Civil Aeromedical Research: Responsibilities, Aims and Accomplishments

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Reprinted from *Aerospace Medicine*, Vol. 34, No. 6, June 1963

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A MAN, A MACHINE, the atmosphere, and an airport: these are the basic functional components of civil aeronautics.

An additional component, consisting of the men and electronic equipment comprising the air traffic system, is now as integral a part of civil aeronautics activities as are the pilots and their aircraft.[57]

Two intertwining threads wind inseparably through the above picture: (1) the maintenance programs related to the health and functional adequacy of airmen and equipment, and (2) the economics of the dynamic, ever changing, often hard-pressed, aviation industry.

The basic mission of a civil aviation flight is to return unharmed the occupants of the aircraft to *terra firma.* At times the pilot may be the sole occupant, at other times, the crew will be the only occupants, and in still other cases, the occupants will consist of the crew and more than a hundred passengers.

Any mission which results in death or injury to an occupant is not a successful mission. Successful missions must constantly be accomplished if civil aviation is to continue to grow and progress. This paper will indicate the role of aeromedical research in helping to prevent unsuccessful missions.

Involved in the safety of a mission are the matters of providing assurance that one aircraft in flight will not jeopardize another, and that the operation of an aircraft will not needlessly endanger the lives or property of the population-at-large.

A DEFINITION OF AEROMEDICAL RESEARCH

Aeromedical research is the scientific study of the interrelation in aeronautics of the human elements and the hardware. All disciplines and skills are involved, including physicians, physiologists, psychologists, physical anthropologists, engineers, and flight test pilots.

Aeromedical research provides the Aviation Industry and the public with answers to questions having a vital bearing upon accident and crash injury prevention. The information derived through aeromedical research when applied to aeronautical activities leads to an enhancement of the air safety record.[58]

Civil Air Carrier Passengers:—Civil aeromedical research is responsible for providing human factors information relating to the preservation of health of general population groups ranging in age from infancy to old age. This is in sharp contrast to the aims of military aerospace medicine research programs.[57]

In 1961, well over 50,000,000 passengers, many with chronic diseases (for example, coronary artery disease, emphysema, asthma, cerebrovascular insufficiency, and extreme obesity), many with the general infirmities of old age, were transported by the scheduled airlines. Many pregnant women, infants and children were carried as passengers. In civil aviation emergency situations (explosive decompression, passenger impact protection in crash landings, rapid aircraft evacuation requirements), traditional safety procedures are often inadequate.[23]

Nonduplication of Effort:—The Air Force and Navy aerospace and aviation medicine research programs, and the space medicine research program of the National Aeronautics and Space Administration, focus their major attention upon the requirements of the young adult male who is a pilot or crew member of a high performance weapons system on wings, or of an orbital craft. Today, these military aerospace medicine research programs have almost no bearing upon the aviation medicine research requirements of civil aviation.[57]

The research of the Veterans Administration deals with a special population of chronically ill veterans, and the findings have little direct bearing on human factors problems in aviation. Similarly, the research of the Public Health Service has only an occasional and isolated instance of a specific contribution to air safety.

Drugs in Civil Aviation:—The general aviation pilots, of whom there are several hundred thousand with current FAA medical certificates, need knowledge of what drugs they may take and still safely fly. Preventive drugs, which are taken for long periods following the early diagnosis of a chronic disease, are becoming more numerous. General aviation pilots have no upper age limit, and as the number of older general aviation pilots increases, the number of pilots with chronic disease will increase.

In all cases undergoing treatment, should the pilot be grounded because he is undergoing good preventive medicine treatment for a condition which in its early untreated stage would not justify grounding the pilot? Many physicians think not (including the author). On the other hand, some of these preventive drugs have side effects in many persons which would make these persons unsafe pilots while taking the drugs. By and large, the military aviation programs remove pilots from flying status while they are taking medication. In civil aviation, through pilot and airman performance studies by aeromedical specialists, information may be developed which will enable us to identify the drugs which are

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not detrimental to pilot performance. Many pilots may, thus, be kept in the air at a safety level equivalent to their level of safety when not receiving medication.

Civil Air Carrier Pilot Aging:—At ninety miles per hour, the corrugated aluminum Ford Tri-motor airliner would drone over its destination airfield, enter the pattern, and glide in at seventy-five miles per hour, to a gentle full stall landing having a roll of three hundred feet or less.[31] So long as the pilot was in reasonably good health for aviation activities, his age made little difference in his ability to land these low-performance aircraft.

Today, the jet airliners have to be greased on at about one hundred and forty miles per hour, or so, and leave little margin for reflex error. Pilot aging, a process having a wide variation in rate within the pilot population (as in all populations), ultimately has a detrimental effect on the ability of pilots to handle these demanding airliners.[35] As yet, no one has developed an index which can be used to assess the functional age of a given pilot and relate this index to his performance capability. The military aerospace medical research programs are doing little which bears upon this question. A major civil aeromedical research program (FAA's Georgetown Clinical Research Institute) is working upon the possibility of devising an index which, for a given pilot, may enable him to fly air carrier aircraft beyond his chronological age of sixty (the upper cut-off time at present), if his functional age is lower.[21]

Crash Impact Survival:—Flight in light and heavy airplanes, helicopters, short take-off-and-landing aircraft, gyropters, gyro-dynes, and other yet-to-be-developed aerial machines, will always entail some risks to those within, for all of these are human creations and are operated by humans. So long as the human is imperfect, he will be a potentially weak link in the operation and maintenance of his aircraft.[20]

In the long run, it will pay (in terms of decreased mortality and morbidity and a decreased fear of flying in the general population) the aviation industry to incorporate features in all new aircraft which will protect the occupants from impact injury. This facet of aeromedical research requires the interdisciplinary team approach wherein biologists, engineers, accident investigators, engineering test pilots, physical anthropologists and flight surgeons cooperate in joint studies.

The military aeromedical escape studies focus attention on the ejection seat and parachute method of avoiding injury through removing the occupants from an aircraft prior to impact. These studies have little application to civil aviation where, for example, the air carrier pilot, as commander of his craft, cannot leave it in flight so long as the passengers are aboard. Providing civil passengers with ejection seats or parachutes seems to be impractical and unlikely escape procedure for adoption in civil air carrier operations.

Improvement in light plane interiors to diminish or prevent injury to occupants in potentially survivable accidents is within immediate reach.[49]

Human Errors:—When we talk about civil airmen, what size is the group we discuss, and what are the medical certification facts in terms of numbers?

During the January 1 to June 30, 1961, period, almost 112,000 persons went to FAA designated Aviation Medical Examiners for Class I, II, or III medical certification.[19] About 15,000 (13 per cent) of these persons had medical conditions and physical deficiencies which potentially could be hazardous to the safe discharge of their respective aviation activities. About 500 applications had to be denied (115 appeals were reviewed by the Medical Review Board of the Aviation Medical Service, and 72 were denied again, 16 were certified, and 27 were deferred for additional information). The over-all history has been that less than two per cent of the applicants are ultimately denied each year.

The persons certified as noted above, are the principals most involved in the discussion which follows.

When a civil aircraft crashes, a constellation of factors usually have interacted to set the stage for the precipitating factor, or "probable cause," the legal determination of which, is the responsibility of the Civil Aeronautics Board.

For a flying aircraft, either the aircraft, the occupants, or an outside factor, constitute the three areas within which the "probable cause" rests. The Comet disasters were attributed to metal fatigue, and, thus, the aircraft was at immediate fault. In the National Airlines bomb accident over North Carolina, neither the airplane nor an outside factor were determined as immediately involved, thus, the solution lay within the sphere of occupant behavior. In bad weather, during a period of decreased visibility, a Capital Viscount was struck over Maryland by a violent thunderstorm; hence, an outside factor was implicated. In addition, the possibility, as reported by the Civil Aeronautics Board, that certain late weather information bearing on this storm was not relayed to the pilot, falls within the outside factors area.

It is estimated that human errors and other human factors are associated intimately with eighty-eight per cent of civil air carrier accidents.[19]

Psychological studies of decreased performance in fledgling pilots, fatigued pilots, and ill pilots, are shedding new light on what have been long standing mysteries in aviation.[33] Also, studies of the best methods of training student pilots are being conducted.[60] These studies are helping us to diminish the possibilities of pilot error, of air traffic controller error, and of errors by maintenance men.

Physiologists are involved in these studies, and relatively recently, the neurophysiologists have cast light on a cause of aircraft accidents in a certain percentage of pilots who have a susceptibility to becoming temporarily unconscious during periods when they are observing flickering light. The condition is flicker vertigo. It may be precipitated by sunlight flickering through helicopter rotors, or through airplane propeller blades, particularly in light single-engined aircraft.

Judgment may be affected by alcohol, drugs, fatigue, hypoxia, carbon monoxide, personality and character deficiencies, and other factors, such as poor pilot instruction and illness. Poor judgment often leads the general aviation pilot to fly into weather conditions with which he cannot cope. Poor judgment leads a pilot to decide to dive on a friend's house. Poor judgment leads a week-end pilot to fly an unfamiliar airplane, or to fly his family and himself into oblivion through careless flight planning and operation of the aircraft.

Judgment, thus, is a quality which in a given individual, moves up and down, in accordance with mood, spirit, mental and physical conditions, and stress factors (for example, a pressing business appointment). Human factors studies by civil aeromedical research scientists are yielding new information in this highly important area.

The human engineers and psychologists are helping to work on diminishing pilot error through decreasing the chances of cockpit mistakes. The opportunity for errors in pilot manipulation of the various switches and other flight, engine and equipment controls (flap control, landing gear control, propeller pitch control, fuel cut-off control, etc.) has been enhanced through the scrambling of location of these elements within successive models of a given aircraft by the same manufacturer, as well as by different manufacturers in their construction of smiliar types of aircraft.[14] FAA's "Project Little Guy" is working on this matter, plus the matter of attempting to devise a standardized instrument design and instrument panel overall lay-out, which would aid in diminishing errors on the part of the pilot.

The possibility that stall warning and gear-up warning lights and horns may not reach the attention of pilots at times because of overloaded visual and auditory sensory channels, has led one CARI researcher to investigate other biological sensory systems as potential avenues for warning signals.[26]

CATEGORIES OF RESEARCH

Organizational Pattern of Research Programs:—The Aeromedical Research Division of the Aviation Medical Service (the Aviation Medical Service is under the direction of the Civil Air Surgeon who reports to the Administrator of the Federal Aviation Agency) works closely with the other three major medical Divisions (the Aeromedical Standards Division, which writes the aeromedical standards for civil airmen and conducts the medical portion of FAA's accident investigations, and the Aeromedical Certification Division, which provides current medical certificates to more than one million civil airmen and conducts special refresher seminars for the designated aviation medical examiners, and the Clinical Services Division, which examines FAA personnel and conducts an employee health program). Questions are referred to the research program and, following appropriate study, answers are returned.

The Aeromedical Research Division also maintains close liaison with the hardware and systems research and development program conducted at the FAA's National Aviation Facilities Experimental Center in Atlantic City.

The Aeromedical Research Division consists of the Civil Aeromedical Research Institute, located at the Aeronautical Center in Oklahoma City, and the Georgetown Clinical Research Institute, located at the Georgetown Medical Center in Washington, D. C. Of the following categories of projects, "A" through "H" are conducted at CARI, and "I" and "J" are conducted at Georgetown.

A. *Air Traffic Controllers and Air Crew Members: Physiological Stress, Fatigue, and Aging Factors Relating to Proficiency.*
B. *Air Traffic Controllers and Air Crew Members: Psychological Stress, Fatigue and Aging Factors Relating to Proficiency.*
C. *Air Traffic Controllers: Proficiency, Selection Factors, and Optimum Characteristics of Air Traffic Working Environment.*

The CARI projects falling within the above three categories are conducted by scientists in each of CARI's six Branches (Biodynamics, Environmental Physiology, Neurophysiology, Pharmacology-Biochemistry, Protection and Survival and Psychology).

The findings of one of the projects in psychology were recently incorporated in the Civil Service Announcement No. 281 B, issued May 22, 1962.[54, 56] CARI investigators gave certain psychological tests to air traffic controller students and correlated the performance of each student with his performance while undergoing air traffic controller training at the Aeronautical Center. Five test areas emerged as highly predictive of school performance: (1) abstract reasoning ability; (2) ability with numbers; (3) ability to conceptualize space in three dimensions; (4) ability to make "non-verbal" analogies; and (5) ability to solve a special test of air traffic control problems.[7]

By setting the minimum cut-off scores on the above tests to an appropriate level, candidates for air traffic controller training, can be screened prior to their entrance in training, and, with as high as eighty to ninety per cent accuracy, those individuals with little aptitude for a career in air traffic control can be eliminated. Previously, these persons were eliminated at the end of their air traffic schooling, or later, during their first year of work as controllers.

Through elimination of unfit candidates prior to training, this study, which cost about forty thousand dollars, is conservatively estimated to save the taxpayers more than two million dollars over a ten year period. A contribution to air safety results also in that with a high degree of confidence, persons poorly fit for air traffic work who, none the less, might scrape by in air traffic school, are not trained. One interesting aspect here has been the discovery that persons who undertake air traffic control training who are over the age of 35, have a very high rate of failure.[55]

Another study in the above area is the longitudinal medical, physiological and psychological evaluation of more than one thousand air traffic controllers, from the day of entrance on duty for training, to a point a few years later in their career when their work efficiency and disease pattern can be assessed. One of the treadmill test techniques is described in *CARI Report 62-5*.[30]

From the more than one thousand air traffic students now studied in detail at CARI, certain patterns are already beginning to appear. Wide variation in physical habitus and conditioning are noted. One hypothesis being tested is that the individual does a better job as a controller if he is in a better state of physical condition from the athletic standpoint.

Many people are of the personal opinion that better physical conditioning leads to better working ability in all endeavors. This has never been tested and, may, in fact, be exactly opposite to the facts with respect to sedentary work. The controller who rates poorly on a physical condition scale with respect to his physical work capacity, may, in fact, be highly conditioned physically to spending long periods in physical inactivity, and, thus, be at his best from his job requirement standpoint. The venerable Wiley Post was of this latter opinion, and spent weeks in physical inactivity prior to his solo round the world flight in 1933.[43] He sat for hours in his parked airplane, and in his hotel room, doing essentially nothing from the physical work standpoint.

It has been observed that in certain demanding locations, controllers as a group are somewhat more prone to develop stress-related medical conditions (for example, peptic ulcer, hypertension, anxiety psychoneuroses), so studies are underway which are attempting to enable us to better pin-point the stress factors which lead to these conditions, and to identify those individuals who are most prone to develop these conditions. The above mentioned longitudinal sample should prove to be of immense value here.

For many years to come, man will be a functioning and integral component in the air traffic system. Human error will, therefore, be an ever present potential threat to air safety. CARI psychologists have investigated several air traffic controller error incidents, and have made recommendations for certain changes in existing air traffic procedures which will help decrease the chances of recurrence of these errors. Of additional interest here is the matter of shift work in the air traffic around-the-clock activity, with reference to the work-rest-sleep cycle of the individual. Also, the period which immediately follows a change to another shift time is being studied.

The working environment of the controllers, some being in glass control towers with large-heavy-fast and small-light-slow aircraft converging from all directions, and others being in small, often dimly lit, smoky and congested en route centers, is being scrutinized from the individual and group work proficiency standpoint. A study on the ecology of these groups, and the factors which may precipitate interpersonal strife, so detrimental to the efficiency of the required team effort, is underway.

Excessive fatigue, an allegedly possible concomitant of piloting large civil jet aircraft, is receiving some attention at CARI.[34] The subject is difficult to define, difficult to measure, and is complicated by possible pilot-airline contract implications. Some have felt that the increased demands of these aircraft for a higher level of pilot alertness have produced mental fatigue which toward the end of a flight can cause a performance decrement which is detrimental to the pilots' safe handling of the aircraft.

Others suggest that since a given flight is now more quickly accomplished with jets, the jet pilots must make more individual flights now to reach the maximum allowable monthly number of flying hours (eighty-five). There is, thus, less time off now, and the extra free-way traveling to the far-out jet airports associated with the additional flights compounds the fatiguing factors. Cutting time-zones more quickly when flying from West to East, or *vice versa,* is also conductive to producing fatigue.

CARI researchers have been in frequent communication with the medical directors of the major airlines, and with various pilots through the Air Line Pilots' Association, and are giving attention to the jet pilot fatigue question.

Other studies in the broad area of proficiency include determinations for pilots, ground support and other essential personnel, of safe levels of function in the following areas:

1. Visual acuity
2. Color vision
3. Hearing acuity
4. Vestibular function.

Accidents have occurred through excessive deficiencies in these areas so vital to aviation. It is recognized that some kinds of aircraft and some types of flying are not as demanding in these neurophysiologic and psychologic areas as is the case in other instances. Therefore, CARI is working closely with the Aeromedical Standards Division in an attempt to match the medical standards for airmen with the type of flying and the nature of the equipment. Through research, the standards can be revised up or down in timely relation to future equipment through extrapolation. In the absence of proper information developed through research, standards must be established in accordance with the best judgment of medical and aviation authorities, and changed only after a retrospective assessment of the accident and flight experience with the equipment in question. Too often, based upon a series of tragedies, this latter approach shows what the standards should have been to insure safety for certain pilots in certain categories flying certain equipment, and by the time new standards are made in this retrospective fashion, new and unevaluated equipment and flying techniques have replaced the older examples.

D. *Civil Aviation: Passenger and Crew Emergency Procedures, Oxygen Equipment and Safety Measures.*

This category of CARI research is focused on providing the aircraft manufacturers and the airlines with information on factors vital to the preservation of life during civil aircraft emergencies.

A study of emergency evacuation patterns in large civil aircraft is underway.[23]

An accident may be considered to be an unplanned experiment (albeit unfortunate), and CARI, from its vantage-point as a component of the FAA, and a not infrequent assistant to the CAB, is obtaining heretofore lacking information on the stumbling blocks to rapid escape in air carrier accidents.

Narrow aisles, rare escape doors, inadequately briefed passengers, elderly women, children, and general confusion which may accompany a crash landing: these are factors which interact to impede a rapid egress from a burning aircraft. Certain corrective measures are possible and are being incorporated in future aircraft. Much more remains to be studied with respect to this topic, and CARI is providing attention to these additional matters.

Better protection of the passengers and crew in today's civil jet aircraft which fly at altitudes up to 40,000 feet, in the event of an explosive decompression, is being studied at CARI.[3]

These studies also anticipate the requirements of the next evolutionary step in the large civil aircraft, which will see the Supersonic Transport rising to altitudes of 50,000 to 60,000 feet. The dive-ram principle of recompression will likely be employed, and a large increase of cabin heat resulting from the compressed air will occur. Survival tolerances of civil air carrier populations (including all age groups, pregnant women and persons with chronic cardiovascular conditions) to these explosive decompressions, and to cabin heats of 170 degrees Fahrenheit for five minutes, are being determined.

CARI is working with the aircraft industry on an explosive decompression study, particularly with Lockheed, to whom CARI has given a contract for the conduct of special high altitude chamber studies, of a type heretofore not conducted by military or other groups.[18]

It is possible that if middle-aged and elderly persons with certain chronic diseases (for example, cerebrovascular insufficiency, coronary artery disease, pulmonary emphysema, obesity, anemia) are found not to tolerate these potential decompressions and recompressions, flight on this next generation of aircraft will be proscribed for them by their physicians.

A CARI investigation of an accident involving a twin-engine Convair revealed how improperly installed rearward facing seats caused vertebral fractures in certain occupants.[25]

Another CARI study revealed that a possible attraction by a popular civil aircraft type for starlings may be due to the similarity of the taxiing sound of the aircraft and cricket chirps.[1, 10, 50] More recent studies indicate that the suspect sound may come from the propeller tips during the taxiing operations, and may possibly be eliminated through cockpit manipulation of the propeller pitch controls.

E. *Civil Aviation Personnel: Drug Effects on Performance and Safety of Aircrew and Ground Support Personnel.*

Aircraft accidents have occurred which quite likely would not have occurred had the pilots not been taking certain drugs. Included in this category of studies is the acute alteration of behavior which immediately follows alcohol ingestion, and the subtle residual effects of alcohol ingestion which persist twenty-four hours after ingestion.

Air traffic controllers, non-pilot aircrew members, and maintenance men may take various drugs (aspirin, antihistamines,, antimotion-sickness drugs, "wake-up" and "diet" medicines, barbiturates, nasal decongestants, and other drugs). No good information exists concerning the role of these drugs in producing performance decrements in these various categories of aviation personnel.

CARI is studying these matters, which do present complex methodological problems. The information, as it is developed, is disseminated to the airlines, the pilots and aircrew members, the controllers, and other persons who are concerned.

F. *Aerial Applicators: Effects of Toxic Chemicals upon Health and Safety.*

More than one million hours per year of flying are conducted in the field of aerial application.[16] The accident incidence is the highest of any segment of general aviation, and possibly one-half of the fatal accidents are due to pilot decrements in performance due to chronic toxicosis.

Organophosphate insecticides are in common use today, and evidence indicates that the high incidence of pilot fatalities in crop-spraying with these substances is the result of chronic absorption by the pilots of small amounts of organophosphates.[47] At a certain constitutional level of absorption, the pilot's nervous system is poisoned to the point where his reactions and decisions in flight are not compatible with aerial applicator maneuvers. Blood tests are being refined at CARI which give an index during the aerial application season of how much poison a given pilot has absorbed. Also, protective equipment is being developed which aids the pilot, his swampers and his flag man to avoid contamination.

The biochemical effects of the chlorinated hydrocarbons used in aerial application (for example, lindane and dieldrin) are being studied at CARI, and recently CARI investigators have found that certain members of this class of compounds have a highly specific and hitherto unsuspected interference effect upon the molecular dynamics involving the high-energy phosphate bond.[13] It is predicted that this discovery will lead to an entirely new biochemical research tool of great potential utility for medical and life sciences investigations. An antidote to acute and chronic poison cases due to these compounds may be devised as a result of this further clarification of their biochemical mechanism of toxicity.

CARI keeps in close touch with the Department of Agriculture on these studies. The DOA investigators, however, are primarily concerned with the acute and cumulative effects of aerial applicator substances on the public which at times may consume food containing traces of these chemicals. The pilot's flying proficiency in relation to his absorption of these substances is the FAA's responsibility.

A brief reference to the CAB report on aerial application accidents in 1959 is pertinent here.[5] Of 314 total accidents, 57 were fatal and 57 fatalities resulted. One hundred and nine aircraft were destroyed, and 35 persons were seriously injured. The accident rate per hundred thousand flight hours was 6.47 for fatal accidents, and 35.69 for all accidents. The fatal rate was 78 per cent above that for all general aviation (although the total accident rate was 3 per cent lower in aerial application than for all general aviation).

The report mentions that at least 10 accidents were experienced by pilots affected by the chemicals being used in aerial application. Among these, parathion is prominent. Three fatal accidents were distinctly due to the toxic effects of the chemicals on the pilots. In many other accidents, the possibility that pilot performance was impaired due to the gradual accumulation of the chemicals in the pilots during the active season is good.

It is anticipated that an index of functional age will be developed which at a later date may enable a revision of the current standards to potentially allow airline pilots who are chronologically over sixty to continue to fly if they are functionally less than sixty in age. Also, the implications for flying safety of certain chronic diseases are being investigated.[36]

BRIEF HISTORICAL RESUME

Mr. Graham-White in his 1912 book, *Aviation,* calls our attention to the fact that the Aero Club of France could document only one fatal accident for every 92,000 miles flown in France during the year 1912.[20] The supposed "perils of aerial navigation" were thus "dispelled."

In 1921, the U. S. Post Office Air Mail Service had one fatal accident for each 104,000 miles flown.[46] No passengers were carried, and the flying was quite rugged due to weather hazards and equipment failures.

In 1938, the domestic U. S. scheduled air carriers handled 1,366,000 passengers over more than 560 million passenger-miles.[38] Five fatal accidents occurred and 35 persons died (crew and passengers). The passenger fatality rate per 100 million passenger-miles was 4.45.

In 1960, the comparable figures are 52,392,000 passengers for almost 32 billion passenger-miles. Nine fatal accidents occurred and 329 persons died (crew and passengers—not counting the 34 passenger and crew fatalities in the January 6, 1960, Bolivia, North Carolina bomb accident). The passenger fatality rate per 100 million passenger-miles was 0.93.

It is clear that for a given individual, a given flight today is much safer than was the case in earlier years. In fact, the degree of safety is steadily improving. However, in spite of this, the total picture over the years in civil aviation is one of an increasing absolute number of deaths. Obviously, this latter fact is due to the continuous growth of aviation activities, and the increasing passenger load per plane in air carrier activities.

For example, there were only 9,072 civil airplanes in the U. S. on January 1, 1936 (7,371 U. S. Bureau of Air Commerce licensed aircraft, 1,701 unlicensed aircraft).[63] This compares with 117,560 on April 30, 1962.

Also, there were 14,805 Bureau of Air Commerce licensed pilots in 1936 (included 736 scheduled air transport rated pilots and 5,961 licensed private pilots; of the total, only 410 were women pilots). This compares with a figure of several hundred thousand today (no one is quite certain what the exact figure at present is for the total number of active airmen; many licensed airmen have let their medical certificates expire without later renewal—others have current medical certificates but are not active airmen—still other persons have current Class II medical certificates but are not pilots: for example, tower air traffic controllers).

The thread of aviation medicine and aeromedical research comes to us along a winding trail. Bert's classical studies in the 19th century in relation to balloonists ascending to high altitudes, set the stage for scientific aeromedical activities.[29] Bert explained why some early balloonists returned to earth dead.

Dr. John Kelly, a Medical Reserve Corps lieutenant, was the first "flight surgeon" in the U. S. when in 1911 he was assigned to College Park, Maryland.[4] The U. S. Army had at that time only one airplane.

Dr. Louis Bauer became Director of the Central Medical Research Laboratory at Hazelhurst Field, Mineola, Long Island, in 1919, and conducted research on high altitude physiology. This facility moved to Mitchel Field in late 1919, and in the early 1930's, a final move was made to Randolph Field, Texas, where the famous School of Aviation Medicine developed.

In the period leading up to World War II, the Navy developed a school of aviation medicine at Pensacola, and an aeromedical laboratory was established at Wright-Patterson Air Force Base in Dayton.

Dr. Bauer resigned his commission in 1926 and became the first medical director in the new Aeronautics Branch of the Bureau of Air Commerce, U. S. Department of Commerce. The designated aviation medical examiner system was established and the original physical standards for civil airmen were defined. An attempt was made in 1930 to relate the accident rates with the types of physical deficiencies.[9] Definite correlations were found.

The Civil Aeronautics Administration medical laboratory was established on Aug. 2, 1946, in Oklahoma City at the Aeronautical Center at Will Rogers Field.[64] Later, Dr. Stovall, Chief of the Medical Division, CAA, transferred the laboratory to Ohio State University, where the establishment of an Institute of Civil Aviation Medicine was planned. Mr. John Swearingen was the laboratory director. In 1958, the Civil Aeromedical Research Laboratory was transferred back to Oklahoma City.

In 1959 and 1960, Dr. James Goddard, the FAA's first Civil Air Surgeon, and Dr. John E. Smith, Chief of the Research Requirements Division under the Civil Air Surgeon, began to lay the basis for the present Civil Aeromedical Research Institute. Dr. H. D. Estes became the first Director of the Institute in 1960.

The evolution of civil air transportation has been a steadily progressing phenomenon, although many setbacks have occurred and are occurring. For a discussion of the economic problems currently facing the airlines, see Mr. Harding's recent article.[61]

The world's first scheduled airline was launched in 1909.[41] Count Zeppelin and Dr. Eckener created the Deutsche Luftschiffahrts-Aktien-Gesellschaft, which operated dirigibles between Friedrichshafen, Frankfurt, Hamburg, Leipsig, Potsdam and Dresden. For five years this airline carried more than thirty-seven thousand passengers without injury. Low speeds, low cruising altitudes, and good maintenance helped to produce this good safety record.

The first scheduled airline to use heavier-than-air equipment operated a Benoist flying boat between St. Petersburg and Tampa, Florida. It made two round trips a day and carried one passenger at a time. This operation began on January 1, 1914. The twenty-two mile one-way flight took twenty minutes.

The Air Commerce Act of 1926 provided for air mail contracts to private operators and marked the start of air transport in the U. S.[45] The first year of private contractor airline operation saw five thousand seven hundred and eighty-two passengers carried. This number makes an interesting contrast with the more than fifty million domestic passengers carried by scheduled U. S. airlines in 1960, and the estimated figure of seventy-five million for 1967.[39]

In the twenties, many of the commercial airliners, for example the Ford Tri-motors, had no safety belts for the passengers. The wicker seats were provided with hand grips for passenger stability in rough air. Overhead baggage racks were used for suitcases, a hazardous transfer to aviation of practices used with reasonable safety by the railroads.

A final historical note seems pertinent. In 1929, Transcontinental Air Transport provided travelers with the possibility of crossing the U. S. in forty-eight hours. The itinerary consisted of going from New York City at night to Columbus, Ohio, via the Pennsylvania Railroad. From Columbus, a Ford Tri-motor was taken to Waynoka, Oklahoma, where a Santa Fe sleeper was taken to Los Angeles. The passengers were subjected to noise, vibration, air pressure changes, temperature extremes, and other stresses.

It is interesting to note that the first human factors fatality in the U. S. in a heavier-than-air aircraft apparently was Professor John Montgomery. Professor Montgomery suffered from periodic attacks of vertigo and loss of consciousness. During a glider flight in 1911 in California, he lost control and crashed. Prior to dying from his injuries, he told of the occurrence of one of these attacks during the flight leading to his disorientation. Along this line, through a contract with the University of Oklahoma, CARI investigators are studying the matter of vertigo, disorientation, and inner ear malfunction.[17]

Through the years, aviation notables have recognized the importance of human factors research.[11, 15] For example, Lindbergh conducted altitude physiology studies in the 1930's, and Amelia Earhart pressed for additional investigations of the effects on the pilot of his aircraft.

Even as far back as World War I, the castor oil used in rotary engines would at times cause incapacitation of the pilots through exhaust fume inhalation. The importance of aviation medicine became clear.

The Oklahoma City Chamber of Commerce held three annual civil aviation clinics in 1943, 1944 and 1945.[8, 52, 53] Industry and Governmental officials active in civil aviation participated, and held brain-storming sessions which attempted to forecast what problems should be tackled in the post-war era to help foster civil aviation safety and growth.

These persons did not overlook the human factors elements, so vital to air safety and development. For example, the following research needs are contained in the 1944 book, as outlined by Mr. M. K. Fahnestock:

I. Biological Sciences
  A. Involving Both Aircraft and Personnel
    1. Pilot and crew fatigue, performance, maintenance and length of service.
    2. Optimum operating schedules for equipment and personnel.
    3. Design of aircraft to reduce injuries in crashes. Available information indicates that structural redesigning of planes may reduce fatalities and serious injuries in crashes from medium heights.
  B. Involving Operating Personnel and Passengers
    1. Pilot and crew training, including mental and physical examinations, and minimum requirements for commercial flying.
    2. Mental and physical examinations and minimum requirements for personal flyers.
    3. Human reactions accompanying fear and emergencies.
    4. Physical fitness and influence on training and performance.
    5. Public health and disease carrying insects.
    6. Food and food service for pilots, crew and all types of passengers.
    7. Effects of factors of flight on impaired physiologically deficient people.

II. Social Sciences
  A. Economics
    1. Influence of air transportation on goods and markets, including consumer demand.
    2. Economic problems of airline and airport management.
  B. Sociology
    1. The effects on people and the social processes of bringing all sections of the world into intimate contact with one another.
    2. Possible effect of small planes and helicopters on individual and community arrangements.

The literal translation of these recommendations into a material program is now seen in the Civil Aeromedical Research Institute.

Interestingly, a large portion of the conceptual foundation upon which the Civil Aeromedical Research Institute now rests can be directly traced to Oklahoma's air genius, Wiley Post. "Secretly, I had been forming the Wiley Post Institute for Aeronautical Research," is a statement by Post in his 1931 book, *Around the World in Eight Days*.[44] He had the idea in 1913, when he was 14 years old. The Civil Aeromedical Research Institute conducts studies which Post undoubtedly would have applauded: High altitude physiological effects (Post was among the foremost in this field with his pressure suit), fatigue (Post studied his own fatigue pattern, especially following the loss of sleep), depth perception (Post conducted studies of monocular vision for obvious personal reasons), and biological rhythms (Post studied the effects on the sleep-wake cycle and digestive system of cutting time zones).

Some historical aeromedical papers of note include an early dissertation by Henderson, et al., on the medical aspects of flight,[27] an early analysis by Anderson of "Aeroplane Accidents,"[2] and early batteries of psychological tests for flying aptitude by Henmon[28] and by Lowenstein.[32] An excellent historical review of the psychological aspects of aeromedicine is given by Viteles.[59] About the earliest report by a pilot on certain aeromedical considerations is that of 1914 by Mr. Ovington in the *Journal of the American Medical Association*.[40]

The evolution of aviation medicine and research programs contains many exciting steps by and brilliant scientists. Among these are Dr. McFarland's program at Harvard, Dr. Lovelace's program in Albuquerque, Dr. Ashe's program at Ohio State, Dr. Tillisch's program at the Mayo Clinic, the programs of the various airlines and aviation industries and the Guggenheim and Flight Safety Foundations. There are others, and all have a common aim: enhanced air safety.

SUMMARY

Were there no aircraft accidents due to human factors, there would be no need for aeromedical research. Aeromedical researchers, thus, frequently ask themselves the question: "What is the current air safety picture?" At CARI we have instituted within the Program Advisory Office a means by which a running up-to-the-minute tally may be kept with respect to all U. S. aircraft accidents. While some persons and groups appear complacent in the face of the present record, we are not.

I am not complacent when I go to the scene of a fatal light airplane accident, as I did recently near my home field, and learn that the two dead occupants probably would have lived through the impact if appropriate relatively inexpensive restraint harnesses, such as developed and recommended by CARI researchers, had been used. I am not complacent when I come across the fact during a recent on-the-scene study of a light-twin accident, fatal to the four occupants, that the pilot had been daily taking large amounts of dexedrine, barbiturates, thyroid extract, and other drugs. This latter accident is particularly noteworthy since a gross failure of judgment on the part of the highly experienced pilot was involved in the steps which led to the accident. The combined dosages being taken by the pilot could easily have had a detrimental effect on his abilities.

In civil aviation tragedies, there are many additional examples of injury and death which resulted from the lack of application of existing aeromedical knowledge or the lack of existence of timely aeromedical knowledge. Examples may be found in the *CARI Reports* and CAB reports.[6] Our aeromedical research program is dedicated to the production of the information which is vital to the human factors aspects in civil aviation. In the absence of this information, civil aviation will continue to be periodically shocked through the occurrence of "difficult to explain" accidents and injuries.

Our tallies show that in the first six months of calendar year 1962, the following accident experience occurred:

Air Carrier Fatal Accidents	4
Air Carrier Fatalities	248
General Aviation Fatal Accidents	178
General Aviation Fatalities	361

The Civil Aeronautics Board reports indicate the major roles played by the human factors aspects in these accidents. Until these human factors aspects are properly defined, and brought to the attention of aviation personnel and pilots through education and training, the accidents will continue at the present, unacceptably high (in my opinion) rate (if you don't believe it's high, ask some of your neighbors why they feel uncomfortable in airplanes, or why some of them won't fly at all).

There were last April, a little more than 114,000 general aviation aircraft registered in the U. S. Also, there were about 2,200 air carrier aircraft. In 1961, 437 fatal general aviation accidents occurred (with 794 deaths), which means that, roughly, one of each 260 general aviation aircraft was involved in a fatal accident. Preliminary estimates indicate that about one of each 20 general aviation aircraft was involved in an accident of greater or lesser importance in 1961.

What is the trend over the past three years in aviation fatalities? There are many approaches to attempting to determine this. Some recommend taking the number of fatalities per mile flown. I would like to point out that many accidents occur during the take-off and landing phases of flight. Thus, for example, a jet passenger is just as committed to undergo the risks of take-off and landing on a short flight as he is on a long flight. An accident rate based upon a fatalities per mile calculation, would indicate, however that the passengers in the long jet flight, assuming a 100 per cent fatal accident occurred at the termination, were traveling at less risk than the passengers in a short jet flight experiencing a 100 per cent fatal accident at the termination.

The same is true with calculations which determine the aircraft accident rate by dividing the number of accidents by aircraft flight hours. Let us remember that the "accident rate" is one thing, and the "risks of flying" another. By-and-large, the present FAA and CAB methods of accident rate computation indicate rates which are somewhat below the actual risks associated with flying, as noted above.

For general information, the following figures are instructive:

	Air Carrier Fatal Accidents	Air Carrier Fatalities
Calendar Year 1960	17	499
Calendar Year 1961	12	312
	General Aviation Fatal Accidents	General Aviation Fatalities
Calendar Year 1960	438	835
Calendar Year 1961	437	794
	Scheduled, Supplemental and Commercial Air Carrier Passenger Fatality Rate/100 million passenger-miles	General Aviation Fatal Accident Rate 100,000 hours
Calendar Year 1960	1.30	3.5
Calendar Year 1961	0.66	3.4

So far this year, there is no spectacular indication that these regrettable rates are declining. When one considers the rapid introduction of new types and categories of civil aircraft, only the concerted interaction of the aircraft industry, the airlines, the FAA and the CAB, could have led to keeping the rates from increasing. However, a large dent can be made in the present rate through the application of the fruits of civil aeromedical research.

I would also like to point out here that quite often when an aircraft accident occurs, the victims represent some of the Nation's top executive, scientific, and cultural talent. Air safety is, thus, doubly important to our country. For example, just a few days ago, on October

6, Mr. Tom Slick, well known Texas philanthropist died in a light plane accident in Montana (CARI researchers are assisting in the investigation), and on October 7, U. S. Representative Clem Miller died in a light plane accident in California.

The title of this paper incorporates three elements in Federal civil aeromedical research. Our responsibilities are clear: (1) to insure that no loss of life or limb in civil aviation activities occurs for reasons which could have been prevented had adequate and timely human factors knowledge been available, and (2) to keep abreast of evolving aviation equipment, and, through anticipation of the requisite future human factors information, conduct appropriate studies.

The aims are consistent with, and part of, the mission of the Federal Aviation Agency: (1) to enhance the air safety record, and (2) to foster the growth of civil aviation.

Selected accomplishments are enumerated in this paper and its bibliography. Much remains to be done, and we shall continue to strive to achieve that level of aeromedical research which insures an optimum air safety record with respect to the human factor elements.

Planned air safety, consistent with economic realities, then, is the key to aviation's continued growth and successes in the years and decades to come.

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