DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

WASHINGTON, D.C. 20590

FEDERAL AVIATION ADMINISTRATION

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Sherman P. Vinograd, M.D.
Director, IMBLMS
NASA Headquarters, Code MM
Washington, D.C. 20546

Dear Sherm:

We appreciated the opportunity to meet with your seminar group at MIT yesterday. This morning I gave the NASA film to your office as you requested.

Enclosed is a copy of my talk.

With best regards!

Sincerely yours,

Stan

STANLEY R. MOHLER, M.D.
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Enclosure

CIVIL AVIATION ACCIDENT INVESTIGATION
AND MEDICAL RESEARCH

Stanley R. Mohler, M.D.

Introduction

In the United States there are two categories of civil aviation operations. The most extensive category, in terms of numbers of airmen and aircraft, is that of general aviation. General aviation is defined as all civil flight activities other than air transport operations. Air transport operations (also referred to as air carrier flying) carry by far, however, the most persons. Table One provides statistics on these two categories.

The Federal Aviation Administration is responsible for promoting safety in both of these categories. The information which follows will describe certain accident investigation considerations in these two categories of aviation activities and also will cover certain aeromedical safety research tasks undertaken by the FAA.

General Aviation Accident Investigation

The major factor involved in air safety relates to those matters which impair pilot performance. Eighty to ninety percent of aircraft accidents result from "human failure." Since 1963, fatal general aviation accidents have been studied

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by aviation medical personnel with respect to possible alcohol involvement. Blood and tissue samples have been collected in the course of individual accident investigations and these have been forwarded to various clinical pathology laboratories, including the Armed Forces Institute of Pathology and the Civil Aeromedical Institute (CAMI). Of course, not all fatal accidents have been studied since some of these have not been located until several months time has elapsed resulting in a loss of tissue. Others have not been studied from the toxicological standpoint because the appropriate investigative equipment was not at hand. Steps have been taken in the past year by the Civil Aeromedical Institute to assure that blood and tissue collection kits are made available to investigators.

Table Two presents the toxicological findings concerning alcohol in general aviation fatal accidents for the years 1963-1968. It is seen that pilots involved in these accidents have decreased in percentage from 43 percent in 1963 to the 22-23 percent level in 1968. It is felt that a very aggressive educational program conducted by the FAA in recent years has helped to alert pilots to the hazards of mixing alcohol with flight and has been partly responsible for the observed downward trend of fatal general aviation accidents in this context.

Another area of study has involved the analysis of the role of aging as a factor related to general aviation accidents. Table Three presents data obtained in a review of all general aviation accidents (fatal and non-fatal) which occurred during 1965 in relationship to pilot age and airman certificate held. Contrary to folk lore, it may be seen that increased age *per se* was not found to be associated with an increase in accident rates. It is felt that perhaps the older pilots may be exercising more caution than their younger colleagues in that in the sample relatively few older pilots having accidents are found to have mixed alcohol with flying. In addition, older pilots are less often found to be undertaking deliberate penetration of adverse weather and they are much less likely to perform an unwarranted low-level manuever (buzz job). The most hazardous pilot in this analysis was the youngest-age group pilot who had achieved the highest level of pilot rating. It may be hypothesized that this group contains the "young tigers" who are prone to fly aircraft closer to the maximum limits of safety and consequently are more accident prone. It can be predicated that with age this tendency will diminish.

In the aeromedical accident investigation program, other factors are assessed. These include cardiovascular disease (especially coronary occlusion), carbon monoxide poisoning, hypoxia, and other factors which can incapacitate pilots. Drugs can impair pilot performance and each year accident investigations reveal cases where drugs of various types were involved. Examples of drugs which have been found to have deleterious effects on pilots are the antihistamines, the tranquilizers, the appetite-suppressing drugs, and many others. Continuing airman education will be accomplished concerning these.

It has been repeatedly found that 80-90 percent of general aviation accidents are due to pilot factors. Accordingly, the thorough investigation of accidents must involve an assessment of pilot physical and mental status. In regard to this point, the FAA has in its medical office a branch devoted solely to coordinating the medical investigation of accidents and analyzing accident data. Also, the National Transportation Safety Board has established a full-time human factors specialist in its Bureau of Aviation Safety to give emphasis to this area.

Another phase of accident investigation which is very significant is that of crash injury assessment. Further information on this area will be given in a later section of this paper under the topic research. It is important to stress that engineers and medical personnel must both work on this aspect if correlations between injuries and structural design features are to be properly made. The FAA's Aviation Medical Examiners participate in the individual accident investigations.

Air Carrier Accident Investigation

When an air transport aircraft crashes, a full-fledged team of aircraft accident investigators is immediately mobilized by the NTSB. This team comprises aviation experts drawn from all segments of aeronautics. There are persons who are skilled in engine design and operation, there are individuals who know the structure of the aircraft involved, its instruments and special systems, and also included are on-the-line pilots who are current in the type of aircraft involved. In addition, persons knowledgeable in air traffic control, meteorology, and aviation medicine (especially pathology) constitute team members. The team convenes near the site of the accident and weeks of intensive investigation may take place.

Two of the most important items sought among the wreckage are the aircraft flight recorder and the cockpit voice recorder. The flight recorder provides detailed information concerning such matters as the altitudes, headings, air speeds, vertical accelerations and time, and certain other parameters which preceded the accident. The cockpit voice recorder provides recordings of all communications and any noises which were picked up by any of the radio transmission and reception circuits plus any intercom communication originating from the crew or cabin attendants for the benefit of the passengers. All air carrier aircraft over 12,500 pounds operated under Federal Aviation Regulation 121 and flown over 25,000 feet, must, after July 1958, contain flight recorders. Many accidents have been clarified with respect to contributing factors by the use of one or both of these recorders. Today, these recorders are located in the aft portion of aircraft to minimize damage to them.

The Aviation Medicine member of the investigation team coordinates human factors aspects including the arrangements for necessary autopsies. He assists in obtaining the appropriate pathologist for accomplishing post mortem studies. Public Law 87-810 authorizes aircraft accident investigators to obtain autopsies where necessary and under proper circumstances in order that any medical causes of the given accident may be determined. Several accidents have had their probable cause determined as a result of the medical portion of the investigation. One example is that wherein the captain's heart showed a recent coronary occlusion. Another example is that where a passenger's body revealed bomb injury.

After all of the individual reports concerning a given accident investigation are transmitted and following a careful analysis of the information, including a public hearing, the NTSB renders a verdict with respect to the probable cause. Quite often, accompanying this decision are a number of recommendations intended to diminish the likelihood of future accidents. From time to time, medical items are contained in these recommendations and subsequent regulation changes may result.

Civil Aeromedical Research

The major governmental medical research effort concerning air safety is accomplished through the Federal Aviation Administration, Office of Aviation Medicine. The FAA medical research laboratories are located within the Civil Aeromedical Institute at the Aeronautical Center, Oklahoma City, Oklahoma.

The civil aeromedical research programs are aimed at two specific objectives. The first is that of identifying and studying ways of improving the design and operation of aircraft and aviation facilities from the human factors standpoint. The second consists of research into the health, performance, efficiency, and environmental effects, as these various items relate to personnel participating in aviation activities. As can be seen, these two approaches involve the man-machine system. At the Institute, the scientific manpower in research is concentrated in four primary laboratories which are Pharmacology-Biochemistry, Physiology, Psychology, and Protection and Survival. A clinical research laboratory is functioning as are a veterinary medicine support group, a biostatistical staff and an engineering support group. Each study undertaken by CAMI falls within the FAA program requirements developed each year by Associate Administrators and Service Directors of the Washington Headquarters. Each research task is individually reviewed and if approved, is signed by the Federal Air Surgeon. A copy of each task is filed with the Science Information Exchange, a component of the Smithsonian Institution in Washington, D.C. A standardized format (FAA Form 1750-1) is utilized for each research task. The form is compatible with Department of Defense Form 1498 and the National Aeronautics and Space Administration Form 1122. In this way, aeromedical research on a particular task currently underway can be assessed in relation to similar work being done by making one communication to the Science Information Exchange.

Examples of research conducted by the Physiology Laboratory include studies of the role of exercise in preventing heart disease in aviators, the degree of fatigue incurred in flying light aircraft, the amount of stress experienced by air traffic controllers, and the effects on respiration of combustion products arising in cabin material fires. In addition, a cooperative study by physiology and psychology scientists is aimed at assessing the effects of sonic booms on sleep.

The Psychology Laboratory conducts studies of air traffic controllers especially age and stress aspects in relationship to length of service, means by which communication intelligibility can be enhanced, human problem solving behavior, motor function under stress, and air traffic controller aptitude studies.

The Pharmacology-Biochemistry Laboratory concentrates on investigating the toxicological aspects of various aerial applicator poisons, the ionizing radiation effects on tissues from the standpoint of the Supersonic Transport and the distribution within the body of certain drugs found in victims of aircraft accidents. The Protection and Survival Laboratory works to quantify the effects on tissues of specific types of impacts (inverted, etc.), to determine the effectiveness of protective oxygen equipment for crew and passengers, to determine the means by which smoke inhalation can be prevented for individual passengers during airline crashes and fires, and to evaluate the means by which more rapid escape can be achieved from large aircraft.

Reports resulting from the above studies are made in the scientific literature and FAA Office of Aviation Medicine Reports. These latter reports are available from the Government Printing Office.

Summary

Intensive accident investigation by the Federal Aviation Administration and the National Transportation Safety Board points the direction for additional medical research. Once the information is developed through research, it is transmitted to the FAA operational offices and the aviation industry. In some cases, a new regulation or a modification of existing regulations takes place. In others, the aviation industry voluntarily undertakes corrective action, and in still others, a concerted airmen education program is launched. All of these activities are vital to a high level of air transportation safety.

TABLE ONE

CIVIL AVIATION STATISTICS

U.S. Airline Revenue Passenger Enplanements - 1967 (Total scheduled service including international)	142,499,000 passengers
Total U.S. Air Carrier Aircraft (1967)	2,595
Total U.S. General Aviation Aircraft (1967)	114,186
Total U.S. Civil Airports	10,126
1967 U.S. Airman Population	617,931
Air Carrier total accidents per million miles flown (1967)	0.032
Air Carrier fatal accidents per million miles flown (1967)	0.006
General Aviation total accidents per million miles flown (1967)	1.7
General Aviation fatal accidents per million miles flown (1967)	0.17

Reference: FAA Statistical Handbook of Aviation, 1968 Edition

TABLE TWO

GENERAL AVIATION ALCOHOL LEVELS

	1963		1964		1965		1966		1967		1968*	
Total Fatalities	900		980		1020		1123		1200		1458	
Fatal Accidents	477		510		543		564		605		702	
	#	%	#	%	#	%	#	%	#	%	#	%
Pilot Toxicology	136	29	215	42	293	54	347	62	394	69	368	55
Pilot Positive Alcohol	59	43	82	39	105	36	94	27	83	22	85	23
↓50 mg percent	19	32	23	28	45	43	44	47	27	32	22	26
50 - 99 mg percent	12	21	18	22	20	19	18	19	15	18	15	17
100 - 149 mg percent	9	15	22	27	16	15	16	17	18	22	16	19
↑150 mg percent	19	32	19	23	24	23	16	17	23	28	32	38

Reference: Aeromedical Applications Division, Office of Aviation Medicine, Federal Aviation Administration

* as of April 30, 1969

TABLE THREE

ACCIDENTS PER 10,000 PILOTS FOR THE YEAR 1965

By Airman Certificate and Age

Certificate	16-29	30-44	45-59	60-74+	Total
Student	60	94	111	82	77
Private	126	118	120	113	120
Commercial	254	146	109	123	152
Air Transport	298	118	59	104	93
TOTAL ACCIDENT RATE	106	121	109	110	114
Totals Excluding Students	167	128	109	115	129

NOTE: This table consists of data based upon the actual accident figures adjusted by division or extrapolation to populations of 10,000 individuals in accordance with the following formula:

$$\frac{\text{number of accidents}}{\text{subject category for 1965}} \times 10{,}000$$

Reference: Mohler, Stanley R., Bedell, Rowland H.S., Ross, Alan, and Veregge, Everett J., "Aircraft Accidents by Older Persons," Aerospace Medicine, Vol. 40, No. 5, May 1969, pp. 554-556.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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REPLY TO
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II. Ultraviolet Radiation

The major natural source of ultraviolet radiation is the sun which emits U.V. in the range of 1,400 to 3,900 Å. Man-made sources include electric arcs used for lights, welding arcs, plasma jets or arcs, germicidal lamps and special lamps used to simulate solar radiation.

The amount of ultraviolet reaching the earth's surface from the sun depends on a number of factors. The position of the sun in the sky is one of these, and therefore, the amount received at a given site will vary with latitude, season of year and time of day. The elevation above sea level is also important. At higher elevations there is more U.V. Air pollution or clouds (water vapor) can reduce the amount that reaches the earth's surface.

Ultraviolet radiation is readily shielded. This weak penetrating ability limits the usefulness of U.V. as a bactericidal or vericidal material, and also allows the human body to protect itself from ultraviolet radiation by increasing the thickness of the stratum corneum--this, with tanning, offers considerable protection from U.V.

Some selected biologic effects of U.V. are presented in Table 1. It should be emphasized that the U.V. from sunlight or from artificial sources is not entirely safe. As with ionizing radiation, biologic manifestations do not appear until sometime after exposure. If the exposure is sufficiently great, there may be marked systemic effects such as fever, nausea and malaise. Apparently the aging effect of the skin bears a high correlation to the accumulated exposure to ultraviolet. In the areas with greatest exposure, premalignant or malignant changes are also most likely to develop.

III. Visible Light

This covers the relatively narrow band of 4000 to 8000 Å that is perceived by the human eye. The hazards of this type of radiation may be divided into direct and indirect. The former result from the radiation itself, such as retinal burns due to looking at the sun during an eclipse with inadequate filtration; the latter from personal injury caused by accidents produced by inadequate quality of illumination due to glare, high contrast or too low levels of lighting.

The retinal burn due to direct penetration and focusing of intense levels of light can produce atrophy of an area of the retina. Since in viewing eclipses or other potentially intense light sources the viewer uses the macula, the injury will be produced in the part of the retina that has the greatest concentration of cones and is used for fine and precise vision. Considerable disability can therefore occur.

Within the range of visible light are the recently developed devices called optical masers or lasers. Such units emit beams of light with remarkable properties. Because of their spatial coherence, laser beams have extremely small divergence or are highly collimated. They are therefore highly directional and can be focused to a spot whose diameter is close to one wavelength of the emitted light. As a result, enormous power densities are possible.

The hazard from laser beams results when a part of the body is placed in the beam. The high-power densities can quickly produce a burn, with destruction of tissue, before any sensation of burning is felt. The devices must be well shielded to prevent scattered radiation, and there should be no reflecting surfaces on which the beam could impinge and then be redirected. Burns have been produced at distances of up to one half mile from a source.

IV. Infrared

Infrared radiations have longer wavelengths than the visible range and are the radiations we "feel" when one holds his hands up to a fire or a hot stove. Their range is from 8000 to 1,000,000 Å. The range of 8,000 to 14,000 Å is referred to as short infrared, and the others as long infrared radiations. The wavelength emitted depends upon the temperature of the body. All objects radiate infrared radiations to other objects with a lower surface temperature.

The sensation of heat is quickly detected and can therefore give adequate warning that extreme conditions may exist. The radiation does not penetrate deeply into tissues. Heating of the body takes place as a result of heat absorption in the surface layers of the skin. Dilation of the capillary bed of the skin occurs, and the heat in the skin is removed by the blood or evaporation of moisture.

The fundamental action of infrared is heating. Sufficient heating can take place to cause burns of the skin, cataracts in the lens of the eyes or retinal burns. The iris in the eye appears to absorb the radiation and increase the heating effect of the lens. The lens is particularly sensitive because it has a poor heat-dissipating mechanism.

V. Microwaves

Microwaves encompass a wide range of wavelengths, from 0.01 to 3,000 centimeters. These wavelengths are used in radar, television, shortwave radio transmitters and diathermy. They are also used to fire photoflash bulbs remotely and can ignite dry steel wool. The energy levels are well below those needed to cause ionization. The effects of microwaves appear to be more complex than simply a heating effect, although most of the changes can be attributed to this phenomenon.

The effects of microwaves on the human body vary with the wavelength (or the frequency). At the lower frequencies (longer wavelengths), the body is transparent to the radiation. As the frequency increases, the body absorbs more and more power until a maximum is reached at about 300 megacycles per second. This is in the ultrahigh-frequency (UHF) television range. With further increase in frequency, less and less power is absorbed, and finally, at 10^4 megacycles per second, the skin acts as a reflector. Penetration at the point of maximum energy absorption (100 to 1000 megacycles per second) is potentially the most hazardous because there is little or no heating of the skin where thermal receptors would be stimulated.

The eye and the testes appear to be potentially the most vulnerable parts of the body. The eye, with its poor blood supply , particularly around the lens, is susceptible to cataract formation in the microwave range that can penetrate to that depth. Temporary sterility can be induced from the heating effect. It is unlikely, however, that it would be more than temporary. For these effects to occur, a man would have to be directly in the beam and close to the source. Persons most likely to be exposed would be workers on or in the vicinity of the transmitting wave guides. Table 2 contains a summary of the effects of microwave radiation on man.

References:

1. Moore, W., Jr., "Biological Aspects of Microwave Radiation, A Review of Hazards", Report TSB 4, Bureau of Radiological Health, Environmental Control Administration, U. S. Department of Health, Education, and Welfare, 127210 Twinbrook Parkway, Rockville, Maryland, 20852 (July 1968).

2. Setter, L. R., Snavely, D. R., Solem, D. L., and Van Wye, R. F., "Regulations, Standards, and Guides for Microwaves, Ultraviolet Radiation, and Radiation From Lasers and Television Receivers--An Annotated Bibliography", Public Health Service Publication No. 999-RH-35 (April 1969). Available from the Information Office, Bureau of Radiological Health (see reference #1 above).

3. Ferris, B. G., Jr., "Environmental Hazards--Electromagnetic Radiation", New England Journal of Medicine, Vol. 275, pages 1100-1105 (November 17, 1966).

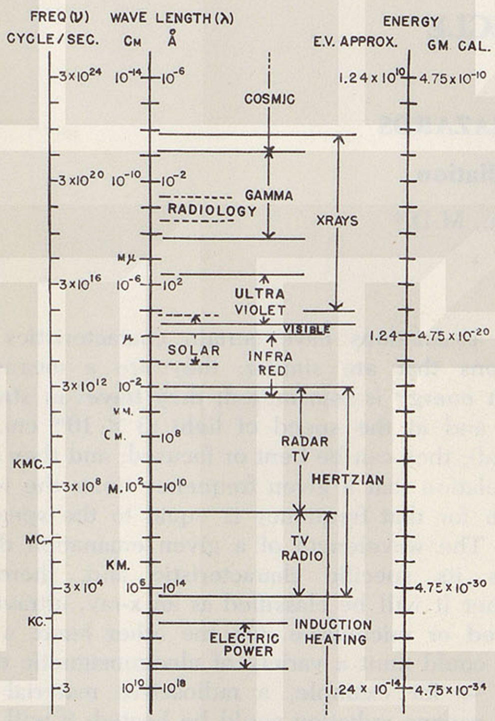

FIGURE 1. *The Electromagnetic Spectrum.*

TABLE 1. *Summary of Some Biologic Effects of Ultraviolet Radiation.*

EFFECT	RADIATION
Ionization	100 Å range — overlays with "soft" x-ray
Germicidal	2600 Å maximum — effect falls rapidly at shorter or longer wavelengths; effective range associated with absorption band of nucleoproteins
Carcinogenic	2000-4000 Å— maximum effect 2900-3200 Å
Ozone production	In germicidal range
Photosensitization	Wavelength at which this occurs varies with absorption characteristic of chemical compounds involved
Pigmentation	2800-3200 stimulates formation of melanin — little tanning; 3000-6500 Å, maximum 3600-5000 Å oxidizes preformed melanin — tanning
Thickening of stratum corneum	In solar range 3000-4000 Å
Degeneration of collagen	Parallels cumulated exposure in solar range 3000-4000 Å
Keratoconjunctivitis	Greater effect at shorter wavelengths — 0.15×10^6 ergs at 2880 Å will produce effect
Antirachitic	Ergosterol to vitamin D; 1 international unit of vitamin D formed from ergosterol when 900 ergs 2490 to 3130 Å absorbed
Erythema	2967 Å 25,000 μ W, sec/cm.^{2} minimal amount of power to produce erythema at this wavelength, which is wavelength of maximum sensitivity; erythema can be produced by shorter or longer wavelengths (within a limited range) but more power is necessary; with extremely short wavelength U.V. there is overlap with soft x-rays, & skin erythema results from effects of ionization.

TABLE 2. *Summary of Effects of Microwaves on Human Beings.*

FREQUENCY megacycles/sec.	WAVELENGTH cm.	BAND* OR SOURCE	SITE OF ACTION	EFFECTS
>10,000	<3	ku k ka	Skin	Skin reflects or absorbs only in superficial layers; no effect or minimal.
10,000-1000	1-30	X C S (radar) L	Skin Lens of eye	 Cataracts
1,200-150	25-200	UHF–VHF (radio & television); shortwave diathermy.	Internal organs	Damage, internally, due to overheating & interface phenomena
<150	>200	Industrial dielectric heating equipment		Body transparent No effects
Threshold limits:				
10 m watts/cm.^{2}		Potentially hazardous		
1-10 m watts/cm.^{2}		Safe for occasional exposure		
<1 m watt/cm.^{2}		Safe for indefinitely prolonged exposure		

*Letters refer to generally accepted symbols for the various wavelengths.