A REVIEW OF THE FAA AEROMEDICAL RESEARCH PROGRAM

PHASE I:  CIVIL AEROMEDICAL INSTITUTE
PHASE II:  OFFICE OF AVIATION MEDICINE

May 1987

Prepared for

THE FEDERAL AIR SURGEON
OFFICE OF AVIATION MEDICINE
ASSOCIATE ADMINISTRATOR FOR AVIATION STANDARDS
FEDERAL AVIATION ADMINISTRATION
WASHINGTON, D.C.  20591

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The Federal Air Surgeon
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edited by

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FOREWORD

The Life Sciences Research Office (LSRO), Federation of American Societies for Experimental Biology (FASEB), provides scientific assessments of topics in the biomedical sciences and reviews of research programs. Reports are based upon comprehensive literature reviews and the scientific opinions of knowledgeable investigators engaged in work in relevant areas of biology and medicine.

This report was developed for the Federal Aviation Administration (FAA), Office of Aviation Medicine (OAM) in accordance with the provisions of Purchase Order No. DTFA01-86-P-08003. The report was edited by John M. Talbot, M.D., Senior Medical Consultant, Richard W. Leukroth, Jr., M.S., Staff Scientist, and Edwin M. Lerner II, M.D., Senior Medical Consultant, LSRO, FASEB, based on discussions of, and materials prepared by, an ad hoc Group of scientists chosen for their qualifications, experience, and professional judgment with due consideration for balance and breadth in the appropriate professional disciplines. Members of the ad hoc Group and others who assisted in the preparation of this report are identified in Section VII.

The ad hoc Group met at the Civil Aeromedical Institute (CAMI), Oklahoma City, Oklahoma on December 10-12, 1986 to review information and materials provided by the scientific staff of OAM and CAMI and to prepare drafts of this report. Members of the ad hoc Group reviewed a draft of the report and provided additional documentation and viewpoints for incorporation into the final report. The ad hoc Group and LSRO accept responsibility for the study conclusions and accuracy of the report; however, listing of these individuals in Section VII does not imply that individual members of the ad hoc Group specifically endorse all statements in the report.

The final report was reviewed and approved by the LSRO Advisory Committee (which consists of representatives of each constituent Society of FASEB) under authority delegated by the Executive Committee of the Federation Board. Upon completion of these review procedures, the report was approved and transmitted to FAA by the Executive Director, FASEB.

While this is a report of the Federation of American Societies for Experimental Biology, it does not necessarily reflect the opinion of each individual member of the FASEB constituent Societies.

[Signature]
April 30, 1987
Date
Kenneth D. Fisher, Ph.D.
Director
Life Sciences Research Office
SUMMARY

This report evaluates the resources, products, and services of the Federal Aviation Administration's Aeromedical Research Program (ARP), estimates future needs for FAA aero-medical research, and provides suggestions for future emphasis of the ARP. The report focuses on that portion of the ARP that involves the Civil Aeromedical Institute (CAMI). The timing of this study is appropriate because as implementation of the National Airspace System (NAS) plan proceeds, increasing demands on the ARP will be made for research in the medical and behavioral aspects of the NAS.

Current ARP activities at CAMI clearly address the FAA mandate for an efficient, safe civil aviation system. The CAMI research staff is capable and productive, generating data of high scientific and technical merit. The research facilities and equipment are excellent. However, the mission-oriented research of FAA would benefit from a more clearly defined, progressive, and well-coordinated research agenda at CAMI.

FAA has a continuing need to conduct research in aviation medicine. Gaps in knowledge about civil aeromedical problems were identified; their resolution will improve current understanding of man/machine interface issues, the physiological and behavioral aspects of human performance, and other issues relevant to flight safety and operational efficiency. A series of research suggestions and opportunities for improving the quality and practical utility of the ARP are presented. Implementation of these suggestions will enhance the ability of the ARP to contribute maximally to the challenges of flight safety and operational efficiency inherent in the NAS.

In view of the limitations on the size of the research staff at CAMI, increased use of outside research capabilities via contractors and collaboration with universities and other laboratories could supplement current ARP programs. The greatest potential for significant impact of ARP on the objectives of the NAS will result from increasing efforts to encourage interaction among biomedical and behavioral scientists, human factors specialists, design engineers, and FAA administrators responsible for development of regulations and standards.
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<tr>
<td>AAALAC</td>
<td>American Association for the Accreditation of Laboratory Animal Care</td>
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<td>AAS</td>
<td>advanced automation system</td>
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<td>AERA</td>
<td>automated en route air traffic control</td>
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<td>AMA</td>
<td>American Medical Association</td>
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<td>AME</td>
<td>aviation medical examiner</td>
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<td>ARC</td>
<td>Ames Research Center</td>
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<td>Aeromedical Research Program</td>
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<td>CAMI</td>
<td>Civil Aeromedical Institute</td>
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<td>CAT</td>
<td>Cockpit Automation Technology</td>
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<td>CFWS</td>
<td>central flow weather service unit</td>
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<td>DARPA</td>
<td>Defense Advanced Research Projects Agency</td>
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<td>FAA</td>
<td>Federal Aviation Administration</td>
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<td>Federation of American Societies for Experimental Biology</td>
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<td>FPL</td>
<td>full performance level</td>
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<td>IDEAL</td>
<td>integrated design engineering and analysis language</td>
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<td>IDEF</td>
<td>integrated computer-aided manufacturing definition</td>
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<td>IFR</td>
<td>instrument flight rules</td>
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<td>LSRO</td>
<td>Life Sciences Research Office</td>
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<td>NAS</td>
<td>National Airspace System</td>
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<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
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<td>NBDL</td>
<td>Navy Biodynamics Laboratory</td>
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<tr>
<td>Abbreviation</td>
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<td>NTSB</td>
<td>National Transportation Safety Board</td>
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<td>OAM</td>
<td>Office of Aviation Medicine</td>
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<tr>
<td>SAINT</td>
<td>system analysis of integrated network of tasks</td>
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<td>USDA</td>
<td>U.S. Department of Agriculture</td>
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<td>VSCS</td>
<td>voice switching and control system</td>
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I. INTRODUCTION

A. BACKGROUND

The Federal Aviation Administration (FAA) is responsible for airworthiness of aircraft, the performance of aviators and air traffic controllers, protection of aircrews and passengers, and the efficient and safe operation of the civil aviation system. In recent decades the activities of the FAA have increased as the nation has become more dependent on a system that has become larger and more technologically complex. There is an increasing reliance on sophisticated automated systems to provide accurate information for both the aircrews and the air traffic controllers. These advancements in the air transport system increase the complexity of the tasks for those using, operating, or overseeing the nation's airways, and for those responsible for identifying and fulfilling research needs that support the system.

The FAA maintains an aeromedical program to provide research and service support in the areas of aviation medicine, employee performance, human resources and behavioral psychology, protection and survival, and related biomedical sciences (Reighard, 1976). Since 1926, the FAA aeromedical research has been responsive to problem solving, public demands, and changes in regulatory policy. In a detailed history of Civil Aviation Medicine (1926-1974), Holbrook (1974) notes that many issues of aviation medicine (e.g., medical standards for pilots, training and performance, safety and survival) continue to resurface with policy changes, new biomedical data, and improved technology. Over the past several decades, there have been numerous reviews, evaluations, or analyses of the scope and direction of aeromedical research in civil aviation.

Traditionally, the Aeromedical Research Program (ARP) maintains considerable flexibility of response to both program directives and specific immediate aeromedical problems. In 1981, the FAA initiated a long-range program, the National Airspace System plan (NAS), to upgrade the efficiency, productivity, and safety of the civil aviation system (Federal Aviation Administration, 1981). Based upon recognition that the NAS would require expanded emphasis on aeromedical research and might require modification of aeromedical research activities, the Federal Air Surgeon requested that LSRO/FASEB review the current status of the ARP and suggest future research needs.

B. STUDY SCOPE

The objective of this study is to examine the available resources and services of the ARP as well as to evaluate the research needs and means for improving the focus and usefulness of the ARP in accordance with the NAS mandate beyond the year
2000. The study included, but was not limited to, human engineering and man/machine interface; employee selection criteria and performance; occupational health and hazards; protection and survival; medical standards*; education and training; combustion toxicology; work force optimization; medical, physiological, psychological, and biochemical aspects of aviation medicine; and other ARP activities.

The LSRO/FASEB review was conducted in two phases. This report, Phase I, focuses on the OAM research efforts and related activities of the ARP conducted at the Civil Aeromedical Institute (CAMI). The report contains the findings of an ad hoc Group of knowledgeable scientists who assisted in the evaluation of ongoing research at CAMI. This Phase I report includes identification of research needs and makes suggestions on topics for future emphasis. The Phase II report discusses observations of the ARP user community, identifies additional gaps in knowledge, and makes additional recommendations on research needs. It also examines the overall scope of the ARP and its services to the FAA.

The LSRO/FASEB review of the ARP is particularly appropriate as the NAS plan enters the next stage of implementation (1985-1990). As the NAS plan evolves, there are new and increasing demands on the OAM for research responsive to the FAA needs and public demands for a safe and effective air transport system. Together, the Phase I and Phase II reports will provide the Federal Air Surgeon with documents useful in program planning for aeromedical research in FAA.

* The study excludes review of the Airman Certification Program because this aspect of the OAM responsibilities was evaluated recently (Engelberg and Doege, 1986; Engelberg et al., 1986).
II. ORGANIZATION OF FAA AEROMEDICAL RESEARCH

The FAA was created by the Federal Aviation Act of 1958 to provide safe and efficient use of the nation's airways and to foster the development and safety of civil aviation. The Federal Aviation Act, as amended (49 App. U.S.C. §1353(c), 1982 ed.), includes administrative authority for the FAA to develop, modify, test, and evaluate procedures, facilities, and equipment required for safe and efficient navigation and control of all civil and military aviation. This mandate includes behavioral research and development as deemed appropriate to protect persons and property aboard aircraft against acts of criminal violence and aircraft piracy (49 App. U.S.C. §1357(d)(1), 1982 ed.). With the implementation of the NAS plan in 1981, the FAA adopted a comprehensive research, education, and development program to modernize and improve air traffic control and airway facilities services through the turn of the century (Blake, 1984; Federal Aviation Administration, 1986a,b,c). The Airport Improvement Act (49 U.S.C. §2201 et seq., 1982 ed.) provides the authorization for these major improvements to the NAS.

Within the disciplines of aviation medicine, behavioral science, and human factors engineering, the FAA conducts numerous activities including research, development, testing, evaluation, education, and promulgation of regulations. Most of the research conducted within the ARP applies to specific operational problems and future needs of NAS implementation.

In one form or another the U.S. has supported a research capability in aviation medicine and related disciplines for several decades. However, as documented by Holbrook (1974), the administrative location of the responsibility for aeromedical research has had a turbulent history. The FAA Administrator has delegated responsibility for these activities to the Office of Aviation Medicine (OAM), which is directed by the Federal Air Surgeon under the supervision of the Associate Administrator for Aviation Standards (Figure 1). Located in Washington, D.C. at FAA headquarters, the OAM is responsible for operational support services and research activities related to the biomedical sciences. OAM efforts are focused on the safety of civilian aviation and the health, safety, and effective performance of FAA personnel (Federal Aviation Administration, 1986a).

The responsibilities of the Federal Air Surgeon include physical standards and certification for pilots, physical and performance standards for air traffic controllers, oversight of aviation medical examiners, certification appeals, collection of data relevant to the Age-60 retirement rule for airline pilots, and the Civil Aeromedical Institute (CAMI). OAM also participates in the man/machine interface problems of the next generation aircraft and advanced automated air traffic control systems, testing equipment and suggesting standards for operational use,
Figure 1. Organizational Relationships of the Office of Aviation Medicine at FAA.
and evaluating work force optimization. These activities are conducted at CAMI and by the divisions of Aeromedical Standards, Biomedical and Behavioral Sciences, Program Operations, and Occupational Health at FAA Headquarters (Figure 2).

According to the NAS implementation plan (Federal Aviation Administration, 1986a), objectives of the ARP are:

- To develop comprehensive, statistical, and conceptual database systems for optimizing the productivity and performance of the Agency operational work force at a minimum cost to the public.
- To develop procedures and analytical techniques for reducing human errors in airspace management.
- To develop appropriate medical standards for airmen and Agency operational personnel, and maintain a high level of occupational health and safety standards in a cost-effective manner.
- To reduce the potential for injury or loss of life following aircraft accidents or incidents.

The ARP has investigated a broad range of topics such as techniques for selection of air traffic controllers, physiological and psychological aspects of fatigue, aircraft security and protection, and interactions between aircrews and air traffic controllers. In addition, the ARP has addressed specialized research topics such as the impact of therapeutic drugs on pilot performance and aeromedical standards, and criteria for educational attainment of candidate air traffic controllers using automated teaching techniques and skill evaluation methods. Dille and Haraway (1983) have prepared an index of reports on aviation medicine and related activities from the FAA Office of Aviation Medicine (1964-1982) and Civil Aeromedical Research Institute (1961-1963).

In response to the NAS implementation plan, the ARP can anticipate increased emphasis on the biomedical aspects of man/machine interface with new automation systems, such as Advanced Automation System (AAS), Voice Switching Control System (VSCS), Advanced En Route Air Traffic Control (AERA), and Central Flow Weather Service Unit (CFWS). The ARP continues to develop a national resource data bank on the selection, training, and performance of the FAA air traffic controller work force, and provides information for improving passenger safety and protection.

The major resources of the ARP are the OAM and CAMI (Figure 2). ARP activities include participation in programs at other FAA offices, test facilities, and government agencies. The Office of the Associate Administrator for Human Resources Management makes use of CAMI in the evaluation of educational criteria.
Key to functions: Support Service □, Research □□, or Combination □□

* Includes aviation and forensic toxicology, pathology, biochemistry, neuropharmacology, radiobiology, vision research, and veterinary medicine.

Figure 2. Functional Elements, Organizational Relationships, and Principal Activities Related to the ARP.
and development of human performance measurement techniques. The FAA Technical Center, located in Atlantic City, New Jersey, has requested ARP participation in biomedical aspects of engineering, instrumentation, and airworthiness activities. The drug screening program of the CAMI pathology and toxicology services are used by the National Transportation Safety Board. Some operational and research activities are supported by contracts.

The Civil Aeromedical Institute, established in 1960 at the Mike Monroney Aeronautical Center in Oklahoma City, became a component of the OAM in 1985. This orients the activities of CAMI more directly to FAA's needs and enhances the transition of laboratory research to the operational environment (Smith, 1983). This also facilitates the management of the CAMI budgeting process and provides continuity in ARP support to the NAS.

CAMI provides specialized research and training facilities and a resource of scientists in the biomedical and related behavioral sciences. The Institute has the following branches: Aeromedical Certification, Aeromedical Education, Aeromedical Research, Human Resources Research, and Aeromedical Clinical. Included within the Aeromedical Research Branch are laboratories for Aeromedicine (aviation toxicology and related disciplines), Protection and Survival, and a Biostatistical Section (Figure 2). A list of ongoing activities of the ARP at CAMI is given in the Appendix.

CAMI activities also include the development and maintenance of a system for the medical certification of airmen; applied research on aviation safety; an occupational health program for FAA employees; educational programs for pilots; a central records system for airmen and air traffic control specialists; medical aircraft accident data; and Aviation Medical Examiner (AME) training, performance, and redesignation (U.S. Department of Transportation, 1975).
III. CIVIL AEROMEDICAL CHALLENGES

Several major challenges were identified that will influence the future direction of the ARP. These include the effect of the NAS's improvements in aircraft systems and equipment, and the influence of human capabilities and limitations on operator performance. A multidisciplinary approach is needed that will include greater participation by the ARP as a major partner in these events. This section addresses these major issues, the resolution of which will be facilitated by increased input from the ARP.

A. EFFECT OF NATIONAL AIRSPACE SYSTEM

The NAS plan has far-reaching consequences for the human operator and the productivity of the air traffic controller workforce. Of particular concern are the changing roles of pilots and controllers as increasing levels of automation are introduced (Federal Aviation Administration, 1986b; Sells and Pickrel, 1984). Introduction of next-generation air traffic control systems must be carefully coordinated as they will affect FAA management philosophy, workforce structure, operations, and training.

One goal of the NAS plan is a reduction in the size of the air traffic controller workforce with an accompanying increase in productivity (Federal Aviation Administration, 1981). The Advanced Automation System (AAS) will call for better trained and motivated operational and maintenance personnel. Fundamental human factors issues pertaining to integration of computer-managed, highly-automated, dynamic systems with dispersed clusters of human operators have not been evaluated in a scientifically rigorous manner. The roles of aircrews and ground controllers will need redefinition in operating sophisticated new flight-deck control systems and the AAS as well as in their interfacing. Situational awareness (understanding the context of critical events and situations as they occur during flight and air traffic control operations) will be crucial in environments where the human operator may be required to back up these new systems and to select strategies for operating during conflicts or system malfunctions.

To avoid excessive stress and the compromise of aviation safety, the ARP will have a critical role in the transition to the new system, particularly in easing the impact of increasing automation on the human operators. It is imperative that the human factors technology associated with the development and introduction of the AAS stay ahead of the hardware changes.
B. IMPROVEMENT OF AIRCRAFT SYSTEMS AND EQUIPMENT

The introduction of new hardware technologies will affect the entire aviation community, from modern commercial aircraft to minimally equipped private aircraft. Advanced flight-deck control systems and the development of the Hypersonic Transport System will add greater complexity. The biomedical and behavioral sciences have the potential of significantly influencing the design of new aircraft and the upgrading of the present fleet. Air vehicle and ground support subsystems will be increasingly dependent on computer resources that must provide the human operator with optimal quality and quantity of information. The potential for information overload is very real unless system designers are provided scientifically-based biomedical and human factors procedures and criteria for assigning the most appropriate tasks to the human operator. Smaller, privately owned, and cargo transport aircraft present a wide variability in structure, state-of-the-art components, and in sophistication of flight control systems. It may be difficult for some private owners to obtain the expensive avionic equipment that will be needed for access to the NAS. This has implications for additional research on human factors in air traffic management in the NAS.

The design of cockpit and passenger spaces and the onboard equipment for flight safety and protection are often less than state-of-the-art (Federal Aviation Administration, 1986d; National Academy of Sciences, Committee on Airliner Cabin Air Quality, 1986; National Research Council and the Institute of Medicine, Commission on Trauma Research, 1985). To help remedy these shortcomings, responsive cooperation between industry and FAA regulatory authority is mandatory. It is essential that the protection and survival testing activity of the ARP and the FAA offices responsible for setting standards be coordinated with these ends in view.

C. HUMAN CAPABILITIES AND LIMITATIONS

The introduction of the Advanced Automation System will modify the nature of aircrew and air traffic control specialist performance requirements. Increased operator skill levels will probably be required as a result of the AAS and the anticipated reduction in the work force related to the NAS plan. The human operator has a natural ability to integrate visual and auditory information input with voice and manual control outputs where spatial registration with the real world is preserved. Under these conditions, workload capacity is large. However, when information is presented in largely symbolic formats, requiring extensive transformation and fusion, workload capacity is sharply reduced. Suboptimal performance of individuals in a highly motivated work force can increase operator frustration, lead to
a higher incidence of self-reported stress, and a change in employee perception of health risk (Shilling and Brackbill, 1987; Silverman et al., 1987).

Sophisticated techniques of personnel selection, training, and performance evaluation must be continuously refined to accommodate the NAS advancements. In order to improve equipment and system design, operational procedures, and the responsiveness of the FAA to identify and manage the future work force, changes associated with occupational stress must be understood and quantified. Control of drug and alcohol abuse is mandatory and requires application of every available resource, as well as close coordination and cooperation within and between the FAA and the air transportation industry. The changing physical and mental demands that will accompany the implementation of the NAS and medical advances that extend the productive work life of the individual will lead to revised regulations for medical and performance standards of airmen and air traffic control personnel. The ARP will have a central role in meeting the challenges raised by human limitations.

D. PARALLEL PROGRAMS

Members of the ad hoc Group identified parallel research efforts focusing on the effects of automation on aviation activities and aircrew. The following examples serve as a basis for examining the man/machine automation issues relevant to the future civilian NAS.

1. The NASA Ames Research Center (ARC) maintains a continuing program to evaluate automation of flight-deck activities (Boehm-Davis et al., 1981; Rouse, 1981). An overview of this program provides an extensive list of research issues on this subject. The NASA/ARC program has demonstrated that automation-associated, computer-aided problem-solving can greatly aid the crew by performing the record keeping. An additional advantage is that these computers can assess the implications of flight actions. Such automation can substantially reduce the frequency of human errors without removing the crew from overall responsibility. The NASA/ARC problem-solving studies have shown that performance can be improved if the crew is aided in goal coordination. This is especially true in failure mode situations. Information provided to the aircrew by higher-level computer aids would be more advanced than the automated equipment currently available.

2. A research program at the Harry G. Armstrong Aerospace Medical Research Laboratory, Dayton, Ohio involves the development of analytic models and procedures for designing large, multi-node, command and control networks and operator workstations. The most recent model construct
called Integrated Design Engineering and Analysis Language (IDEAL) has been developed by fusing a large scale static network model called IDEF (Integrated Computer-aided Manufacturing Definition) with a dynamic bottom-up analysis routine called SAINT (System Analysis of Integrated Network of Tasks). This technology is sufficiently general to be easily adapted for use in designing air traffic control networks and workstations.

3. A cooperative project, involving scientists at the Harry G. Armstrong Aerospace Medical Research Laboratory and the Air Force Wright Aeronautical Laboratories (Flight Dynamics Laboratory and Avionics Laboratory), is being conducted to specify and validate a crew-station design procedure for assuring the optimal use of automation. The procedure exploits analysis (models) and man-in-the-loop simulation to iterate alternative concepts to choose a final design that assures acceptable pilot workload, optimal system performance, and affordable system cost. The program called Cockpit Automation Technology (CAT) is tailored for design of air-to-ground fighter cockpits; however, the technology products would provide an excellent starting point for developing similar design procedures for the improved use of automation in air transport applications.

4. The Defense Advanced Research Projects Agency (DARPA) is sponsoring a research effort called the Strategic Computing Initiative. Part of this activity, the Pilot Associate Program, is being conducted by the Wright Aeronautical Laboratories with the participation of the Harry G. Armstrong Aerospace Medical Research Laboratory. Human factors research of this program addresses requirements for maintaining an optimal dialog between the human operator and the "electronic copilot" (computer), the human operator and the flight environment (information displays), and the "electronic copilot" and the aircraft subsystems. This technology will have direct application to air traffic control system and future transport design.

5. A new advanced development effort, the "Super Cockpit" program, was initiated at the Harry G. Armstrong Aerospace Medical Research Laboratory in 1986, and is supported by the Air Force Wright Aeronautical Laboratories and the Aeronautical Systems Division. This effort will demonstrate a radically new concept for design of the man/machine interface in high technology fighter or bomber aircraft. The effort will demonstrate the profound benefits of presenting both audio and visual information in three-dimensional virtual image space, maintaining one-to-one spatial registration between all synthetic representations of the world and the actual physical environment. Intuitively natural control strategies employing
voice and head, eye, and hand position sensing will be integrated with the virtual display environment. This technology will have direct application for reducing cockpit information overload and will provide an attractive control and display medium for future air traffic control workstations.

6. The Navy Biodynamics Laboratory (NBDL) in New Orleans, Louisiana as well as other military laboratories have conducted extensive research on injury mechanisms found on exposure to high acceleration force fields. While most of this work is focused on human tolerance to forces encountered during emergency escape from high speed military aircraft, the database has relevance to the FAA work on impact injuries suffered during civilian aircraft crashes and to the design of appropriate seat restraint systems.

The greatest potential influence to meet these challenges will result from increasing efforts to encourage interaction among biomedical scientists, human factors specialists, design engineers, and FAA regulators. It is essential that ARP scientists utilize information available from parallel research initiatives, anticipate future applications for civil aviation, and access the aeromedical aspects of new technologies.
IV. EVALUATION OF THE AEROMEDICAL RESEARCH BRANCH AT CAMI

This chapter presents the opinions of the members of the ad hoc Group on the strengths and weaknesses of the ARP, topics needing greater emphasis, and suggestions for research program planning. The ad hoc Group recognizes that current research activities at CAMI are germane to aviation medicine, the behavioral sciences, and the ARP. The suggestions of the ad hoc Group provide additional validation for these areas of research emphasis.

Research at CAMI includes individual tasks conducted by the constituent laboratories of the Aeromedical Research Branch and the Human Resources Research Branch (see Figure 2). The primary tasks are in some instances divided into a number of subtasks. These tasks, listed in the Appendix (Tables 1-5), are as described by the CAMI staff to the ad hoc Group on December 10-12, 1986, at the meeting in Oklahoma City*. There may be discrepancies between the number of tasks as presented and formal line items in the ARP. No attempt has been made to correlate them with or distinguish them from line items in the FY 1987 ARP.

The division of the material in this chapter into three categories (Human Resources, Aeromedical, and Protection and Survival) is arbitrary, for the convenience of this report. Occasional overlaps of a task in one category with that of another are evident; however, these appear to be the result of the nature of the research tasks and do not cause significant management problems.

A. HUMAN RESOURCES RESEARCH

The main areas of emphasis include: personnel selection, training, maintenance, and evaluation; and human factors research including human performance, and human factors engineering design of equipment and systems for optimal operator effectiveness and man/machine interaction.

1. Program evaluation

The Human Resources Research Branch is one part of the CAMI program that most clearly supports an agenda tied largely to Agency needs. The Human Resources Research Branch maintains close liaison with the FAA's Associate Administrator

* Program details are available upon request from the Manager, Civil Aeromedical Institute, AAM-100, FAA P.O. Box 25082, Oklahoma City, Oklahoma 73125.
for Human Resource Management. In addition, there is an ongoing support relationship with the FAA Academy to conduct research efforts directed toward specific problems of controller selection, training, utilization, and retention. The ad hoc Group observed that this is a seasoned approach to research management illustrating the necessary components of an effective applied research program. These include: 1) an identified need validated by a specific user group, 2) a research program tailored to the needs of the user group, and 3) a feedback loop for continued evaluation of the research product. This proven approach leads to a highly focused research program that efficiently integrates basic research findings into practical applications. This model should be expanded where feasible so as to include other research efforts at CAMI.

Most of the current research of the Human Resources Research Branch is devoted to issues of selection, training, performance evaluation, and retention of air traffic controller personnel. Other tasks address problems in physiological psychology. However, expanding the scope of this program will be essential to include other critical issues (see IV.A-2 below) involving air traffic control specialists and aircrew who must interact with increasingly sophisticated systems. In the opinion of the ad hoc Group, the current psychology research program is highly productive and responsive to well-defined Agency needs.

2. Research needs and suggestions

Future research in the behavioral sciences must continue to explore methods to alleviate any adverse impact that may be induced by NAS automation requirements. The NAS plan introduces fundamental changes in the role of the air traffic control specialist that must be superimposed upon a recently reconstituted work force. As part of this research, it is especially important to determine whether present selection and training procedures are effectively feeding into the system the employees who will accommodate, for prolonged periods of time, to the tasks that automation will create. Particular attention must be given to identifying the optimal environment that promotes job satisfaction and a safer, error-free air traffic control operation. Automation raises the prospect that the air traffic controller's sense of accomplishment will be lessened or removed while the workload and resultant stress that will accompany the monitoring of automated systems will not be lessened (National Academy of Sciences, Committee on Human Factors, 1983, 1984; Sells and Pickrel, 1984; Sheridan and Hennessy, 1984).

Thus, key areas of interest involve personnel issues related to increased automation such as acquisition and retention of operator skills, and the requirement for trained personnel back-up to handle failure modes. Issues involving job
variables such as motivation, satisfaction, group structure and cohesiveness, and organization structure all impact on the continuing FAA requirements for work force productivity. Employee assistance programs are one approach to improving productivity.

An important aspect of air traffic control specialist productivity depends upon the instructor population. Most instructors are senior level air traffic controllers seeking a career change or advancement. There is a need to improve selection criteria, motivation, task analysis, optimize career incentives, and control substance abuse. The same elements of productivity management apply to the maintenance work force of the aviation industry.

More effective methods of evaluating air traffic controller performance are needed. The ARP should contribute to the transition of the current controller work force to the more fully automated systems. Attention must also be given to monitoring and upgrading the performance of Full Performance Level (FPL) controllers. It is especially important to assess how well selection procedures can predict the ultimate performance of FPL controllers.

Conservation of available time of lead scientists at the CAMI Human Resources Research Branch appears to be impaired by nonresearch, service-oriented assignments required for various FAA activities. Such assignments could presumably be conducted with technical advice from CAMI research scientists.

- On the presumption that the Human Resources Research Branch will have to continue its service-oriented activities, the ad hoc Group suggests the establishment of an appropriately staffed sustaining capability for this type of professional activity, possibly expanded via contracts.

The Branch is apparently expected by FAA to increase the scope and content of its research to meet emerging requirements, but is fully committed in terms of its lead scientific staff.

- The ad hoc Group suggests that expansion of the Branch's research capabilities via contractual support should be a research planning objective. It could provide additional high-level capabilities such as investigators with a strong background in management and the use of computers in management sciences. This is especially noted for the tasks of Development and Application of Measurement Instruments to Improve Employee Selection and Work Climate Factors, and Air Traffic Controller Job Task Tracking System Design and Analysis.
Criteria for selection, training, and performance evaluation of air traffic control specialist personnel to meet the needs of the contemplated NAS technology are not yet available.

- The Human Resources Research Branch should participate in developing these criteria, working closely with the Office of Human Resource Management, the Air Traffic Service, the Aeronautical Center, the Technical Center, and other FAA and industrial activities.

- The Branch should also address psychological aspects of aircrew issues that will result from the AAS and advanced flight-deck communications and control equipment. The traffic control problem will require a dynamic partnership between the computer, the air traffic controllers, and the airmen acting as "flight managers". Provisions for handling malfunctions and dealing with suboptimal skill levels at various nodes in the system must be established. When addressing problems of automation, it is important to remember not only the special problems of man/machine interface but those caused in people-to-people interactions in a largely automated environment. The ad hoc Group has identified examples of related research programs addressing these issues in Section III.D (see page 11).

- Systematic appraisal is needed of the psychic impact upon both air traffic control specialists and flight crews of the forthcoming AAS and the implications for workload sharing. A similar appraisal of the effects of candidate advanced flight deck control systems upon flight crews related to hypersonic transport concepts is also indicated.

Cockpit design criteria for light general aviation aircraft are frequently below the state-of-the-art.

- Analysis of workloads, particularly those imposed by single pilot Instrument Flight Rules (IFR) flight, should be conducted, and criteria developed for the more efficient design of instrumentation, controls, and layout. Both FAA and the aviation industry share responsibilities in this area. In addition, for this to be meaningful, coordination with FAA aircraft certification authorities is mandatory.

Schedules of work for air traffic control specialists and flight crews require that large numbers of employees work in shifts that are disruptive to circadian rhythmicity. Available data are insufficient for precise estimation of optimal work schedules, selection of "tolerant" individuals, and means of intervention.
More intensive study of this problem as it applies to aviation is essential with particular attention to possible pharmacologic or dietary approaches to intervention.

B. AEROMEDICAL FACTORS

The main areas of emphasis include: medical standards for airmen and air traffic control specialists, biomedical effects of the flight and air traffic control environments, preventive medicine, and toxicology. As noted in Figure 2, many of the laboratories supporting these main areas of emphasis are within the Aeromedical Research Branch.

1. Program evaluation

The members of the ad hoc Group concluded that a detailed, coherent research plan for the guidance of the several research initiatives of the Aeromedical Research Branch would aid in improving both program content and program management. Many new research initiatives within this Branch are laudatory, for example, the intramural study of dynamic visual acuity, and the contractual tasks in pharmacology, neuropsychiatry, and endocrinology. The contractual research should be emphasized as a means of increasing research productivity in the face of limited manning resources. The research and technical support activities of the Aeromedical Research Branch meet various Agency needs satisfactorily.

2. Research needs and suggestions

Significant elements of concern in this area include health maintenance and monitoring, work scheduling and overload, monitoring and control of substance abuse, inflight illness and injury, and medical standards for airmen and air traffic controllers. For these and other problems that arise in this broad category, available scientific data are frequently inadequate to support optimal applications. The ad hoc Group offers the following observations and suggestions.

- A system of surveillance should be developed for identifying emerging behavioral and physiologic problems of flight crew personnel related to continuing changes in air carrier and general aviation equipment, schedules, and procedures.

- CAMI should develop a research capability for sustained epidemiologic evaluation of its unique and extensive medical databases to define civil aviation career occupational health problems and assess the
potential or extant environmental hazards in aviation. Procedural and analysis methods used by the Centers for Disease Control (Centers for Disease Control, Center for Environmental Health, 1984), the Navy (Economos and Miquel, 1979; MacIntyre et al., 1978), and the Air Force (Clark et al., 1980) can better define civil aviation career occupational health problems and assess potential hazards in aviation. Increased exploitation of the Aeromedical Certification Database through application of rare event epidemiology will provide a valuable means of pinpointing new problems and validating research results. Validation of performance degradation from substance abuse should be one of the parameters for analysis.

- Focused occupational stress studies should be planned in civil aviation populations to include topics such as family stress assessment, coronary risk categories, problems related to certification renewal, and employment of personnel with known medical disorders.

- There is a need for a continuing evaluation of emerging biomedical data for development and validation of medical standards for airmen and air traffic control specialist personnel. This should facilitate transition of certification issues to research problem definition, with specific attention to upgrading visual and cardiovascular criteria and standards.

- In relation to aircraft accident databases, correlations of environment factors influencing airmen and air traffic control specialist performance should be updated and efforts to develop strategies for extracting medical information should be sustained.

- In the area of environmental toxicants in aviation, greater emphasis should be accorded to studies of radiation, ozone, biological aerosols, and tobacco smoke.

- Current literature indicates that inhalation of toxicants from the thermal decomposition of building and cabin materials can hinder escape behavior in laboratory animals and humans (Alarie, 1985; Annau, 1986; National Academy of Sciences, Committee on Airliner Cabin Air Quality, 1986; National Academy of Sciences, Committee on Fire Toxicology, 1986). The CAMI capability for combustion toxicology should be sustained and strengthened rather than phased out. Evaluation of these toxicants should lead to improved criteria for structural materials, components, equipment, and procedures for protection of crews and passengers (Federal Aviation Administration, 1986d). The scope of toxicity studies
related to aircraft fires should go beyond identification of flashpoint values of cabin materials, and research should continue to be coordinated with the program of chemical assessment of aircraft fire gases conducted by the Fire Safety Branch at the FAA Technical Center. Related information generated in the academic community, the National Bureau of Standards, and the Department of Defense should be fully exploited.

Research in radiobiology should continue to involve primarily the effects of low levels of microwave radiation leaking from wave guides. Databases on low level microwave radiation effects in the air traffic control and aviation environments should be continuously updated. The effects of other forms of electromagnetic and particulate radiation are subjects of intensive research in numerous governmental, industrial, and university laboratories. Results of these studies should be closely monitored by responsible OAM scientists.

The research issues implicit to the introduction of the NAS technologies will require greater emphasis on the blending of physiologic and behavioral approaches to applied research problems. For example, issues of workload management, mental stress, decision theory and judgment, illusory perceptions, and detachment will need critical examination in the context of the effects of subclinical disease states and medications, both casual and prescribed.

The report of the American Medical Association on medical standards for airmen (Engelberg and Doege, 1986; Engelberg et al., 1986) provides recommendations on testing dynamic visual acuity and other visual parameters. Additional studies are indicated in view of these recommendations, the findings of other vision research (American Academy of Ophthalmology, 1984; Grandjean and Vigliani, 1980; Greenwald et al., 1983), and the imminent introduction of widescale cathode ray tube (CRT) technology in air traffic control facilities and on the flight deck. Future research in vision must concern itself with the legibility of the CRT. It must identify the factors involved in seeing and interpreting events on this display. Individuals are known to differ greatly in the extent to which they rely on peripheral vision and there is a need to determine whether individual differences have the potential to increase operator errors under high background lighting and other environmental conditions.

Future vision research must include not only dynamic visual acuity in pilots and air traffic control specialist personnel but also development of job-related visual
acuity tests for air traffic control specialist personnel. There is a need to evaluate color vision requirements for both pilots and air traffic control specialist personnel and to study the effects on performance of visual distortions induced by progressive power lenses. In addition, the role of color perception in new visual display concepts should be a part of current and future research in visual physiology.

The veterinary medicine resources at CAMI are utilized for research on wild animal problems, safety in animal air transport, and matters of pest control or quarantine. Inadequate wildlife control around airports is a continuing issue that may lead to runway incursions or strike hazards. The animal care and holding facilities at CAMI support experimental animal work and are well managed. CAMI is to be commended for maintaining an American Association for the Accreditation of Laboratory Animal Care (AAALAC) accredited animal facility.

- This important resource should be augmented and utilized for purposes other than maintenance of the animal colony. The FAA's concern for the protection of airports against incursions by deer and other animals is laudable and should be continued. Research for bird strike protection and the control of avian populations should be programmed.

There is some evidence that aircraft accident investigating teams deployed in the United States could benefit from participation of pathologists and aviation medical examiners (AMEEs) trained in pathologic aspects of accident investigation (Ellis, 1977; Mason, 1977).

- CAMI should increase efforts to secure an active role in the investigation of accidents including the use of its pathology resources. A much more intensive effort must be made to extract medical data from accidents, to assess the human role in causation, to determine toxicologic aspects, and to identify any contribution from preexisting disease. It is important to determine how effectively current and projected medical standards prevent pilots with certain pathologic disorders from obtaining pilot certification.

- The training of AMEEs should be modified to include uniform emphasis on collection of pathological data and specimens in accident investigations.

Research tasks at the CAMI physiology laboratory were phased out following a report about the ARP resources needed to support the NAS plan (Smith, 1983). The ad hoc Group considers
as ill-advised the recent elimination of CAMI professional capability in physiology and the possible loss of resources in biochemistry. Integration of physiologic and biochemical investigations with research on human workload and performance will be essential in the future. For example, current techniques for measuring workload include physiological procedures such as evoked potential measurements, electromyography, evaluation of heart rate variance, and eye blink analysis, all of which require physiological expertise. The contributions of staff physiologists are important for OAM to assure that FAA receives adequate support in research tasking and monitoring and evaluation of related NAS initiatives in this field.

New investigative approaches in toxicology applying physiologic and metabolic modeling techniques to predict pathologic outcomes and scale toxicity data across species (so-called toxicodynamics) are absolutely dependent upon biochemical support. Food safety assessment, waste disposal methods and monitoring, and transport of biologicals are other areas that rely in part on biochemistry. If CAMI has no in-house resources to meet these needs, contractual relationships with appropriate research institutes should be implemented.

C. PROTECTION AND SURVIVAL

The main areas of emphasis include: biodynamics, crashworthiness of aircraft and safety-related equipment, survival gear and procedures, anthropometry, and associated design criteria.

1. Program evaluation

The program of the Protection and Survival Laboratory is solidly focused on passenger safety issues including, as examples, cabin evacuation, adequacy of seat and restraint equipment designs to prevent injury in survivable accidents, safety provisions for ditching, and protective breathing equipment. An impressive amount of good work is conducted by a very small staff at an array of specialized support facilities. The technical staff is well informed about complementary research conducted within the Department of Defense and at commercial laboratories. The horizontal impact track is both simple and versatile, ideally suited for equipment testing, and the hypobaric chambers are available for decompression studies as well as physiology training. The work in aircraft cabin safety enhancement is notable for its thoroughly developed database which provides a sound basis for hardware development and operational safety doctrine. This Laboratory is an extremely valuable resource to the aviation community. However, the FAA research program at this Laboratory is encumbered by near-term service test requirements and deficient in the longer-range
research initiatives needed to enrich the FAA's capabilities for addressing problems in protection and survival (e.g., new concepts in protective breathing equipment, water survival, and seat restraints). The special research facilities and equipment in the Laboratory are unique and should be utilized more extensively for data on the safety of aircrew and passengers.

2. Research needs and suggestions

There are serious shortfalls in knowledge and technology needed for improving the safety of general aviation as well as air carrier aircraft and safety-related equipment in terms of protection and survival. An additional problem not of a research nature, is that design criteria and manufacturer-furnished safety equipment are in some cases below existing state-of-the-art, particularly in light general aviation aircraft. The cockpit environment of the average small private aircraft is inadequately engineered in terms of occupant safety in the event of an accident. Restraint harnesses are inappropriately designed. The practice of using a center point lap belt connection for a commonly used torso restraint system has not been adequately tested and is likely to increase the probability of serious injury with exposure to relatively low crash forces. No adequate database exists defining the anthropometrics of the private pilot population or the private aircraft passenger population. In some aircraft, instrumentation may be out of reach or out of view or both, and stick forces may be out of range for pilots with smaller than average physique.

- In addition to the research implications of the foregoing, it is suggested that more emphasis should be placed on the accommodations for flight attendants of varying physical stature. This should include, but not be limited to, the design of seating, instrumentation, and the placement of emergency equipment. The area of restraint for cabin crew also requires major research attention as does the need for physiologically compatible protective breathing equipment for cabin crew who must be mobile and active in the postcrash environment. In general, research should be pursued to develop techniques and equipment to increase the safety and efficiency of these personnel.

- The area of passenger behavior in an emergency needs much more work; evacuation process modeling must be refined to provide a rational basis for both designing evacuation support equipment and establishing effective procedures for implementation by cabin crews.

A great deal of valuable information needed to support design for improved crashworthiness could be obtained from scientifically-based accident reconstruction technology. By
recreating the forces needed to produce the strain patterns and failure modes found after an accident and comparing these forces with the injury patterns observed, design inadequacies can be uncovered and design improvements can be defined.

- In physical anthropology, a support program needs to be established which will have as its endproduct a set of standards defining body dimensions, performance capabilities, and tolerances relating to civil aviation. Currently available information is very fragmented and there is little agreement on what information to use as the basis for design specifications.

- Standards should be developed for noise protection equipment in light general aviation aircraft.

- There is a pressing need for development and use of dynamically realistic nonliving surrogates (manikins) for evaluating advanced support and restraint designs as well as identifying the effects of fire and fragmentation. A modest effort in this regard is underway in various Department of Defense laboratories that could provide the basis for an efficient interagency program. Joint programs could provide for the FAA's civil aviation requirements.

During their visit to CAMI in December 1986, members of the LSRO ad hoc Group became aware that CAMI lacked formal guidelines for safeguarding the rights and safety of volunteer human subjects participating in research studies. It is understood that responsible authorities at OAM are in the process of establishing such guidelines as standing operating procedures. The ad hoc Group suggests that such guidelines be put into effect immediately by FAA and compliance should be required for all projects involving human subjects. In addition, the scope of work for this study did not include a review of standard operating procedures, records management, and good laboratory practice (GLP) monitoring procedures at CAMI. In the event that GLP guidelines are not in place at FAA, the Agency should take immediate action to develop such guidelines and assure that all aspects of CAMI research activities are in compliance with acceptable GLP procedures.
V. CONCLUSIONS

Current ARP activities clearly address the FAA mandate and respond to operational needs in civil aviation. The ad hoc Group considers ARP activities to be clearly applied research. Nevertheless, in some instances the ARP is, at the same time, conducting research at the leading edge of discovery where new information will provide significant improvements to understanding problems such as man/machine interface of the new AAS.

The staff is capable and productive and there are outstanding examples of research excellence apparent throughout the major technical areas. There is good potential for program improvement which should help to correct perceived shortfalls in program content and anticipated new Agency research needs. However, additional funding and manpower will be required at CAMI if the future ARP is to meet the needs of the NAS and other FAA initiatives. The ad hoc Group identified a number of factors that appear to hinder full development and more effective operation of the Aeromedical Research Program at CAMI. The constraints involve problems that are typical in government laboratories as well as factors that are not immediately obvious.

The FAA is an operationally oriented service organization with significant regulatory responsibilities. Accordingly, the Agency often must work in a crisis-intervention mode and is sensitive to public pressure. Because the final product of much FAA activity is regulatory in nature, ARP research often has a regulatory goal. This impacts on the continuity of applied aeromedical research because so much of what needs to be done should lead only to information useful in guiding the pilot or the aircraft designer towards safer procedures and equipment. This environment appears to hinder the full development of a detailed mid- to long-range aeromedical research program and its thorough integration with FAA's major activities. A result of this is the apparent lack of a comprehensive, mid- and long-term research agenda at CAMI (as distinguished from the current ARP at CAMI) that would lead to a stable, progressive, and well-coordinated ARP. This will be considered further in the Phase II report.

The FAA is a primary regulatory agency managing a large work force (air traffic controllers) that must interface with a profit-oriented airframe manufacturing and airline transportation industrial complex that manages the aircrews and airline maintenance personnel. In addition, the FAA must interface with local governments that control and staff airport facilities with another large work force. Furthermore, all of these populations negotiate with the federal government and industry through organized labor unions. This complex relationship has a net effect wherein research program initiatives and endproducts depend, in part, upon industry acceptance, again mediated by federal
regulation. Transition from research programs to products is rendered more difficult and may require marketing operations where not federally mandated. Examples to illustrate this are:

1. Industry has not yet accepted biodynamic testing for crashworthiness evaluation of general aviation seats and restraint systems. As a consequence, some crew protection systems now flying are years behind state-of-the-art. Nevertheless, the CAMI Protection and Survival Laboratory must continue to maintain its status as a credible, independent test and evaluation facility and operate at no cost to industry.

2. Industry (and FAA) is slow to move from reliability on flammability control and fire-suppression standards to more realistic human toxicity criteria in survivable crash protection standards.

Several offices at the FAA Headquarters, each with a specific mission, share in the responsibility for the requirements-responsive activities of the ARP. Funding to perform aeromedical research is assigned to the Associate Administrator for Development and Logistics. A more comprehensive mid- to long-term aeromedical research plan as outlined by the FAA (Federal Aviation Administration, 1986a,b) and endorsed by the FAA Headquarters is not available at this time. A consequence of these various factors is that program guidance to the OAM and the ARP research community tends to be fragmented. The problem is complex and will not be resolved merely through the publication of a research prospectus.

A challenging problem for laboratories such as those at CAMI is to balance research programs developed to satisfy near-term requirements for specific application with long-term "technology push" programs, to ensure that the state-of-the-art will progress at a sufficient pace to provide FAA sponsoring activities with the necessary advanced technology in the biomedical and behavioral sciences in the future. Although some exceptions were evident to the LSRO ad hoc Group, communication between key individuals in participating offices at FAA Headquarters and those involved in the ARP at CAMI, including individual research scientists, appears less than optimal. This common problem in large organizations with diverse activities needs continuing effort toward improvement. These two topics will be described in greater detail in the Phase II report.

In view of the limitations on the size of the research staff at CAMI, members of the ad hoc Group noted that the increased use of outside research capabilities via contracts and collaboration with universities and other laboratories would enhance the FAA research program. Although previously
recommended by another study group (Smith, 1983), this has apparently not been more vigorously pursued. The new initiatives in vision, endocrinology, and neuropsychiatry appear highly appropriate as examples of contracted research. If currently designated funds are inadequate, increased funding should be requested to support additional contracting and the sponsoring of university graduate student training programs. However, expansion of contractual research at CAMI will require firm policy and fiscal support at all management levels in the FAA to ensure the preservation of existing intramural research programs and resources at CAMI.

Finally, the members of the ad hoc Group detected signs of an apparent morale problem among some of the research staff at CAMI who perceive their work as generally not appreciated and their visibility in CAMI, the FAA, and the scientific community as obscured. Despite the commendable, sometimes outstanding, quality of their work and support and encouragement from the OAM, they lack adequate identification and visibility as a contributing unit of FAA to maintain enthusiasm and high morale. This problem may be inherent to large, decentralized organizations. The ad hoc Group considers this to be a complex issue involving interaction among all levels of Agency and DOT management, the resolution of which could be improved via communication and program supervision.
VI. LITERATURE CITED


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APPENDIX

CAMI RESEARCH TASKS IDENTIFIED FOR THE AD HOC GROUP*

A. AVIATION PSYCHOLOGY

Most of the current research projects of the Human Resources Research Branch are devoted to issues of selection, training, performance evaluation, and retention of air traffic control specialist personnel. Other tasks address problems in physiological psychology. Current research is listed in Table 1.

B. PROTECTION AND SURVIVAL

The programs of the Protection and Survival Laboratory are focused on passenger safety issues including, as examples, cabin evacuation, adequacy of seat and restraint equipment designs to prevent injury in survivable accidents, provisions for ditching safety, and protective breathing equipment. Current research activities of the Protection and Survival Laboratory are listed in Table 2.

C. AVIATION TOXICOLOGY AND RELATED DISCIPLINES

Most of the remaining research activities of the Aeromedical Research Branch are conducted or directed by the Aviation Toxicology Laboratory, laboratories in related disciplines (pathology, biochemistry, neuropharmacology, radiobiology, and vision research), and the Office of the Branch Director. Current research of the Aviation Toxicology Laboratory is listed in Table 3, and that in aviation vision in Table 4. Current contract research is listed in Table 5.

D. RELATED ACTIVITIES - AEROMEDICAL CERTIFICATION DATABANK

CAMI also maintains the Aeromedical Certification Databank. There are two main databases, the airman database and the medical accident database system; in addition, there are the health data from certification and postcrash information. These databases include approximately 500,000 applications per year plus 8,000,000 in the history file.

* Program details are available upon request from the Manager, Civil Aeromedical Institute, AAM-100, FAA P.O. Box 25082, Oklahoma City, Oklahoma 73125.
Table 1. Human Resources Research Branch

Current Research Activities

1. System analysis of various FAA management structures or programs.

2. Developing and applying various psychological measures of performance, primarily to air traffic controller-related personnel categories.

3. 1986 FAA employee survey construction, distribution, and analysis.

4. Air traffic control specialist screening, training, and tracking system design, data verification, and evaluation and validation.

5. Developing the air traffic control specialist operational error reporting system as a CAMI database.

6. Monitoring of the Airway Science Curriculum Demonstration Project.

7. Analysis of color-coded cockpit displays on pilots with color vision medical waivers.

8. Structuring multiple task performance batteries which simulate relevant pilot and air traffic control specialist behavior (impact of sleep deprivation, altitude, and age on pilot performance).

9. Determination of specific factors that maintain or degrade air traffic control specialist performance and quantifying same for simulated radar tasks using advanced system characteristics.
<table>
<thead>
<tr>
<th>Current Research Activities</th>
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<tbody>
<tr>
<td>1. Dynamic testing of various existing and improved aviation-related seat and restraint combinations.</td>
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<tr>
<td>2. Extensive consultation activity on new seat and restraint standards.</td>
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<td>3. Testing of improved passenger oxygen masks.</td>
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<td>5. Testing and development of improved water survival equipment for aircraft occupants.</td>
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<tr>
<td>6. Coordinating physiological test components of pharmacology research addressing medical certification of pilots.</td>
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<tr>
<td>7. Recently evaluated aircraft evacuation scenarios utilizing improved floor proximal marking systems.</td>
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<tr>
<td>9. Transitioning to water survival equipment testing.</td>
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<tr>
<td>10. Systematic assimilation of cabin safety data with subsequent analysis leading to improved training and inspection guidelines.</td>
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<tr>
<td>11. Focus on operational factors in need of remedy and/or research.</td>
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Table 3. Aviation Toxicology Laboratory

**Current Research Activities**

1. Southwest Region Accident Investigation Program -- prototype for national expansion.

2. Toxicological studies on biological specimens submitted from fatal aviation accidents; recent expansion of toxicology program to support federal railroad administration.

3. Detailed definition of toxicity endpoints associated with combustion products related to aviation-related fire environments.

4. Identification of aerial applicator experience with newer pesticides.

5. Separate seats and shoulder harness study addressing use and efficacy in general aviation crash scenarios using data collected by CAMI investigators and specially-trained aviation medical examiners.

6. Developing advisory circulars addressing the relevance of cosmic radiation to cockpit and cabin crew personnel.

7. Cooperative studies with USDA to define improved animal shipping conditions.

8. Monitoring animal incursions in runway environments.

9. Resident consultants in: aviation pathology (to FAA and NTSB); radiation hazards in the aviation environment; animal hazards and concerns in the aviation environment.

10. Standardization of combustion toxicology methodology: baseline data and animal testing.

11. Pharmacological parameters relevant to aviation tasks; the impact of therapeutic drugs on pilot medical certification decisions.

12. The assessment of smoke toxicity; evaluation of the relative individual contribution of carbon monoxide and hydrogen cyanide to the total toxicity of mixtures of the two.

13. Identification of ionizing and RF/microwave health hazards in the aviation environment.
Table 4. Aviation Vision Research

Current Research Activities

1. Optometric studies addressing dynamic visual acuity of pilots:
   a) Under conditions of altitude hypoxia.
   b) With artificial lens implants.

2. Identifying program of research priorities to address recommendations from AMA review of FAA pilot medical certification standards.

3. Development of job-related visual acuity tests for air traffic control specialist personnel.

4. Evaluation of functional color vision requirements and job-related selection tests for pilots and air traffic control specialist personnel.
Table 5. Contract Research

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<th>Current Research Activities</th>
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<tr>
<td>1. Pharmacology: effect of beta-blockers on actual patients regarding problems of medical certification.</td>
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<tr>
<td>2. Neuropsychiatry: cognitive function evaluation in AME setting.</td>
</tr>
<tr>
<td>4. Psychology: improvements for shoulder harness restraint system use in general aviation.</td>
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A REVIEW OF THE FAA
AEROMEDICAL RESEARCH PROGRAM

PHASE II: OFFICE OF AVIATION MEDICINE

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Office of Aviation Medicine
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FOREWORD

The Life Sciences Research Office (LSRO), Federation of American Societies for Experimental Biology (FASEB), provides scientific assessments of topics in the biomedical sciences and reviews of research programs. Reports are based upon comprehensive literature reviews and the scientific opinions of knowledgeable investigators engaged in work in relevant areas of biology and medicine.

This report was developed for the Federal Aviation Administration (FAA), Office of Aviation Medicine (OAM) in accordance with the provisions of Purchase Order No. DTFA01-87-P-08000. The report was prepared by Richard W. Leukroth, Jr., M.S., Staff Scientist; John M. Talbot, M.D., Senior Medical Consultant; Edwin M. Lerner II, M.D., Senior Medical Consultant; and Kenneth D. Fisher, Ph.D., Director, LSRO, FASEB. The report was developed by LSRO on the basis of information, data, and views provided by selected FAA staff during the course of this study.

The final report was reviewed and approved by the LSRO Advisory Committee (which consists of representatives of each constituent Society of FASEB) under authority delegated by the Executive Committee of the Federation Board. Upon completion of these review procedures, the report was approved and transmitted to FAA by the Executive Director, FASEB.

While this is a report of the Federation of American Societies for Experimental Biology, it does not necessarily reflect the opinion of each individual member of the FASEB constituent Societies.

July 29, 1987

Kenneth D. Fisher, Ph.D.
Director
Life Sciences Research Office
EXECUTIVE SUMMARY

This report evaluates the Federal Aviation Administration's Aeromedical Research Program (ARP). It reviews the mission and organizational support for this program as well as the mechanisms used to identify research requirements, solicit ARP services, and approve research initiatives in the biomedical sciences and related disciplines. The report focuses on the management of the ARP by the Office of Aviation Medicine (OAM), the origin of requests for ARP services, the development of ARP products, as well as the acceptance and utility of these in support of other FAA activities.

There are two primary findings of this evaluation study which affect a number of related issues. First, the ARP lacks an identifiable and consistent structure. As a result, the FAA does not derive maximum benefit from the products and professional expertise of the ARP. Second, and closely related to the first conclusion, there is a lack of support within FAA for the ARP. Indeed, confusion and differences of opinion exist within FAA as to the need for the ARP and the specific contributions that such a program can provide.

These findings suggest that there is a need for clarification of the FAA mission statement to present the rationale for the ARP and the objectives to be pursued by this program. Further, mechanisms to assure the integration of the ARP with technological and engineering developments should be mandated explicitly and receive full support of senior FAA management.

The ARP mission statement should identify the organizational structure of the ARP, precise information about the role of the ARP in the National Airspace System (NAS), the relation of the ARP to other components of the FAA, and the scope of the ARP programmatic mandate. The organizational structure should address lines of authority, responsibility, and funding. In addition, the mission statement should reflect the functional needs of FAA rather than disciplinary orientation of ARP component resources. The objectives and boundaries of the ARP should include information on shared responsibilities and specific reference to complementary research of other FAA units.

A third major finding, notwithstanding those previously described, is that most ARP research reports and program activities reviewed in this study contain information of scientific merit and value to civil aviation and the advancement of the NAS. However, deficiencies in identifying, coordinating, and communicating mid- and long-term research requirements exist. As a consequence, operator performance, human factors, and other aspects of the behavioral and biomedical sciences are often not fully considered in long-range program planning.
Based on these findings, the report identifies several issues and develops suggestions for consideration by the FAA.

1. Research Priorities. In the current mix of research activities, including crisis-intervention responses, many important ARP goals receive low agency priority. It is suggested that FAA management bring OAM scientists into early plenary activities involving major initiatives at FAA. This would alert FAA to potential human-oriented problems before they become issues that require crisis-intervention responses.

2. Program Planning. FAA is not fully meeting its Research, Engineering, and Development (R,E&D) responsibilities in regard to including aeromedical research results that provide for a safe and efficient navigation and traffic control system for civil aviation. It is suggested that a series of interactive workshops be sponsored by FAA Headquarters involving multidisciplinary groups of selected representatives from within FAA, academia, industry, and other government agencies. The objective would be to develop a coordinated aeromedical research plan addressing not only scientific and technical program content, but also FAA investment strategy for its execution.

3. Support Tasks. The limited resources of the OAM are being siphoned off by service-oriented tasks in support of clearly important operational needs as well as equally important crisis-intervention projects for other FAA offices. This impairs the ability of OAM to meet mid- to long-term research program goals. It is suggested that the future ARP plan provide sufficient resource allocations to include such services along with the required depth and breadth of scientific skills. The conduct of research should be given equal priority with support services.

4. Research Initiatives. Procedures for solicitation and application of research Initiatives are not well understood by many ARP clients. It is suggested that mechanisms for soliciting ARP research and support services be reviewed and procedures developed to make these mechanisms known throughout the FAA.

5. Human Element in Program Development. The Agency has been criticized when major initiatives fall short of anticipated goals because the human element was insufficiently considered during development. It is suggested that application of available or specifically derived new biomedical and human factors data for use in the technical decision-making process be strengthened. A multidisciplinary approach that includes participation by ARP scientists and exploitation of expertise from the Department of Defense (DOD), National Aeronautics and Space Administration (NASA), and National Institute for Occupational Safety and Health (NIOSH), as well as extramural consultants should be considered to assure a more responsible and balanced outcome. Encouragement of these activities will improve the credibility, coherence, and accountability of ARP activities and research initiatives.
6. Quick Response Capability. The FAA frequently operates in the quick response, crisis-intervention mode. By the very nature of biomedical research, the pace of ARP research is not always consistent with this mode. There is a need to develop a mechanism for adequately funding short-term studies without compromising longer-range ARP activities.

7. Communication of Technical Information. The FAA should give serious consideration to enhancing its capabilities to interpret and integrate biomedical information for the operational and regulatory community. Use of peer review service procedures conducted by extramural contractors should be considered to improve communication. Peer review procedures provide opportunities for multidisciplinary interaction among FAA regulators, other ARP clients, ARP scientists, and with extramural scientists from industry, academia, and related government agencies.

8. Contribution of Biomedical and Behavioral Sciences to FAA. This review suggests a serious lack of awareness or misunderstanding about the role of the biomedical and behavioral sciences at FAA. It is suggested that FAA evaluate current and planned R,E&D programs to identify activities that would benefit by the inclusion of adequate biomedical and behavioral sciences expertise. In many instances, performance of technology teams might be enhanced through the inclusion of biomedical and behavioral sciences personnel to address specific human-oriented issues in the development or application of aeronautical technologies.
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I. INTRODUCTION

A. BACKGROUND

This report is Phase II of a study of the Aeromedical Research Program (ARP) requested by the Federal Air Surgeon (FAS). Additional background information on this study may be found in the Phase I report (Talbot et al., 1987). The FAS sought extramural evaluation of the role and effectiveness of the ARP and guidance in improving its usefulness in support of FAA's mission. Phase I of this study reviews the contributions of the Civil Aeromedical Institute (CAMI) to the ARP; this Phase II report discusses the role of the Office of Aviation Medicine (OAM) in managing the ARP, the products of the ARP, and the use of ARP products and services by other FAA offices.

B. STUDY SCOPE

The objectives of the Phase II study are to examine the adequacy of ARP services, including such factors as quality of products, funding, and satisfaction of those who use ARP products. The study includes a review of ARP materials and reports as well as information obtained from key FAA personnel who have current or potential needs for ARP services. The report suggests methods to optimize the ARP potential for supporting the FAA mission, including its R,E&D program, and approaches to resolve issues that appear to detract from the effectiveness of the ARP.
II. MANAGEMENT OF THE AEROMEDICAL RESEARCH PROGRAM

The Federal Air Surgeon is responsible for overall management of the ARP; however, the FAS has numerous other responsibilities such as administration of the Pilot Medical Certification Program. Consequently, the FAS, while retaining program approval authority, delegates most responsibility for the management of the ARP research-related activities to the Biomedical and Behavioral Sciences Division (B&BS) (see Phase I, Figure 2). The activities of this Division include development of research requirements, interaction with potential users of ARP services, liaison with ARP clients, as well as coordination with CAMI and other research resources available to OAM (Table 1).

However, the four staff scientists* in the B&BS Division have other responsibilities in the ARP. They manage ARP research activities within this Division, function as principal research investigators, and act as Contracting Officers' Technical Representatives on extramural research efforts. Examples of OAM-based ARP research activities conducted by the B&BS Division include the development of a pilot judgment training program (Diehl, 1983; Diehl and Buch, 1986), color perception and air traffic controller job performance (Pickrel and Convey, 1983), survivability following air carrier water accidents (Federal Aviation Administration, 1984), and air traffic controller operational errors (Federal Aviation Administration, 1986a).

In addition, B&BS Division scientists are called upon for scientific and technical advisory services for the FAA and the aviation industries including preparation of reports and advisory circulars as well as ad hoc consultation. The Division retains, by individual contracts, several specialists in various scientific disciplines (e.g., physiology, psychology, human factors engineering) for ad hoc assistance in program planning and evaluation as well as participation in research tasks.

The procedures (see Table 1) used by OAM to develop ARP initiatives are designed to produce periodically updated and validated research program requirements. However, LSRO staff noted some client uncertainties about the extent of their contribution in developing research requirements. At present, many of the potential ARP clientele are not familiar with existing procedures for initiating the research requirements proposal process. As a consequence, excessive demands may be made on ARP scientists to assist clients in defining ARP research requirements, suggesting protocols for studies, rewriting ARP research proposals, and soliciting support for funding approval.

* The number of B&BS Division staff scientists was recently reduced to three.
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<td>• Annually solicits research requirements throughout the Agency</td>
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<td>• Interacts with requestors to develop viable projects</td>
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<td>• Develops and defends budget needed to conduct research</td>
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<td>• Interacts with requestors to insure useful application of results</td>
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III. ARP RESEARCH REQUEST AND FUNDING MECHANISMS

A. ORIGIN OF RESEARCH REQUESTS

During discussions with key FAA personnel and ARP scientists and clients, LSRO staff sought information about the mechanisms for identifying and approving research requests and funding of ARP studies. FAA has several approaches to support research, engineering, and development (R,E&D) activities related to aviation medicine within the ARP. The majority of R,E&D requirements are generated from continuous intramural review of programs. In the FAA, research needs are also identified from the National Transportation Safety Board (NTSB), Congress, industry, and public recommendations in particular program areas. Research requirements are reviewed annually, and approval of funding can take as long as 18 months.

Requests for ARP services or activities can originate from several levels by several routes within the Agency. Most ARP research needs are identified by offices within FAA such as OAM, Air Traffic (AAT), Aviation Safety (ASF), Aviation Standards (AVS), or by AVS component units (see Phase I, Figure 1). These offices request ARP activities either through AVS or directly to the Federal Air Surgeon (FAS). Requests from Congress and the Secretary of the Department of Transportation are transmitted to OAM through the Office of the FAA Administrator. There are four mechanisms by which ARP projects can be approved. These are classified as: 1) imminent need; 2) FAS approval; 3) AVS requirements review process approval (for AVS projects only); or, 4) FAA consensus approval.

1. Imminent need

Many requests of this type are initiated as a consequence of findings from accident investigations and safety inspections or alternatively, to develop information supporting new or revised operational rules. These study requests focus on issues related to upgrading safety equipment, new procedures, use and development of databases, enhanced training programs, and advisories. The Offices of Air Traffic Services, Personnel and Training, Airworthiness, Flight Standards, and Aviation Safety appear to be the most frequent users of this approach. These ARP clients may choose an informal process of soliciting information directly from ARP scientists within OAM or at CAMI, or petition a request for the B&BS Division to manage the study.

While this approach is both timely and flexible, funding of these initiatives, regardless of requestor, comes from the OAM research budget. The sensitive nature of these studies often requires that the resources and testing facilities available to FAA be used exclusively. Thus, if resources are committed to
studies of imminent need, the ability of the ARP to address other research needs of the FAS or continuing ARP activities is compromised.

2. FAS approval

The FAS maintains several R,E&D activities in support of the scope of OAM responsibilities. These include the ARP, collection of biomedical data on physical and performance standards for regulatory purposes, the updating of medical certification requirements, and oversight of aviation medical examiners. The Medical Research Program Guides (MRPG) provide instruction for documenting management of aeromedical research (Federal Aviation Administration, 1974). The MRPG outlines the principles for initiating research tasks, the preparation of research and technology resumes, the research task review process, and the reporting requirements associated with research efforts. In addition, the MRPG describes FAA medical objectives and research characteristics; R,E&D program planning and budgeting; ARP structure, research categories, and establishment of task areas; and task approval criteria.

Annually, the FAS prepares a program guidance and policy statement in collaboration with CAMI management and FAA Headquarters staff. This statement conveys research priorities to task and planning personnel. Both self-generated tasks and requests submitted by ARP clients serve as guidelines in establishing research areas outlined in this statement. Research resumes are developed in accordance with the annual statement and submitted for evaluation by the Research Task Review Panel. Membership on this panel originally included the Chiefs of the Aeromedical Applications Division, Office of Aviation Medicine; the Research Planning Branch, Office of Aviation Medicine; the Bioengineering Branch, Office of Aviation Medicine; the Civil Aeromedical Institute, Aeronautical Center; and the Aeromedical Research Branch, Aeronautical Center. Currently, the Panel establishes acceptability of proposed research tasks and sets priority within the scope of the ARP. The FAS maintains approval responsibility for all research tasks which are conducted by ARP scientists or contractors. Examples of this research include vision research, the effect of endocrine imbalances on pilot performance, pharmacological studies of therapeutic agents and substance abuse, judgment training, test and evaluation of improved safety procedures and equipment (see also Phase I Appendices A-D).

It is evident that much thought was given in preparation of the MRPG; however, the LSRO staff review identified that numerous organizational and research objectives have been modified or totally changed since these guides were issued. There is an immediate need to update the MRPG to include: 1) objectives that correspond with the NAS plan; 2) the present organizational
structure; 3) identify available ARP resources; and, 4) outline present task approval policy consistent within the FAA. In addition, the LSRO staff scientists note that this process lacks adequate extramural review. Suggestions for use of peer review procedures are discussed in Section VI.B.

3. AVS Requirements Review Process

The Order establishing the AVS Requirements Review Process was instituted in 1982 (Federal Aviation Administration, 1987) to establish basic guidelines for AVS R,E&D program reviews, office project tracking systems, and AVS guidelines for review and comment on draft updates to the R,E&D plan (Federal Aviation Administration, 1986b,c). This procedure established a mechanism for quasiformal review and recommendation of AVS projects for approval by the Associate Administrator for Aviation Standards.

The AVS Requirements Review Group (RRG) procedure is used primarily for engineering initiatives. The Order indicates that the OAM review may differ somewhat since that office manages funding for both OAM R,E&D contracts and CAMI research projects, as contrasted with the Office of Development and Logistics management of other AVS office R,E&D projects. Further explanation of how the OAM review process might differ was not indicated in the AVS/RRG Order. Explanations of criteria for aviation medicine research requirements approval via the AVS/RRG process were not clearly defined and were considered by some FAA officials as inconsistent. The availability of written criteria for OAM to participate more effectively in the AVS/RRG process would make OAM/AVS project approval clearer and more uniform.

The AVS/RRG procedure provides an outline of minimal standards for the objective review of a project proposal. These include: 1) identification of study sponsorship; 2) explanation of perceived need; 3) conformity with the Agency research requirements; 4) adequacy of available funding; and, 5) ranking in relation to other AVS priorities.

Project approval via this process should be based upon evaluation by a research review group that includes biomedical scientists who can also identify areas of future concern, minimize duplication of effort, and justify adequate support. Projects approved by this process are approved in accordance with a special conditions clause, whereby additional information is deemed appropriate to understand the effects of technologies not envisioned previously. Proposals should include adequate literature search and development of background materials to justify a unique need to the FAA.
4. FAA consensus approval

Another pathway by which ARP projects can be initiated is in association with major FAA initiatives. The Agency recognizes the need for biomedical information in support of new NAS technology and designates by consensus the ARP-related activities necessary to accomplish these goals. Funding for these projects is designated from resources for research, engineering, and development and may in certain instances be derived from facilities, equipment, and development funds from the programs of the Associate Administrator for Development and Logistics (ADL). The ARP activities described in the FAA plan for R, E&D are examples of this mechanism (Federal Aviation Administration, 1986d).

B. ARP FUNDING

In FY87 the FAA received $150 million in support of all R, E&D activities. The OAM has an overall budget of about $4.1 million to perform research and development studies, support service activities, and maintain medical certification requirements.

LSRO staff were neither asked nor qualified to evaluate the manner in which these funds were assigned to ARP projects. While there was ample indication that available funds for ARP research needs were inadequate to maintain long-term programs, it was also evident that ARP research projects may receive funding from multiple sources depending upon sponsorship within OAM, AVS, FAA, NTSB, Federal Railroad Administration, DOT, or, in some cases, co-sponsorship by other agencies and/or private sources. However, funding of ARP studies from these other sources rarely occurs. Currently, studies for ARP clients are funded from the OAM R&D budget, frequently at the expense of other long-term ARP programs. Consideration should be given requiring ARP clients to share the expenses of research for which they are the prime beneficiaries.

The degree of pooling and redirecting of available funds within the ARP and OAM would require far more detailed analyses than was possible in this study. However, as noted in subsequent sections of this report, the ARP research project documents that were examined did indicate the work was clearly within the FAA mandate.

C. RELATED ISSUES

It is evident that the FAS and ARP maintain a flexible approach to funding research projects. This approach allows pooling resources, redirecting funds, and providing for new initiatives. It is consistent with the approach to be expected
of offices in an agency with goals that require quick response
to operational needs and emergency situations. However, con-
tinual influx of emergency requests over prolonged periods can
drain resources, tax facilities, and mask the original intent of
research program components. The current approach to funding of
research does not include provision for anticipating the impact
of future needs and long-term planning for aeromedical research.
This deficiency limits the ability of the FAS to respond to
potential users of the ARP even when research needs are evident.

Discussions with several FAA personnel noted that the
OAM participates infrequently in the AVS/RRG approval process
for non ARP-related proposals that may have potential impact on
future ARP studies. However, the FAS and OAM staff have come
to recognize the importance of assisting potential ARP clients
to develop their needs. The research programs developed for
the Office of Civil Aviation Security exemplify the Agency-wide
benefits that can be derived when the activities of an operation-
ally-oriented client are provided ARP guidance. There is a need
to provide additional opportunities for the interchange of con-
cerns among potential ARP clients, the OAM, ARP scientists, and
those responsible for research requirements approval. Several
procedures are explained in Section VI.B.

If demands on OAM resources increase, FAA should have
a plan in place to provide additional staffing for OAM or addi-
tional contractor support to assist these potential ARP sponsors.
IV. PRODUCTS OF THE AEROMEDICAL RESEARCH PROGRAM

The principal tangible products of ARP research are information, data, and reference materials. They are disseminated in a variety of formats, including intramural scientific and technical reports and compilations, bibliographies, topical reviews, indexes, databooks, manuals, contractor reports, technical advisory circulars, and staff memoranda and reports on selected issues. In addition, ARP products are also communicated informally (i.e., visits, conferences, telephone communications, letters, and memoranda) between FAA offices, the OAM, and CAMI and other satellite facilities.

LSRO staff selected a sample of aeromedical research reports on a broad range of topics from an index of aviation medicine reports (Dille and Haraway, 1983; Office of Aviation Medicine, 1986). This sample provided examples of ARP products available to the FAA during the past 10 years. In addition, LSRO staff received reports and technical memoranda from the CAMI staff during the December 1986 site visit. Several additional reports, presentations, training manuals, and publications were also received during visits with ARP scientists and clientele at FAA Headquarters.

LSRO staff used these materials as representative samples of ARP research products in an evaluation of scientific merit. The sample contained a wide range of subjects including reports about aircraft accidents, air traffic controllers, alcohol abuse, cabin safety, profiles of medically disqualified pilots, regulatory aspects of aviation medicine, and the effects of the FAA and aviation work environments on the physiological and behavioral aspects of human performance. Most reports were prepared by ARP staff scientists.

The materials reviewed by the LSRO staff compared favorably with scientific and technical publications of other government laboratories. The formal reports follow the recognized format for reporting scientific information including: 1) abstract; 2) background and/or introduction; 3) materials and/or methods; 4) results; 5) discussion; 6) summary and/or conclusions; and, 7) references. Similarly, technical memoranda and advisory circulars contained the essential elements in sufficient detail to communicate the information presented. An encyclopedic report prepared by the American Medical Association presented the findings of expert panels about medical certification standards for civilian airmen (Engelberg and Doege, 1986). One example of a compilation that integrated 40 years of individual research reports into a single volume on selection of air traffic controllers was considered a comprehensive review of this literature (Sells et al., 1984).
The majority of reports were written to provide detailed information to individuals knowledgeable in the biomedical sciences and were stylistically acceptable for publication in scientific journals. Typically, data are presented using scientific terminology readily identified with the area of the biomedical sciences addressed by the report. Tables, figures, and other presentations of data and study results provide sufficient information to permit knowledgeable readers the opportunity to follow the discussions of the research findings.

In summary, the reports reviewed by the LSRO staff are contributions of meritorious research in aviation medicine and related disciplines. This body of information is a national resource providing benefits to the FAA, those actively participating in the National Airspace System, the aircraft industry, and the private citizen. From a broader perspective, the unique nature of this information sets a precedent for use by other nations with limited resources. Nevertheless, as with any review of this nature, the LSRO staff observed several issues worthy of further consideration by ARP scientists preparing reports for the FAA.

Several ARP reports were of such a technical nature that they were viewed by some operational or engineering-oriented FAA staff as irrelevant or tangential to the FAA mandate to conduct applied research. LSRO staff noted that in these instances, ARP scientists had not provided sufficient background information to explain the research rationale or the anticipated benefits to the FAA. While it is not necessary to present textbook explanations, it is important to recognize that the report user should receive a description, in understandable language, of the meaning of the research and how the clientele will benefit from the use of the information. For example, a technical report about anthropometric and mass distribution characteristics of the adult female (Young et al., 1983) represents a database that should be mandatory reading for design engineers of airliner cabins. However, the value of the data is virtually lost as a consequence of an introduction that does not place the practical application of the data into perspective. On the other hand, a report about the effects of smoking withdrawal on complex performance and physiological responses (Mertens et al., 1983), provides a clear statement of the technical problem in the introduction.

Reports that cite a limited number of references or references from only the investigator's laboratory are subject to skepticism throughout the scientific community. Some ARP reports would benefit by inclusion of more references from related scientific literature. A characteristic of applied research is that the techniques employed and the experimental findings can frequently be applied to and/or borrowed from other situations. For example, although the problems of passenger restraint devices in aircraft are somewhat unique, experience from extensive research about passenger restraints in automobiles
provides a basis from which more relevant information can be developed, improved, and applied in civil aviation. Another example is evident in a report by Thackray and Touchstone (1983). They indicated that one effect of computer automation on the role of system operators will be a change from a personalized manual control mode to oversight system managers, functioning primarily as system monitors, detecting occasional malfunctions, and acting as backup. Reference is made in the introduction of the report to the similarities in operator performance between the automated nuclear reactor control room and the air traffic control room of the NAS. By giving additional consideration to the applications of parallel research, the reader gains a wider perspective of the issues and applications discussed. Reports that indicate broader applications are of greater value because they validate consistency of observation across situations or disciplines and build on the foundations of previous discovery.

Few reports in the sample indicated that collaborative efforts have occurred with investigators at other research facilities. This impression may be the result of an inadvertent sampling error. The research facilities at CAMI should be used to provide more opportunities for collaborative research with other government laboratories and universities. As noted in the Phase I report, collaborative and liaison activities can provide FAA with insight about new developments and technologies from parallel programs.

Few ARP reports have appeared in the peer-reviewed scientific or technical literature, although almost all materials are available from the National Technical Information Service, Springfield, VA. The availability of written research reports in the scientific community is an important aspect for the exchange of ideas among scientists that adds vitality to a research program. ARP scientists should be encouraged to increase publication of reports, presentation of papers at scientific meetings and public forums, and participation in intramural and extramural panel discussions and workshops where their scientific expertise may prove useful. The increased visibility of ARP research investigators in the scientific community would improve their morale and build public confidence that the FAA is engaged in activities related to safety concerns and other improvements in the public interest. Consideration should be given to instituting procedures whereby the FAA Offices of Public Affairs, Aviation Medicine, and Aviation Standards monitor these activities to assure that they are announced publicly and consistent with FAA regulations and policy standards. Appropriate funds should be designated to support such efforts.

Although the ARP materials reviewed were scientifically meritorious, there was a lack of reviews and position papers on topics in aeronautics of importance to the FAA [the recent review of certification by Engelberg and Doege (1986) was an exception]. Such documents traditionally present the opinions
of peer groups assembled in an advisory capacity to assess topics of concern and identify areas for future research need. Because OAM staff are already occupied by the ARP and other duties assigned by the FAS, consideration should be given to retaining extramural organizations to provide these services. Topics for further consideration might include:

- Recent advances in the physiology and endocrinology of work/rest cycles
- Neurobehavioral effects of toxicants
- Anthropometric criteria in the design and use of safety equipment and procedures (e.g., seat restraints, evacuation procedures, respirator design and use)
- Impact of system automation on operator vigilance and performance
- Guidelines for improved effectiveness of Aviation Medical Examiner (AME) investigations
- Possible role of increasing automation on employee and aircrew selection criteria
V. APPLICATION OF ARP PRODUCTS

A. DIVERSITY OF ARP PRODUCT APPLICATIONS

The broad range of ARP products was equaled by the diversity of applications within the ARP client community. Examples of the types of ARP products used by various FAA offices are shown in Table 2. Although different ARP clients may seek similar information from the same producer (e.g., Human Resources Branch, Toxicology Laboratory, Protection and Survival Laboratory), the application of this information may be significantly different from the intent of the report received. Several offices made use of ARP products as a basis to develop rules and regulations, while the focus at other offices was to support requirements or accountability. It was apparent from discussions with several clients, that their degree of satisfaction about the usefulness of reports closely paralleled the ability of the ARP investigators to show an appreciation of the ARP client needs in the research report or product.

However, several ARP scientists noted that many clients did not always provide a comprehensive description of the application for which the research information was requested. This was especially true for crisis intervention matters when the client was seeking information from one of the CAMI databases. The Agency would benefit by improved communication so as to avoid the assumption that ARP scientists are fully aware of the rapidly changing events and agendas at FAA Headquarters. This finding is equally relevant to interactions among all FAA facilities that use ARP resources.

B. EFFECTIVENESS OF ARP PRODUCTS

The views of the client community varied about the quality of the ARP research products. The range of opinions included those who considered ARP research products to be extremely useful; others viewed the products as esoteric, incomplete, or generally lacking in Agency perspective. There was no consistency of finding with regard to one type of ARP product as compared to another within any office. For example, the experience of several users of quick response statistical reports and letters of information was quite satisfactory, whereas others using the same means to obtain information were not satisfied. A similar finding was evident in regard to the effectiveness of study reports that included scientific assessment in conjunction with a mid- to long-term research project. In general, among FAA staff, these reports prepared by B&B scientists or by some contractors were deemed more useful than those originating from other FAA facilities. However, this perception is probably a reflection of the ability of the user to communicate directly with the producer.
Table 2. Examples of ARP Product Applications at FAA.

<table>
<thead>
<tr>
<th>USER OFFICE</th>
<th>TYPE OF ARP PRODUCT OR SERVICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviation Safety</td>
<td>Forensic toxicology and pathology reports, AME accident investigation reports, pilot certification and performance databases, toxicity of airliner cabin materials, evaluations of airliner seat performance.</td>
</tr>
<tr>
<td>Air Traffic Operations Service</td>
<td>Human resources psychology assessments of operator errors.</td>
</tr>
<tr>
<td>Air Traffic Plans and Requirements Services</td>
<td>Demographic and historical information from CAMI databases, employee screening for substance abuse, employee stress education and task analysis studies.</td>
</tr>
<tr>
<td>Civil Aviation Security</td>
<td>Psychology profiles, human factors research, effects of drugs and substance abuse on performance, animal diversion on runways.</td>
</tr>
<tr>
<td>Human Resources Management</td>
<td>Development of employee selection criteria, trainee testing procedures, methods to evaluate employee performance, conduct of employee attitude surveys.</td>
</tr>
<tr>
<td>Aviation Standards</td>
<td>Budgeting and R,E&amp;D accountability.</td>
</tr>
<tr>
<td>Airworthiness</td>
<td>Protection and survival reports including: job task analysis, use and design of airliner cabin equipment (e.g., respirators, life vests), evacuation procedures.</td>
</tr>
<tr>
<td>Flight Standards</td>
<td>Protection and survival reports (e.g., airliner cabin design, attendant training, job task analysis, human factors research).</td>
</tr>
<tr>
<td>FAA Work Force</td>
<td>Occupational health programs for the general work force (medical examinations, CPR training, alcohol and smoking awareness) and use of the Health Information System and the Safety Management Information System databases.</td>
</tr>
</tbody>
</table>
LSRO staff observed that those offices most satisfied with the quality of the ARP products had developed a close liaison with OAM scientists, researchers at CAMI, or OAM extramural contractors. Successful users of ARP research and services were able to identify their needs to the ARP scientists, establish a mechanism for follow-up and feedback, and participated in the development of the final product. In general, those offices least likely to succeed in procuring useful information through the ARP had not clearly identified the problem to be addressed by ARP scientists, had little concept of the resources or the mechanisms available to obtain useful information for their needs, frequently had unrealistic expectations for a quick fix to a chronic problem, and had little appreciation for the costs involved in generating useful products from applied research efforts.

Several clients and producers described experiences where the ARP research product contradicted or conflicted with contemporary Agency opinion or policy. These situations engendered some mistrust between the client and ARP scientists or among FAA scientists working at different locations. Several of these clients expressed an unwillingness to solicit additional ARP services while the ARP scientists expressed concern that important research findings were being neglected without due consideration for the consequences or the opportunity to make improvements. These difficulties are not unique to the FAA. They are in fact, common to situations where there is a need to integrate research findings and information from multiple disciplines into approaches that address regulatory needs. Historically, significant advances in science have been achieved whenever the interface between new technology and new application can be exploited via the contributions of a multidisciplinary approach. Examples include the nuclear power industry (National Research Council, 1986), the exploration of space (Smith, 1981), and current trends in environmental management of toxic waste (Grisham, 1986). In many instances these differences of opinions can be related to the mechanisms by which ARP services are initiated or the FAA approach to integrated research programs.
VI. FINDINGS AND SUGGESTIONS FOR FUTURE CONSIDERATION

A. GENERAL CONCLUSIONS

There is considerable confusion on the part of some FAA personnel about the FAA mission to conduct aeromedical research. Some FAA staff were of the opinion that the FAA has no responsibility to include basic aeromedical research while defending the need to conduct applied research, test, and analysis of a wide range of hardware and associated human operator problems of equipment and procedures intended for use in civil aviation and air traffic control. The principle that any applied research program must protect the underlying technology base to insure future viability and competence to manage research applications must be clearly respected by responsible FAA leadership.

Controversy about several FAA research programs and the effect, or lack thereof, of research activities on FAA policy has existed for several decades. The lack of appreciation for the relevance of applied research in aviation medicine within FAA is not new, despite the federal mandate to conduct research (49 App. U.S.C. §1353(c), 1982 ed.; 49 App. U.S.C. §1357(d)(1), 1982 ed.) (Holbrook, 1974a). Intramural and extramural critics of FAA R,E&D activities have expressed concern that the existing applied research programs lack sufficient emphasis on the biomedical implications of applied new technologies or consideration for human performance in the FAA work force, and that FAA policy toward research could be improved (Alarie, 1985; General Accounting Office, 1987; U.S. Congress, 1987). Other concerns focus on safety issues (National Academy of Sciences, 1986; Nolan, 1986). Generally these concerns are of a crisis nature and the consequence of increased public awareness following accidents, errors, or poor functioning of various elements that contribute to or participate in the NAS. As with other government agencies, the FAA is frequently asked to justify policy decisions during times of crisis intervention even though the Agency is well aware that a more effective approach would be to incorporate long-range planning to avert problems before crisis. Constraints in budgetary and personnel resources have exacerbated the Agency's inability to address long-range planning in civil aeromedical research adequately.

The FAA does not have a clear mandate to conduct "basic research". However, the differences between basic and applied research can be tenuous, and basic research of today often becomes the applied research for tomorrow. Similarly, developing new applications of applied research could be misinterpreted as basic research. For example, extending knowledge about visual perception of color or dynamic visual acuity is, at present, one of the frontiers of neurophysiology but is also essential to various work situations where dynamic visual acuity is critical. Information from studies of basic neurophysiology is highly
relevant to the design criteria of CRT displays and operator selection criteria to optimize the performance of the future work force.

The expert guidance of the FAS and the ARP services are assets to the overall FAA mission. This has been substantiated repeatedly by intramural and extramural study groups commissioned by FAA to advise on civil aeromedical research [Special Committee for Aviation Medicine, 1936 (Holbrook, 1974b); Medical Advisory Committee, 1960-1971 (Holbrook, 1974c); Office of Aviation Standards (Smith, 1983); Life Sciences Research Office (Talbot et al., 1987)] and by reviews of selected aeromedical topics (Engelberg and Doege, 1986; National Academy of Sciences, 1986; Sells et al., 1984). These program reviews have separately concluded that FAA has the responsibility to conduct research in the biomedical and behavioral sciences as they relate to the broad field of aviation medicine. However, vacillation within the Agency about the role of the ARP, the needs of OAM managers and scientists, and the expectations of the FAA continue to surface (Holbrook, 1974a; Smith, 1983; Talbot et al., 1987). Furthermore, the continual reorganizing of OAM and the restructuring of the ARP by the FAA suggest managerial and policy uncertainties about the need for the ARP or the relationship by which OAM can best provide aeromedical R,E&D services to the Agency. These are expressed as lack of funding, insufficient manpower, and fragmentation of program management.

Some basis for this originates within the FAA R,E&D mandate (49 App. U.S.C. §1353(c), 1982 ed.; 49 App. U.S.C. §1357(d)(1), 1982 ed.) which can be interpreted as excluding applied research by those involved in the administration of limited funds and operational management of a diffuse and highly specialized work force. However, both the LSRO staff and the ad hoc Group (see Phase I report) consider the mandate in the U.S. Code to be of sufficient breadth to provide the Administrator opportunities to support programs that enhance a safe and efficient NAS with consideration for both the human operator and the engineering advances of the instruments in use. Although logic dictates that such considerations require input, at all levels, by a multidisciplinary team of biomedical scientists, engineers, government regulators, and other concerned individuals from industry and academia, experience at FAA has shown this to be the exception rather than the rule.

As a consequence, evidence of a sustained administrative conviction that applied research in aviation medicine and the allied biomedical disciplines should be conducted within FAA is lacking. There is minimal effort on the part of the Agency to identify future biomedical research needs or to have the FAS coordinate these activities within the ARP. Frequently, those who could benefit from ARP services are typically crisis-oriented and unaware of their needs in terms of capabilities and limitations
of the human operator or the mechanisms to obtain assistance to resolve problems which involve human performance, physiological or psychological limits, or medical implications.

FAA should give consideration to setting aside a portion of its human, fiscal, and facility resources to examine, test, develop, and otherwise further explore the application of new knowledge to issues in civil aviation medicine. This is the field of applied aero medical research that is analogous to evaluation of aircraft instrument design for maximum efficiency, testing of navigational systems for reliability, and use of new materials for crashworthiness. The field of aero medical research clearly addresses all aspects of the man-machine interface including performance; operation; and interaction with the aircraft, passengers, and air traffic control. The LSRO staff suggest that the FAA Administrator should not only preserve and enhance the resources of the ARP but also act to improve the participation of ARP scientists in a broader spectrum of activities at FAA.

If the existing provisions of the Federal Aviation Act that form the basis for the FAA to conduct scientific investigation (49 App. U.S.C. §1353(c), 1982 ed.; 49 App. U.S.C. §1357(d) (1), 1982 ed.) are interpreted by the Agency as insufficient to warrant firm support of the ARP, then it is the responsibility of the Administrator to clarify the intent or undertake the acquisition of new legal authorization to conduct research in all areas essential to proper support of its mission including the aero- medical and behavioral sciences. If deemed necessary, further clarification of the intent of this mandate should be obtained through the Department of Transportation and Congress. Consideration should be given to additional financial support. Should this be done then the Airport Trust Fund may become a source for research funding as proposed in the Airport and Airway Improvement Amendments of 1987 (U.S. Congress, 1987).

Finally, there is ample justification for a stronger ARP than the diffusely organized program which is presently an adjunct of the OAM. It would be appropriate for FAA to reexamine the administration of the ARP, addressing such issues as the Agency's need for an ARP, the expectations of contributions from such a program, and its potential benefits to overall FAA objectives. The Agency should also consider the most efficient structure of the ARP and the specific talents required to maximize the contributions to be derived from the program. Any possible administrative restructuring of the ARP should give full cognizance to improving the capabilities of this program to address support services, crisis-intervention applications, and long-term research goals to acquire new knowledge. All three foci of the ARP require balanced emphasis and additional support. The FAA would clearly benefit from closer identity of the ARP with a higher administrative level, active in well-defined long-range R,E&D objectives. The support services and crisis-intervention activities of the ARP should serve to orient long-term
research goals for the FAA as well as the ARP. Nevertheless, ARP research planning and development of long-range research objectives requires sustained programmatic leadership, integration of new technologies, and maximum cooperation among R,E&D elements within FAA Headquarters and Research Centers. If civil aviation medicine is to continue as an important activity of FAA, the Agency must resolve these issues in its own best interests.

B. SPECIFIC FINDINGS AND SUGGESTIONS

In the course of this review, the LSRO staff identified the following issues that relate to the efficiency and effectiveness of the ARP:

**FINDING:** In the present mix of operational, developmental, and research activities that are distributed over a constantly changing array of crisis-intervention responses, many research goals of the ARP receive a low Agency priority. Even under these circumstances the OAM is doing an adequate job.

**SUGGESTION:**

OAM scientists should have greater visibility in early plenary activities involving major initiatives at FAA. This would alert FAA managers and program directors to potential problems before they become major issues. Examples of this type of cooperation include participation of OAM program scientists in activities such as the National Airspace Review Enhancement Advisory Committee and the Task Force in Air Traffic Controller Operational Errors.

**FINDING:** The FAA R,E&D plan (Federal Aviation Administration, 1986b,c) provides both mid- and long-term research requirements grouped by technology area. The goals and objectives of this plan are well conceived to include considerations through the year 2020. However, some programs as presently described are fragmented artificially and show little consideration for the broad spectrum of contributions available through ARP activities. Because it has not formulated and supported a detailed comprehensive, mid- to long-term aeromedical R,E&D program plan that fully integrates ARP activities within this master plan, FAA is not adequately meeting its R,E&D mandate to satisfy the needs for safe and efficient navigation and traffic control in civil aviation (49 App. U.S.C. §1353(c), 1982 ed.). Reasons for this are multiple; they include the relatively low priority of the ARP and the associated insufficiency of human and fiscal resources to correct this situation. Also included are the diversion of limited ARP scientific resources to crisis interventions and
service-oriented tasks to a degree that is incompatible with conducting an orderly R,E&D program in aviation medicine and related biomedical disciplines. Such programs are impossible to establish in the absence of consistent Agency leadership and support.

SUGGESTION:

A series of interactive workshops should be sponsored by FAA Headquarters involving selected representatives from sponsoring FAA offices, the OAM, the Office of Science and Advanced Technology, ARP scientists from CAMI, and possibly representatives from the Department of Defense, NASA, academia, and the aviation industries. A multidisciplinary advisory group of no more than six members should be convened to oversee these activities. To establish corporate memory and continuity of purpose, membership to the advisory group would be limited to 3-year terms with two members rotating off the group annually.

The product of such an effort would be useful in building a coordinated aeromedical research plan that would responsibly address not only scientific and technical program content, but also FAA investment strategy for its execution. A research program based on well-defined Agency needs will make the FAA the prime customer of ARP research products. This, in turn, will improve research definition, development of a coordinated aeromedical research program, and, of considerable additional importance, the general marketability of the ARP.

FINDING: One factor that impairs the ability of the OAM to meet mid- to long-term research program goals is that the limited resources of this office are being siphoned off by service-oriented tasks in support of clearly important operational needs (e.g., air traffic controller training, certification issues, ARP client development), and crisis intervention projects for other offices.

SUGGESTION:

The FAA benefits from a strong ARP actively contributing to both support service and applied research activities. For proper management of the ARP, it is imperative that the OAM and the ARP scientific staff have depth of numbers and breadth of scientific skills. The conduct of research activities of the ARP should not be considered to be a lower priority than support services. ARP clients requesting support services from the ARP should be co-funders as well as co-sponsors.
FINDING: The effectiveness of the ARP is impaired because procedures for solicitation and application of research initiatives are not readily discernible to many ARP clients. The generation of research requirements for the ARP is cumbersome and time-consuming for the available staff resources of OAM.

SUGGESTIONS:

a) The OAM Medical Research Program Guides (Federal Aviation Administration, 1974) should be revised to update and streamline the process. Furthermore, there is a need throughout the FAA for potential ARP clients to understand the mechanisms for soliciting ARP research and support services and methods available for adapting research products for client use. Existing mechanisms could benefit from further clarification of the procedures and responsibilities of both client and producer.

b) There is a need for FAA management to understand and be involved with the requirements generation process that actually determines both the workload demand and the resource needs of the ARP.

c) A headquarters designed and sponsored annual indoctrination course in standardized FAA research program planning, budgeting, and execution for all key participants could be a flexible and effective means to address these requirements and provide a mechanism for routine updates.

FINDING: The Agency has been criticized when major initiatives fall short of anticipated goals, or defects have been discovered in equipment or safety procedures because the human element was insufficiently considered during development.

SUGGESTIONS:

a) Use of applicable extant biomedical and human factors data in the technical decision-making process needs to be strengthened. The development of new information and/or databases may be required in support of Agency objectives. The use of a multidisciplinary approach that includes participation by ARP scientists and extramural consultants should be considered as it would assure a more responsible outcome in future efforts.

b) There is a need to improve channels of communication and the resolution of information needs at all levels within FAA Headquarters and R&E&D centers. Representatives of R&E&D activities should be given opportunities to participate in a team approach to accomplish program goals for the FAA. A team approach could improve design
criteria, performance efficiency, and visibility of ARP scientists in FAA initiatives. Effective communication would clearly benefit from establishing and carrying out regular, informal liaison directly between the ARP scientists and the FAA Headquarters staff that sponsor elements of or monitor the ARP.

**FINDING:** The time between research start-up and study reporting to the Agency is out of synchrony with the quick response, crisis-intervention mode of operation at FAA. The extent to which quick response operational needs for investigation currently drain mid- and long-term research resources is not fully appreciated in mechanisms of funding OAM programs such as the ARP. This is detrimental to the stability of ARP programs.

**SUGGESTION:**

A mechanism for adequately funding short-term investigational activities without jeopardizing longer-range ARP research efforts is needed. The clients receiving these services should contribute to the costs incurred by OAM.

**FINDING:** It is apparent that FAA has a need for special services to interpret and integrate biomedical information for the operational and regulatory community.

**SUGGESTION:**

Experience has shown that this requires the expertise of extramural support organizations familiar with all aspects of analysis and evaluation of scientific information and the peer review process (American Chemical Society, The Conservation Foundation, 1985; Fisher, 1982; Siu et al., 1977). Peer review procedures provide opportunities for multidisciplinary interaction among FAA regulators, other ARP clients, ARP scientists, and with extramural scientists from industry, academia, and related government agencies. Advantages of this approach include improved credibility, greater coherence, and better accountability for the focus of future FAA research programs.

**FINDING:** Neither the magnitude nor the complexity of the problems besetting the ARP can be fully appreciated from the two brief evaluation studies conducted for the FAS by the LSRO. These initial findings suggest that lack of awareness or misunderstanding about the role of the life sciences at FAA may be broader than originally perceived.
SUGGESTION:

There is a need for the FAA to evaluate R,E&D resources at other important nonaeromedical facilities (e.g., Technical Center, Transportation Systems Center) and in conjunction with other programs (e.g., National Airspace Review Enhancement Advisory Committee) to identify activities that would benefit by the inclusion of adequate life sciences expertise. Results of such evaluation would disclose opportunities for enhancing the technologies by such means as adding life scientists to existing teams or redirecting elements of the ARP to meet emerging needs.
VII. LITERATURE CITED


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