3,2	5-1,4	1-1	6-1,5
NIEHS	7	I = 4 O = 3	2-2	2-2	-	-	-	-	2-2	-	-	-	-	-	-	1-1	3-3	-	-
NIOSH	1	I = 1	-	-	-	-	-	-	-	-	-	-	-	-	-	1-1	-	1-1	-
EPA	9	I = 6 O = 3	3-2,1	1-1	2-1,1	-	1-1	-	1-1	-	-	2-2	-	-	2-2	1-1	1-1	2-2	-
DOC-NBS	4	I = 4	-	-	-	-	-	-	-	-	-	-	-	-	-	4-4 (2T)	-	-	-
NSF	1	O = 1	-	1-1	1-1	-	-	-	1-1	-	-	-	1-1	-	-	-	1-1	-	-
FEC	1	I = 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1-1	-
FAA	1	O = 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1-1	-
CIA	1	O = 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1-1	-
VA	2	I = 2	-	-	1-1	-	-	-	-	1-1	-	-	-	-	-	1-1	1-1	-	1-1
TOTALS	112	I = 70 O = 42	29	21	16	7	5	2	10	13	1	24	8	3	10	18	21	6	13

KEY

Example: DOD has a total of (54) projects; 29 are being conducted within DOD and 25 by outside contractors, grants, or another agency.

In program area no. 1, G/H/D (defined in Fig. 1) there are 15 relevant projects:

- 5 of the 15 are concerned only with program area no. 1,
 - 10 of the 15 are concerned with program area no. 1, and other program areas as well.
- One of these projects (LJ) is jointly funded with another agency.

I - indicates a project funded by transfer dollars from another agency. (2T) indicates 2 transfer fund projects.
J - indicates a project jointly funded with another agency.

FIGURE 3

FREQUENCY DISTRIBUTION OF RESEARCH IN SOME PROGRAM AREAS - FY 73

Program Area	No. of Agencies	Relevant Projects *	ELF 0-3 kHz	VLF 3-30 kHz	LF 30-300 kHz	MF 300-3000 kHz	HF 3-30 MHz	VHF 30-300 MHz	UHF 300-3000 MHz	SHF 3-30 GHz	EHF 30-300 GHz	Other 300-3000 GHz EMP, vague, etc.
1 G/H/D	7	29 - 12, 17	1 Hz	10	60							
			1 45-75 Hz 60				10 13			400 1.7 2.45 (13) 1 3.5 10.18 1.5 5.2 7.1 25 33		50
2 NERVOUS SYSTEM	7	19 - 0, 19	1 Hz	10								
			45-75 Hz (3)				(2)	104 200	918(2)			
3 BEHAVIOR/ PSYCHOL.	6	16 - 3, 13	45-75 Hz (6)									
							200	365 918 750-915		1.5 5.2 1 12.4 1 1.75 2.45 (8) 1 (2)		
4 GROSS COND	2	7 - 1, 6	45-75 Hz (3)									EMP (3)
5 EPIDEMIOLOG.	5	5 - 3, 2										
									1.5 5.2 11 1.5 2.45 (and other diathermy)			
6 CLINICAL EXAM.	2	2 - 0, 2	45-75 Hz									
7 MECHANISMS	6	10 - 0, 10	1 10	10								
							10 13	100		1 1.5 1 12 918 (2) 1.5 5.2 11 33 1.7 2.45 (2)		50

FIGURE 3 (Continued)

Program Area	No. of Agencies	Relevant Projects *	ELF 0-3 kHz	VLF 3-30 kHz	LF 30-300 kHz	MF 300-3000 kHz	HF 3-30 MHz	VHF 30-300 MHz	UHF 300-3000 MHz	SHF 3-30 GHz	EHF 30-300 GHz	Other 300-3000 GHz EMP, vague, etc.	MW	
													←	→
8A OCULAR	4	13 - 5, 8						200	2.45 (8) 3	10 10			MW	(2)
8B C-V	1	1 - 0, 1							2.45					
8C MET/END/ BIOCHEM	5	24 - 3, 21	1 10 45 (3) 75Hz 60Hz	10	60		10 (2)		1.5 (2)	9.3				
8D T./T. REG./ LETHALITY	5	8 - 0, 8		10	60			200	750 1.75 (4) 918 (2)	10 10 3.25 12 (10)				
8E CYT/HIST/ MORPH	2	3 - 2, 1							2.45 (3)					

Explanation: A number in () indicates that more than one project applies.
Note, however, that a single project may deal with more than one frequency (or range).

* Number designations are explained in figures 2 and 4.

FIGURE 4. PAR/BIOEFFECTS PROGRAM - FY 74
(Summary Data)

PROGRAM AREAS (See Figure 1 & Key Below)

AGENCY	#PRO-JECTS	I/O = Inhouse /Out	1	2	3	4	5	6	7	8A	8B	8C	8D	8E	8F	9	10	11	12
			G/H/D	NS	BEHAV/ PSYCH	GROSS COND	EPIDEM	CLIN EXAM	MECH	EYE	C-V	MET/END/ BIOCHEM	T.T. REG	CYT/HIST /MORPH	OTHER	INST	ABSORP	ENVIR/ SAFETY	SPECIAL FEATURE
DOD	(66)	(12-3,9)	(13-2,11)	(7-0,7)	(2-0,2)	(4-0,4)	(9-0,9)	(6-2,3)	(1-0,1)	(18-1,17)	(6-0,6)	(5-1,4)	(11-0,11)	(9-2,6)	(9-2,4)	(5-0,5)	(9-2,7)		
	total	1-24	2-0,2	1-0,1	1-0,1	1-0,1	3-0,3	2-1,1	3-0,3	3-0,3	3-0,3	2-0,2	2-0,2	1-1,0	2-2,0	-			
Army	(1w/BBE)	0-8	10-2,8	12-4,8	3-0,3	5-0,5	4-2,2	1-0,1	1-0,1	12-1,11	1-0,1	1-1,0	7-0,7	3-0,3	3-1,2	1-0,1	4-0,4		
	total	0-26	1-1	1-0,1	1-0,1	1-0,1	2-1,1	2-1,1	3-0,3	4-1,3	1-0,1	3-1,2	3-1,2	5-2,3	4-2,2	3-0,3	1-0,1		
AF	I=3	0-7	1-0,1	-	-	-	1-0,1	-	-	3-0,3	2-0,2	2-0,2	1-0,1	-	-	-	-		
DWA	I=1	0-1	-	-	2-0,2	1-0,1	-	-	-	-	-	-	-	1-0,1	-	-	-	-	
	total	0-1	-	-	2-0,2	1-0,1	-	-	-	-	-	-	-	1-0,1	-	-	-	-	
HBM	(30)	(10-6,4)	(5-0,5)	(2-1,1)	(1-0,1)	-	(5-0,5)	(3-1,2)	-	(4-1,3)	(1-0,1)	(3-1,2)	(5-2,3)	(4-1,3)	(3-1,2)	(3-1,2)	(3-1,2)		
	total	1-15	8-4,4	2-1,1	1-0,1	-	3-0,3	3-1,2	-	4-1,3	1-0,1	3-1,2	3-1,2	3-1,2	3-1,2	2-0,2	3-1,2		
BRH	(4w/DOD)	0-8	2-2,0	-	-	-	2-0,2	-	-	-	-	-	-	-	-	-	-	-	
NIRBS	I=4	0-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	total	0-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
NIOSH	I=1	0-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	total	0-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
EPA	I=11	0-1	3-1,2	2-0,2	1-0,1	-	4-0,4	-	-	4-0,4	-	1-0,1	2-0,2	3-0,3	-	-	3-0,3	1-0,1	
DOC-NBS	1 + 8T	I=1+8T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1-1,0	1-1,0	
NSF	3	0-3	2-1,1	-	-	-	1-0,1	-	-	1-0,1	-	1-0,1	-	-	-	-	-	-	
FCC	1	I=1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
FAA	1	0-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
CIA	1	0-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
VA	2	I=2	-	-	-	-	1-0,1	-	-	-	-	-	-	-	1-0,1	1-0,1	-	-	

TOTALS* 114 I=59 O=55** 26 19 17 7 4 4 18 8 2 24 7 9 13 20 15 13 14

KEY

Example: DOD has a total of (66) projects; 24 are being conducted within DOD and 42 by outside contracts, grants, or another agency.
 In program area no. 1, G/H/D (defined in Fig. 1) there are 12 relevant projects:
 • 3 of the 12 are concerned only with program area no. 1,
 • 9 of the 12 are concerned with program area no. 1, and other program areas as well.
 One of the projects (1J) is jointly funded with another agency.
 I - indicates a project funded by transfer dollars from another agency. (8T) indicates 8 transfer fund projects.
 J - indicates a project jointly funded with another agency.
 * Totals are adjusted to account for joint and transfer funding.
 ** In-Government = 67; non-Government = 47.

FREQUENCY DISTRIBUTION OF RESEARCH BY AGENCY - FY 74

AGENCY	ELF 0-3 kHz	VLF 3-30 kHz	LF 30-300 kHz	MF 300-3000 kHz	HF 3-30 MHz	VHF 30-300 MHz	UHF 300-3000 MHz	SHF 3-30 GHz	EHF 30-300 GHz	Other 300-3000 GHz EMP, vague, etc.
ARMY							950 1700 (2) 400 2.45 700 (4) 4	7.5 10 4.5		Various, radar MW Rad lit.
NAVY	45 (13) 1 Hz	10 10	(2)		10		1.5 1 1 1 918 (2) 2.45 (11) 5.2 11 2.45 10	9.0 14 10 12.4 3.25 9.3 11 12		EMP
AIR FORCE		10		1000		(2)	400 1000 (3)	10		(multiple frequencies)
DNA						(EMP)				EMP
BRH							385 383 1000 500 918 500 915 1000	2.45 (15) 5.2 11 2450 2450 12 10		Various, radar
NIEHS						100	(2) 2.45 (2)	5 10		

FIGURE 5 (Continued)

FREQUENCY DISTRIBUTION OF RESEARCH BY AGENCY - FY 74

AGENCY	ELF 0-3 kHz	VLF 3-30 kHz	LF 30-300 kHz	MF 300-3000 kHz	HF 3-30 MHz	VHF 30-300 MHz	UHF 300-3000 MHz	SHF 3-30 GHz	EHF 30-300 GHz	Other 300-3000 GHz EMP, etc.
NIOSH					10 13 27 40					
EPA	1 kHz						1.7 500 500 (4) 1.7-2.66 (4) 8.5-9.6 1000 2.45 (4) 9.5 10	18 8.5-9.6 (4)	58-74 86-94 -----	
NBS				1000	10 (2)		1 1 1 (2)	18 10		EMP
NSF							1000 500 1000 350			
FCC						50		10		
FAA					10			20		
VA							2.45 (2)	10 (2)		

Explanation: A number in () indicates that more than one project applies.
 Note, however, that a single project may deal with more than one frequency (or range).

APPENDICES

APPENDIX A

SUMMARY OF ERMAC OVERVIEW OF THE PROGRAM TO ASSESS BIOLOGICAL EFFECTS OF NONIONIZING RADIATION

The Office of Telecommunications Policy has encouraged an interactive program between concerned Government agencies based on independently funded programs of research into biomedical effects of nonionizing radiation.

The status and progress of the current Program effort has been overviewed by the ERMAC from the perspective of the basic Program objectives. Activities in various areas of investigation were examined in an attempt to determine the extent to which they, and the directions they portend, will provide answers needed to achieve those objectives in a practical time frame. The review was predicated on the understanding that we are, as yet, in the formative stages of establishing a cohesive, coordinated research effort of reasonable critical mass in a relatively new and complex interdisciplinary field.

Program Objectives:

It is the purpose of this Program to establish a rational scientific foundation for use in determining potential hazards to man and his environment in order to assure their protection while avoiding unnecessary restriction of man's ability to use this energy.

This requires that:

- a. Biological effects of electromagnetic radiation (0Hz-3000 GHz) be determined as a function of frequency, intensity and duration of exposure.
- b. The health or ecological significance of any effects be determined.
- c. Appropriate control measures including safety criteria and standards be determined and developed, as may be warranted.

Findings of ERMAC Overview:

- o The present funding level for the program as a whole (\$6.0 million, as compared to the originally recommended \$10.6 million) is too low with respect to current and foreseeable needs and is not responsive to the level of public, professional, or governmental concern. The present level of effort requires amplification if answers are to be produced in a realistic time frame.
- o There has been a buildup of activity in many of the currently recognized critical program areas.
- o The relative distribution of effort by major areas of activity is reasonably appropriate with respect to program objectives and priorities as outlined in the ERMAC program recommendations of December 1971.

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- o The research effort in most areas of investigation is excessively fragmented. It consists of a number of diverse, currently unrelated individual efforts. This is frequently characteristic of a new and complex field at an early stage. However, better focusing, coordination and integration of resources is necessary as the program progresses to ensure meaningful results.
- o Most of the current research appears to be concerned with key priority areas, namely: genetic effects, central nervous system effects, gross physical effects, and underlying mechanisms of interaction, (with emphasis on power levels below 10 mw/cm^2) at microwave and other frequencies associated with major electronic systems.
- o The portions of the above work likely to yield results in the near term (1-3 years) v.s. longer term (3-10 year period) are estimated to be approximately equal.
- o In general, most of the current work involves the short term effects of brief exposures; including multiple exposures over relatively short periods of time. Greater emphasis is needed on repeated and continuous exposures over longer periods of time (particularly during the most vulnerable periods of the animal's life), and on observation for latent effects. Truly long-term (chronic) exposures involve a considerable commitment of resources and time but consideration should be given to how this might be accomplished in the future (perhaps by the use of some dedicated facilities) and some planning of parameters of interest, protocols, etc. should be initiated.
- o The distribution of effort with respect to frequency within the various program areas, roughly follows the overall frequency priorities recommended in the basic program. Concentrations of effort are apparent in the microwave region (particularly at 2.45 GHz) and at ELF with some work in the VHF, less at HF and very little in the LF and MF regions. While this is appropriate for the present, future considerations should not overlook the LF and MF regions which include a variety of high powered systems and extensive use for AM broadcast.
- o There is a need for greater emphasis on the role of pulsed or other modulated radiations as well as more comparative studies of these modes with CW radiation.
- o Instrumentation and methodologies to characterize the EM field and its interaction with exposed material continues to present difficulties and many unresolved problems remain. There is a pressing need for sensors and instrumentation (i.e. implantable

electrodes) to measure biological parameters of interest which can be dependably used in RF fields without producing field distortions or concentrating the energy. Standardization of terminology and measurement protocols are needed to permit comparison of experiments and more uniform definition of exposure in non-experimental situations. Work is also urgently needed on factors to permit scaling from one life form to another.

- o Although definitive results are not to be expected at this early stage of the program, there have been some tentative and as yet unverified observations of effects in certain nervous system and behavioral indicators, developmental processes, and in some other areas. The validity, circumstances, causal relationships, and significance of these observations have yet to be determined but they underscore the need for additional research. Effort should be focused sharply on resolving these questions.

Recommendations:

- o The importance of determining the following is reemphasized:
 - a. The effects of long term low level exposures and thresholds for any effects.
 - b. Effects of different EM exposure regimes (frequencies, intensities, modulations, time, multiple frequencies, -- including EMP);
 - c. The effects of EM exposures in combination with other environmental and biological factors, e.g., age, sex, etc.
 - d. The possible existence of effective mechanisms of interaction in addition to or other than thermal deposition.
- o To avoid excessive diffusion of effort and dissipation of resources, continuing coordination of the various program areas will be necessary. Toward this end, it is suggested that:
 - 1. The need for effective program management within each agency be reemphasized as a step toward resolving the issues outlined herein.
 - 2. OTP and ERMAC meet soon with the principal agency program officers to discuss the above observations, comments and concerns, and solicit their views.

3. Thereafter, ERMAC hold reviews of activities in each significant program area (across agency lines). Specialized subcommittees should be considered to assist in the scientific evaluation of work in these areas. These reviews should consist of presentations by those directly involved in, and responsible for, the research after meeting with each other to prepare their view of the status, significance and directions of this research. This should serve a twofold purpose:
 - a. The interaction among the actual participants will, of itself, help achieve a more cohesive and focused effort.
 - b. It will provide an opportunity for evaluation in greater technical depth and for encouraging a more coordinated approach to this work.

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The following are some reports, articles and presentations, etc., associated with the program efforts which were published or presented in 1973. Items are based on intramural and extramural activities grouped by agency program affiliation. Multiagency support of extramural activities is noted where information was available. This is not an all inclusive compilation nor does it correspond directly to work performed during Calendar Year 1973 due to the normal phasing of reporting and publishing cycles. Many articles and reports based on activities during 1973 are yet to be prepared, currently in preparation or have been submitted for publication and will appear during 1974. The information, referenced here reflects, in greater detail, activities and progress in some of the program areas cited in this report.

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