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CURRENT STATUS IN AEROSPACE MEDICINE

Walton L. Jones

Advisory Group for Aerospace Research and Development
Paris, France

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Current Status in Aerospace Medicine

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CURRENT STATUS IN AEROSPACE MEDICINE

Edited by

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Papers presented at the Aerospace Medical Panel Specialist Meeting held in Glasgow, Scotland, 7-8 September 1972.

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AEROSPACE MEDICAL PANEL

Panel Chairman:	Group Captain T.C.D.Whiteside, MBE, RAF
Panel Deputy Chairman:	Colonel J.F.Culver, USAF
Panel Executive:	Wing Commander E.M.B.Smith, RAF

Meeting Organization

Host Coordinator:	Group Captain T.C.D.Whiteside, MBE, RAF
Technical Programme Organizer:	Dr Walton L.Jones (US)
UK National Coordinator:	Mr D.B.Smith

PREFACE

On September 7th and 8th, 1972 during the Annual Meeting of the Aerospace Medical Panel of the NATO Advisory Group for Aerospace Research and Development in Glasgow, Scotland, a two day scientific session of papers was held on the Current Status in Aerospace Medicine. The session was intended to provide a selected review of some recent research in aerospace medicine and included studies of flight stress and physiological adaptation, advances in protection and protective equipment, and the results of recent space flights.

Eleven very excellent papers were selected for the session. They ranged from discussions of aerospace technology spinoffs to in-depth research findings, discussing methods employed, and recent operational items of interest.

The timely submission of papers made it possible to provide attendees of the Specialists' Meeting with preprints (AGARD Conference Pre-print No. 110). As a result, speakers were able to present their topics concisely and entertain questions following the presentations.

CONTENTS

TECHNICAL EVALUATION
OF THE
AEROSPACE MEDICAL PANEL SPECIALISTS' MEETING
ON
CURRENT STATUS IN AEROSPACE MEDICINE

by
Walton L. Jones, M.D.

On September 7th and 8th, 1972, the Department of Physiology of the University of Glasgow hosted the AGARD ASMP scientific session of papers on Current Status in Aerospace Medicine. The two-day session provided an informative and, in many cases, provocative overview of current aerospace research and technology problems and developments. Because the subject matter was as diverse as are areas of interest in aerospace medicine, a technical evaluation of the overall meeting would be difficult. Consequently, the following text attempts to summarize and very briefly evaluate each of the papers individually.

At the request of the Host Coordinator, Group Captain T.C.D. Whiteside, MBE, RAF, the Technical Programme Organizer and Session Chairman led off the discussions with a paper describing recent NASA aerospace medicine technology developments. Briefly summarized, the paper described some of NASA's continuing preparations for the day when a laboratory in space will be available to scientists for the study of basic life processes in the far space environment. The presentation described the role of the space shuttle in making this goal possible. Also described were selected ground based experiments to be accomplished to render tasks in space simpler and more reliable and insure that they are honed to a finer scientific edge.

Captain Ewing (USN) (paper C2) discussed vertebral fracture mechanisms and the implications of this costly and vexing problem for all our air forces. The statistics reviewed by Dr. Ewing indicate that 25 percent of combat major injuries on ejection are non-fatal vertebral fracture. This is a high penalty to pay but it must for the time being be tolerated if the alternative is losing aviators. Work must, however, be aimed at reducing, and finally eliminating, this concomitant of ejection seat escape. To neglect this problem would be to both ignore our humane instincts and to disregard sound economics. Aviators are highly trained individuals and, once experienced, virtually irreplacable. Captain Ewing's data indicate that the mechanism involved is primarily an anterior fracture mechanism. He postulates that there is some mechanism limiting posterior compression but not anterior compression of the vertebral bodies. To prevent fracture, he suggests, a means must be devised for placing the vertebrae in relative hyperextension and maintaining this hyperextension so that the anterior lips of the vertebrae do not come into contact. Although this reasoning is undoubtedly sound, other possible causes for the vertebral fractures experienced in ejection escapes must not be overlooked. The frequency response of the seat and propulsion system, for example, has never been determined, and only preliminary data are available concerning the frequency response of the body. It is in this line of investigation I feel that another causative element in ejection vertebral fracture mechanisms may be found, and I would encourage investigators to seek it here. Captain Ewing's study, nevertheless, is important in this chain of investigative efforts and represents a very important element leading toward the solution of a very complex problem.

The next presentation (paper C3) emphasized our lack of understanding of carriers of various diseases. In a large scale Hellenic Airforce study, a 5.2 percent incidence of asymptomatic carriers of hepatitis-associated-antigen was found in the Greek aviator population. This causes a high morbidity in operational air force personnel and represents a potentially high non-effective rate for all military operations. The problem outlined by Major Vissoulis and Lieutenant Colonel Giannopoulos is worthy of considerable additional investigation.

Dr. Apel described a case of syringomyelia found on autopsy in a German Air Force aviator, clearly underscoring the need for improved aerospace medical examination procedures and techniques. The pilot in question had shown no clear signs of performance degradation before the accident, and it might well have been that his medical condition played no important role in the accident that caused his death. Nevertheless, it is important that this degenerative disease of the spinal cord be identified in aviation personnel so that it can be reckoned with in the operational usage of the aviators concerned. Depending on localization and extension, the disease may exert a negative effect on flying fitness. Syringomyelia is just one of many diseases of which the clinical practitioner of aerospace medicine needs to be aware and for which he must be alert in the course of all routine physical examinations. In this area, aviation medicine might benefit by the application of some of the techniques being used in space flight physical examinations. Many of the procedures employed in space flight medical examinations cover the gamut of many more conditions than can be evaluated in the rather routine aviation physical examinations provided today. Additionally, a great many space medicine procedures are automated or otherwise streamlined so they can be performed quickly and in a cost effective manner.

A space biology experiment known as BIOSTACK--for the layers of biological materials sandwiched between radiation detective layers--was flown on Apollo 16 (paper C5). The aim was to discover more concerning the effects of galactic radiation. This radiation study was conducted during a translunar flight because, at the current time, it is not possible to simulate heavy, high-energy particles on Earth.

It is hoped that such simulation will be possible in the near future at facilities planned by the U.S. Atomic Energy Commission. The variety of biological effects produced by the heavy ion flux during the Apollo 16 mission is being analyzed and should yield interesting data on the influence of a single penetrating radiation particle on cellular and tissue development, nuclear damage, and mutation induction.

Dr. Bourne described the efforts being made at the Yerkes Primate Research Center to build a base of disease-free, physiologically normal animals. These animals can be used to provide reliable preflight baselines for space flight experiments in which subtle changes are being sought. It has been customary practice to use feral animals in research, provided these were disease free. While such animals have been described in the literature as "normal," they do exhibit considerable pathology. Dr. Bourne's paper described methods for breeding Rhesus monkeys, which show many characteristics similar to man's. These captive-bred monkeys show much less pathology than wild born animals. It should be remembered that the more subtle the physiological change being sought, either in space research or ground-based research, the more normal the tissues must be. This has meaningful application, of course, to all animal research.

Dr. Byford described an interesting method for precluding the collection of reams of experimental data for which there will be little if no use and with which most aviation medical laboratories are now glutted. The essence of his solution includes a means for rejecting parts of the data considered to be of little importance. He described the real-time analysis of a multichannel electrophysiological recording using uncomplicated mathematics and the parallel-serial hybrid computing installation at the RAF Institute of Aviation Medicine. The next step anticipated should be very useful in the collection of electrophysiological data since it will permit off-line as well as on-line analysis at speeds that should allow reasonably economical use of computers.

Major Krutz described an evaluation of the phased-dilution concept for oxygen breathing systems. This concept is part of an overall program to provide oxygen in aircraft from ambient air or by some other means without providing oxygen logistically while the aircraft is on the ground. In the phased-dilution system, a bolus of oxygen is provided followed by ambient air. The concept is based on the hypothesis that with a fixed rate of oxygen flow, a breathing system which delivers at the mouth and nose a volume of oxygen at the beginning of each inspiration and in which the remainder of the inspirate is air, should produce a higher oxygen tension in the lungs than a system which delivers the same volumes of oxygen and air thoroughly mixed to the respiratory tract. This open technique, as well as other closed-loop systems which reuse all oxygen, is a most cost-effective approach to oxygen supply. Because closed-loop systems require rebreather equipment which is more complicated than what is required with straight demand systems, considerable effort has been expended to provide an open demand method that is more cost effective than the demand-dilution methods used in World War II. The system described by Major Krutz is conceptually a new one and, while it is theoretically highly effective, it may be extremely difficult to implement because its efficacy depends on extremely precise timing and so forth.

Dr. Thomas described an effective way to provide mandatory improvements in injury protection through quantitative anthropometric measurements. His presentation discussed the precise anthropometric information concerning size, shape, and mass distribution characteristics of human beings needed to simulate human response so that equipment designed to protect the human from mechanical forces is appropriate. Only with this information can one be sure that protective equipment will fit the individual and the situation in which he finds himself.

Representatives of the United States Air Force (paper C10) discussed the need for understanding the hazards associated with the use of lasers. The application of lasers is relatively new in aerospace medical operations and therefore poses new hazards. The Air Force has developed permissible exposure levels (PELS) designed to permit individuals to operate safely in the presence of high-energy monochromatic light beams. Even after the promulgation of safety precautions, however, accidents can and do occur. Major Mabson described one such accidental exposure, which was fortunately not injurious, to illustrate the need for reinforcing promulgated safeguards.

An Italian Air Force study revealed that in some aircraft (and motor vehicle) cabins, the climate can reach severely stressing levels in the summer daylight period in theaters of operations with climates approximating those on the Italian peninsula. This is particularly true when long delays are encountered during which aviators must remain in the cockpit in a ready status. These situations indicate the need for ground support equipment. Such equipment, in the form of liquid cooling garments, is currently being used in the U.S. Space Shuttle Program and may be applicable to situations similar to that described by Lieutenant Colonel Rota.

The authors and presenters at this scientific session deserve a special note of commendation for both the quality of their papers and their cooperation with the Session Chairman in adhering to the presentation schedule. Compliments must also go to the interpreters, who did a superb job. All these factors along with the enthusiasm and interest shown by the audience made the sessions really worthwhile.

RECENT NASA AEROSPACE MEDICINE TECHNOLOGY DEVELOPMENTS

by

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SUMMARY

NASA is continuing to prepare for the day when a true laboratory in space will be available to scientists to study basic life processes in the far space environment. The primary parameter is the absence of gravity. One of the first steps necessary to the fulfillment of this goal is the shuttle. It will be able to service at low cost and at convenient times such a research facility in earth orbit.

The second step necessary to obtain this goal is the ground preparation of the science to be studied in space. Here on earth much can be accomplished to make the space tasks simple, more reliable, and honed to a finer scientific edge. To this end a team of university, government, and industry is being forged. This team is studying many areas of life sciences to obtain the necessary baseline data, strategies, and technology to permit the successful accomplishment of this new way of life-research in the space environment.

One of the fundamental body systems affected by space flight is the cardiovascular system. Next year in our twenty-eight day and two fifty-six day flights we should know much more of this adaptive process, for there are many Skylab experiments devoted to this end. These results will put a finer focus on our ground based research for the next and longer studies in a space station or lunar research activity.

Accordingly a second order of medical investigative technology is emerging from our researchers. From these efforts is coming new technology applicable to military medicine and clinical medicine as well. Examples are cited.

NASA is continuing to prepare for the day when a true laboratory in space will be available to scientists to study basic life processes in the far space environment. The primary parameter is the absence of gravity. One of the first steps necessary to the fulfillment of this goal is the shuttle. It will be able to service at low cost and at convenient times such a research facility in earth orbit.

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Accordingly a second order of medical investigative technology is emerging from our researchers. For instance one team led by Dr. Harold Sandler (1) of the NASA Ames Research Center and assisted by Stanford University is developing a means to view the beating heart from any angle to determine the effect on this important pump caused by the space environment. This will allow the cardiac output to be determined virtually in real time by computer calculation of the changing volume of the heart.

These computer techniques are an outgrowth of the basic aerodynamic research conducted by NASA on wind flow over air foils. Two and three dimensional displays were used to study the images of the left ventricle of the heart. Using angiocardiography the heart chamber is shown on a rideosystem CRT display in two orthogonal planes, either simultaneously or sequentially. The margins of the opacified left ventricular image are traced manually with a Calma 303 digitizer (Fig. 1) producing a digital magnetic tape which is analyzed by an IBM 360/67 computer.

Chamber dimensions and/or shape are derived and the heart image is divided into 100 slices by diameters perpendicular to its long axis. Such a fashion, a series of images over a given heartbeat can be constructed into a three dimensional representation of the chamber. The size of each slice or diameter determines the shape of the three dimensional model shown on the right of Figure 1. Viewing the beating heart contours can be displayed in real time or in slow or fast speed as desired. Further the beating ventricle can be viewed from various angles because the image may be rotated. These procedures have already been used clinically in evaluating patients with valvular heart disease and for calibrating non-invasive procedures. These latter procedures utilized non-invasive ultrasonics in place of the X-ray. They have achieved some 90 per cent validation with this new method. The potential application to our studies in weightlessness are most encouraging. At the same time they offer great promise to clinical medicine, as indeed they have been already used with heart catheterization procedures.

A second example of what I have termed second order medical investigative technology to be considered in future space station studies is the effect of atmospheric particulates on the lung. Because of weightlessness, particles will not settle as here on earth with gravity, we have a particulate measurement experiment on Skylab to better define this potential problem. Of course filters will be used in our atmospheric conditioning systems, but the extent of the problem should be known next year. In the meantime we have been studying an earth bound analogue of this problem.

In a study at the Ames Research Center, evaluations of changes in the ultrastructure of lung tissue of coal miners, in collaboration with the Department of Health, Education and Welfare, is providing a point of reference with respect to the state of damage which may occur in astronauts exposed to particulate contaminants. Examination of autopsy material suggests that cell destruction can be induced by release of intracellular digestive enzymes into the cell cytoplasm following penetration of the cells by particles, in the case of coal miners, silicates. Figure 2 is an electron photomicrograph of an area of a coal miner's lung magnified 66,000 times, illustrating the cell structure and the fine, needlelike foreign particles of silicate.

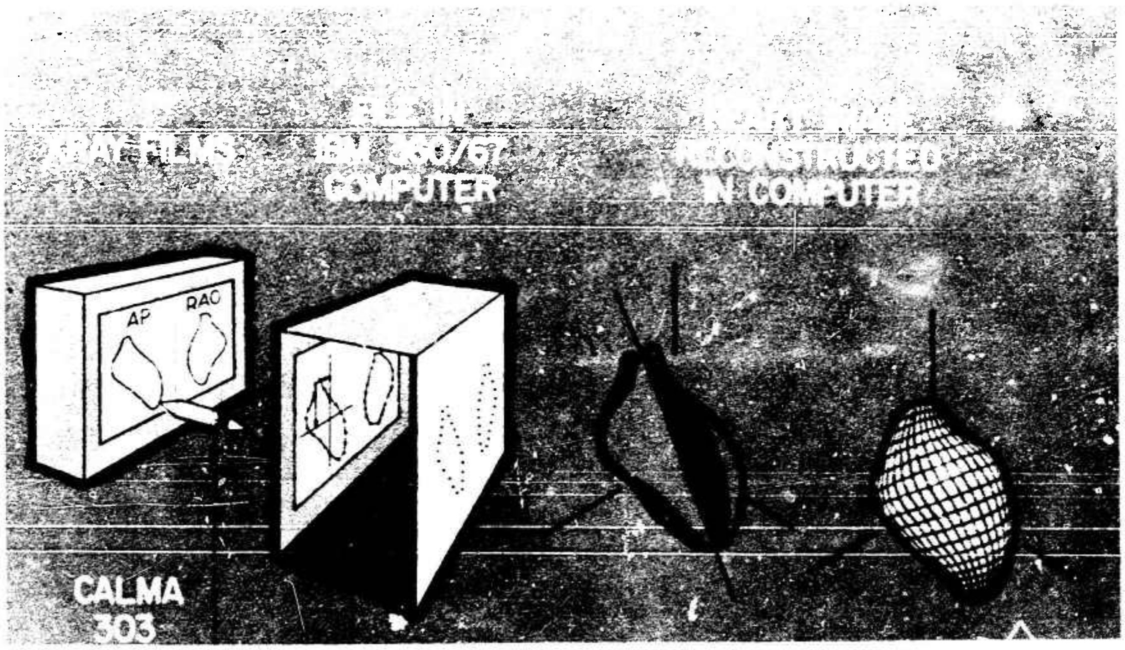


Figure 1 CARDIOVASCULAR DYNAMICS
Cardiac Output Through
Angiographic Geometrical Analysis

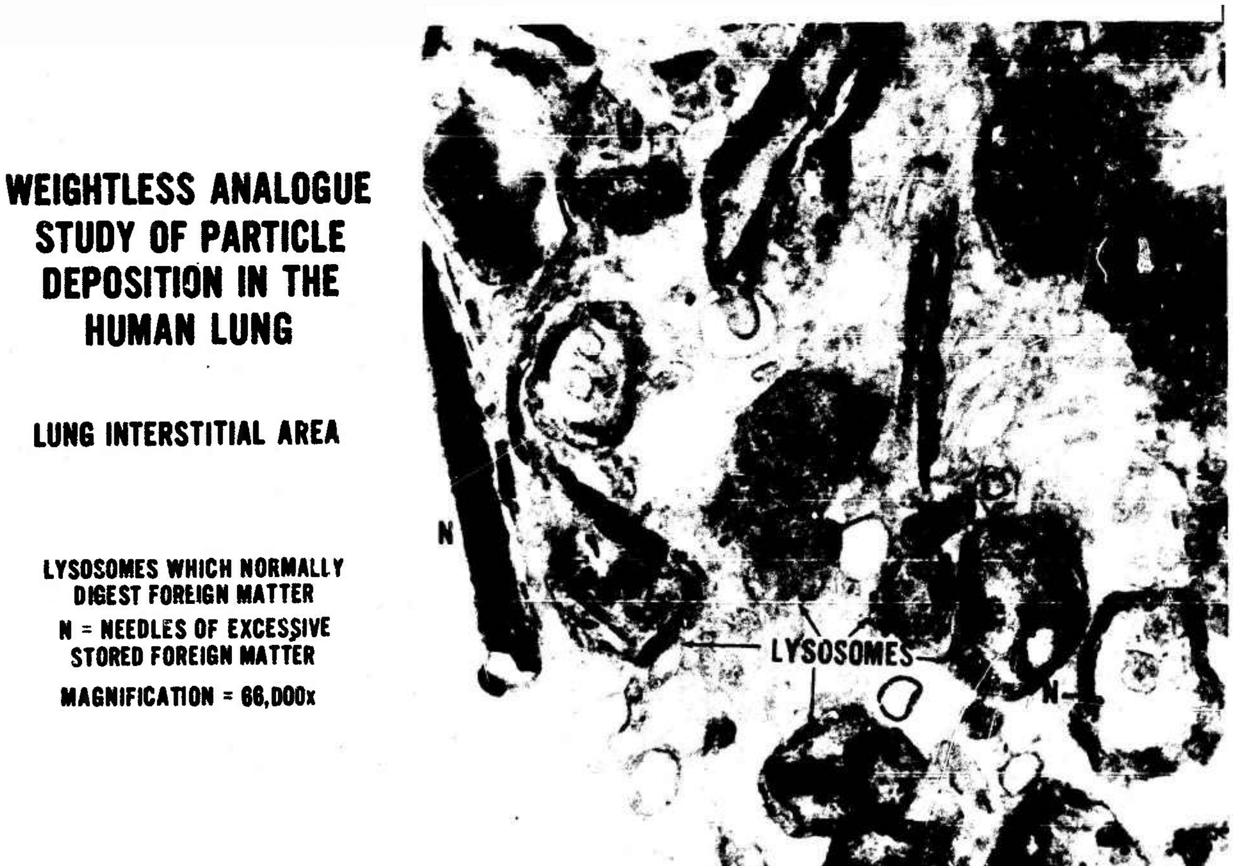


Figure 2

In the technology area of life support, we have developed through the Hamilton Standard Division of United Aircraft an Independent Respiratory Support System (IRSS). This emergency breathing device (Fig. 3) would be used for oxygen therapy using either a nasal catheter or a mask. It would supplement the oxygen in the cabin atmosphere and as can be seen in the figure it is a small package which can fit under the arm or carried by an assistant. The unit weighs 7.7 pounds, and is 210 cubic inches in volume. It is rechargeable from a commerical 2000 psig source, and provides a constant flow of 0.5 to 2.5 liters per minutes of 100% oxygen for durations of 2.5 to 0.5 hours respectively as shown in Figure 4. This respiratory system can be utilized for ambulatory emphysema patients or those with asthma and other respiratory ailments.

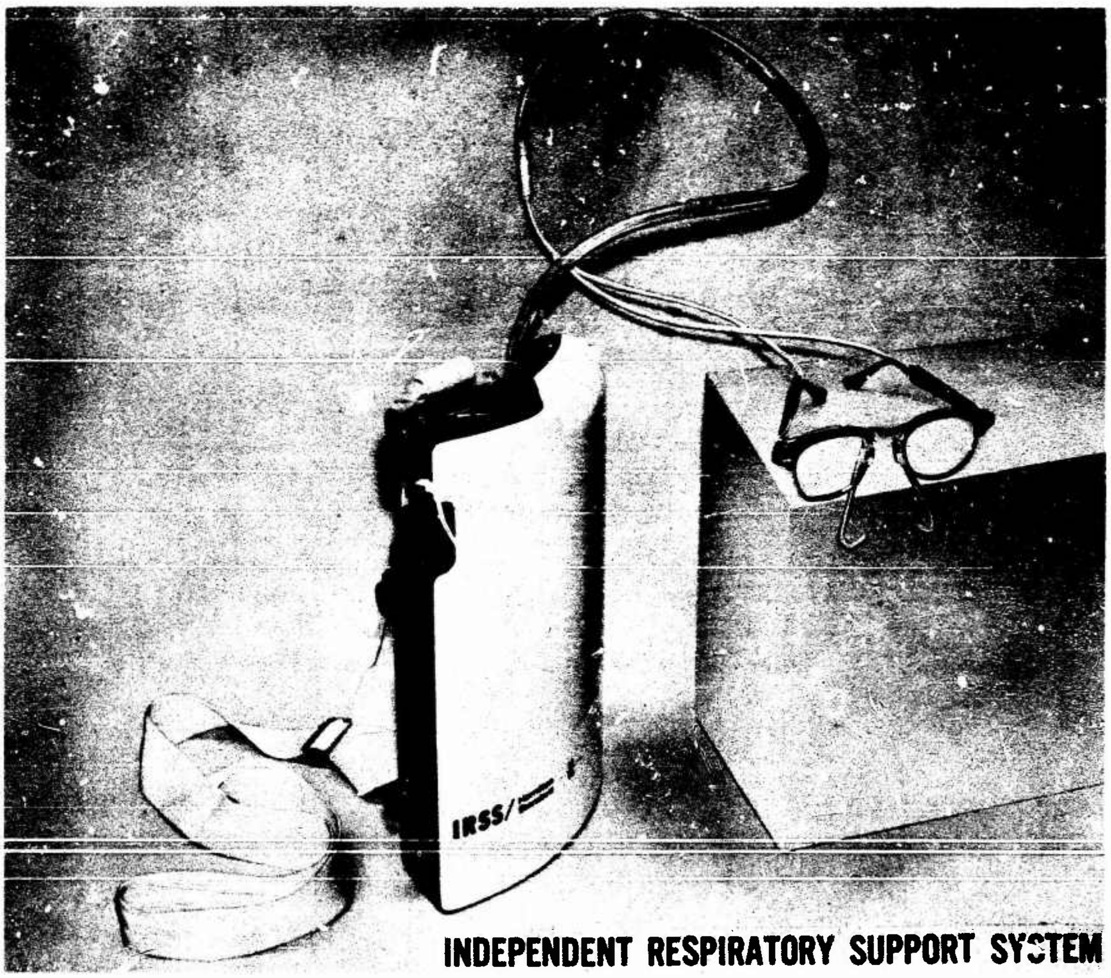


Figure 3

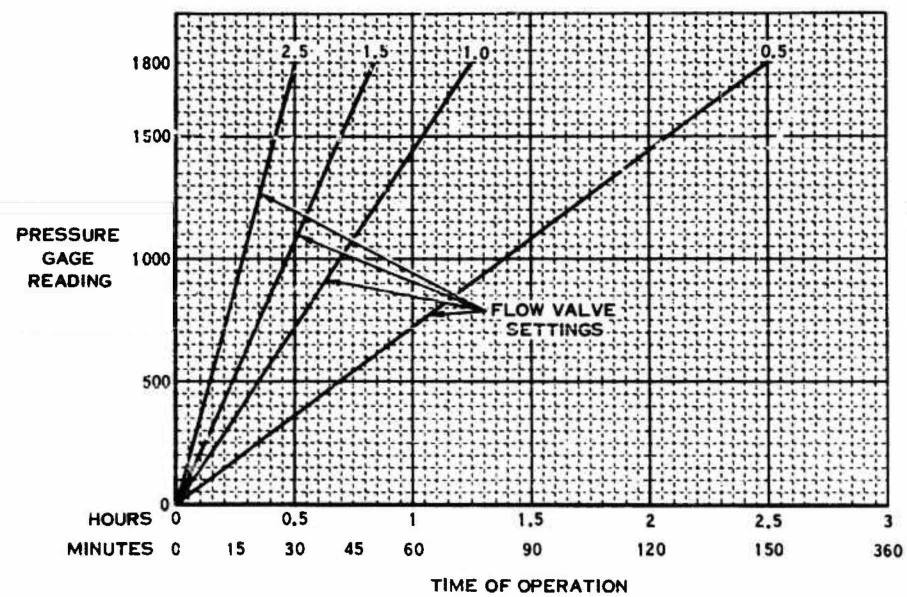


Figure 4 Pressure Vs Operating Time Remaining

The provision of food for space crews poses certain challenges in terms of food service technology. Since space missions are constrained by weight and volume limitations, conventional methods for storing, preserving, and preparing foods cannot be used. A feeding system has therefore been utilized which relies primarily upon freeze dehydrated foods. Such techniques, however, preclude the use of fresh vegetables or salad type food which have a very high morale factor. The logical way to solve this problem is to produce this type of food in space, as it is needed, using a hydroponic-type system. Such systems provide for accelerated growth of plants such as vegetables suitable for the preparation of salads under spaceflight conditions.

A laboratory version of a device suitable for hydroponic food cultivation in zero gravity is illustrated in Figure 5. This device is the result of a collaborative effort of NASA with the U. S. Department of Agriculture. It is a rotating drum two feet in diameter by two feet in length containing a light source. Seeds are planted in an ion-exchange matrix which contains all the nutrients required for several generations of plants. Water is fed to the soil in a water reservoir. Seeds have been successfully germinated during rotation despite the abrogation of the directive force of gravity. As the figure shows Bib lettuce growth with this device far outstrips the rate of that grown on sand. At the top left of the figure dwarf tomato plants are shown, 55 days after seeding with continuous rotation at 5 rpm. The fruit-to-vine ratio, as can be seen, is high. Moreover, yields from such plants appear two to three weeks earlier than from controls. It should be possible to produce lettuce crops in about 21 days, and, with daily planting and harvesting, two to three heads of lettuce per day could be continuously provided. The principle investigators have stated that in addressing attention to this space problem they are developing a new system of agriculture wholly applicable to highly intensified production on earth.

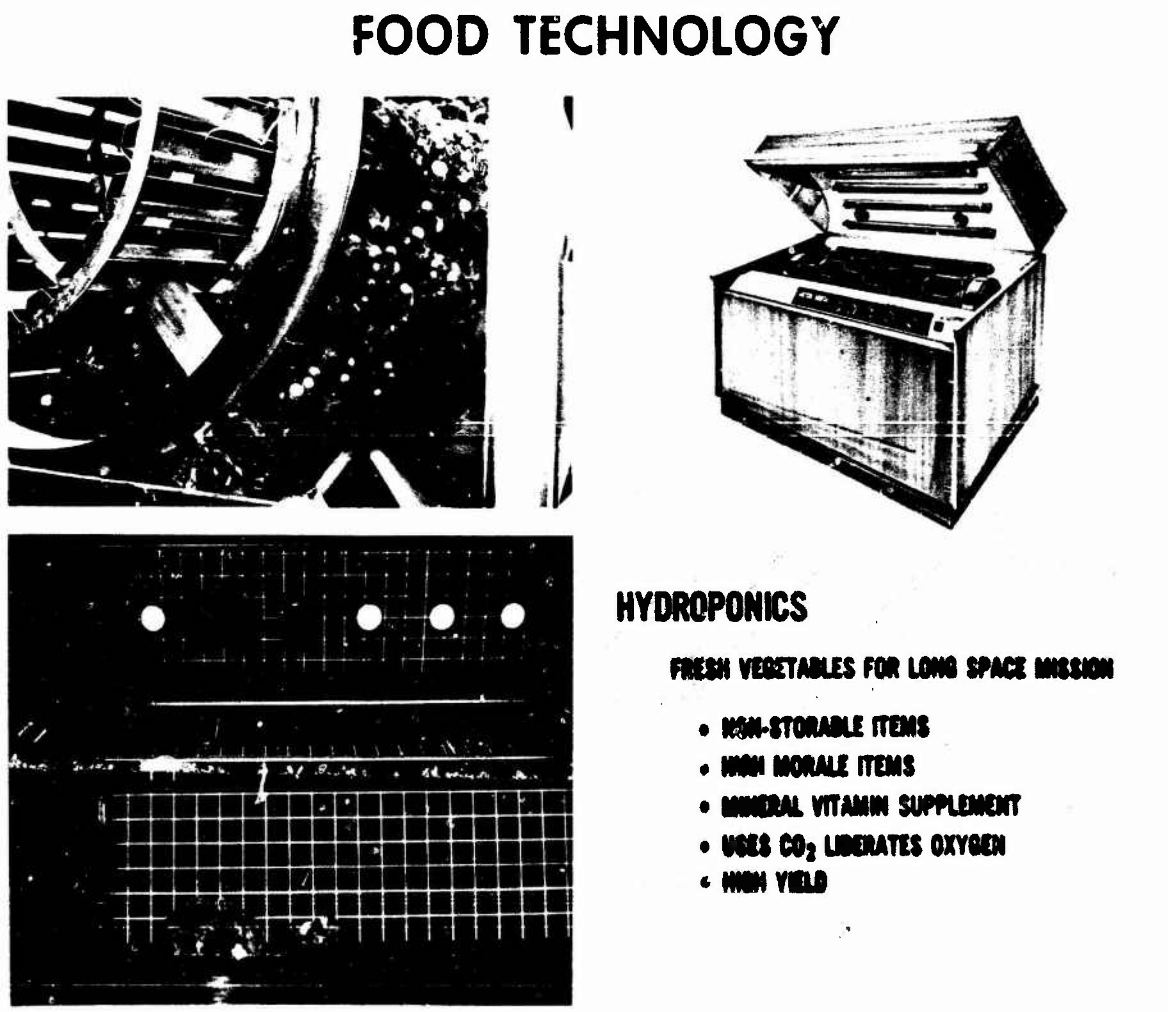
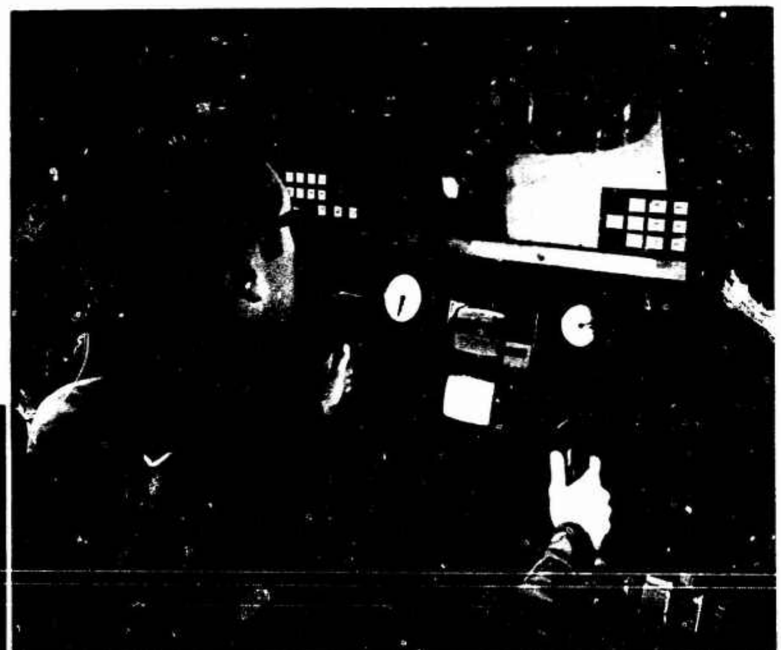


Figure 5

Other research teams are studying man's performance, maintenance of proficiency as well as enhancement through telefactors. It is well recognized that time exerts a degrading influence on task performance. While these degrading effects of time are often overlooked for some simple tasks, the effects on complex tasks can be severe. Time based skill degradation is particularly critical in piloting of high performance aircraft, or space craft such as the shuttle, where a great number of tasks requiring fine eye-hand coordination, rapid decision making and data integration, and split second timing must be successfully construed. Using ground based simulators at Boeing, Seattle, (Fig. 6), Dr. Bitterly, the investigator, evaluated instrument flight control and emergency procedure performance. Five skill retention intervals ranging from one month to six months were investigated. The results clearly show both procedural and continuous control skills unacceptably deteriorate in one to four months. Further, the results reflect the fundamental difference in skill deterioration for procedural as comapred to flight control tasks. Instrument flight control tasks remained relatively unaffected for up to two months after which performance deteriorated rapidly. On the other hand, procedural tasks showed unacceptable deterioration after only one month with degradations reaching an order of magnitude after four months. This difference is further highlighted by the finding that while rebriefings and static training techniques counter skill degradation effectively for procedural tasks, training methods which include dynamic display and control techniques appear necessary for continuous flight control skill retention.

SKILL RETENTION OVER PROLONGED PERIODS

- **CONTROL TASKS RETAINED LONGEST**
- **PROCEDURAL TASKS DEGRADE FASTER**



PILOT PERFORMING SIMULATED APPROACH AND LANDING

SIMULATION TERRAIN MODEL

Figure 6

Pilot perceptual and visual flight control skills are to be evaluated, in addition to instrument flight control, flight procedure, and emergency procedure performance, in the second study currently being implemented. In this study, pilots will be trained to fly a simulated, high performance, landing spacecraft. The flight regime will require the pilots to fly a descending turn, on instruments, from 31,000 feet to 12,000 feet, after which a visual approach and landing will be made. During the flight a number of flight control and avionics failures will occur, requiring the pilot to perform appropriate emergency procedures. The retention of flight procedures including heading changes, altitudes at control points, descent rates and flap and landing gear actuations will also be evaluated. Four months after the pilots complete the training program, the magnitude of their skill deterioration will be measured and the skill retention effectiveness of selected static and dynamic training techniques will be evaluated.

From the results obtained to date, the anticipated successful completion of the program will provide significant new insights in the understanding of skill retention and the methods required to successfully counter skill degradation. The rate at which flight skills deteriorate and the ultimate magnitude of the degradation will provide an empirical basis by which training cycles for each category of flight skill may be specified. Through the identification of the most effective training technique for each task and task element, the optimum techniques may be combined to provide time and cost effective maintenance of acceptable pilot flight skills. It is this type of empirically based knowledge that will meet the skill retention challenge faced not only by the astronauts on extended manned space flights but also by commercial and military aviation pilots in the future.

In the area of human augmentation and teleoperators, we are attempting to provide a useful combination of man and telefactors for work in the space environment. In this program, devices such as remote manipulators, tools, and cargo transfer equipment concepts are investigated and developed. This is an attempt to transfer man's capabilities to a remote and hostile environment while he controls them from a more benign or convenient location.

Remotely controlled manipulators operating from the space shuttle are being studied. The Marshall Space Flight Center has investigated the human factors problems concerned with the control of a free flying teleoperator during rendezvous and docking with a satellite as shown in Figure 7. Here the man moves his arms, hands, and fingers and the teleoperator moves in a corresponding fashion. This is achieved by position sensors on his arms, etc. servoed to the robot outside of the spacecraft. Television provides the visual cues. In this manner the dynamics of grasping cooperative and noncooperative satellite targets have been determined. This is the most difficult phase of satellite retrieval and servicing. Effort is currently under way to define the most efficient capture devices for various sizes and masses of satellites. Monocular versus sterovisual sensors (TV cameras) and displays for performing docking and servicing tasks are also under study.

REMOTELY CONTROLLED MANIPULATORS

PERFORMING REMOVAL & REPLACEMENT OF SIMULATED SATELLITE COMPONENTS

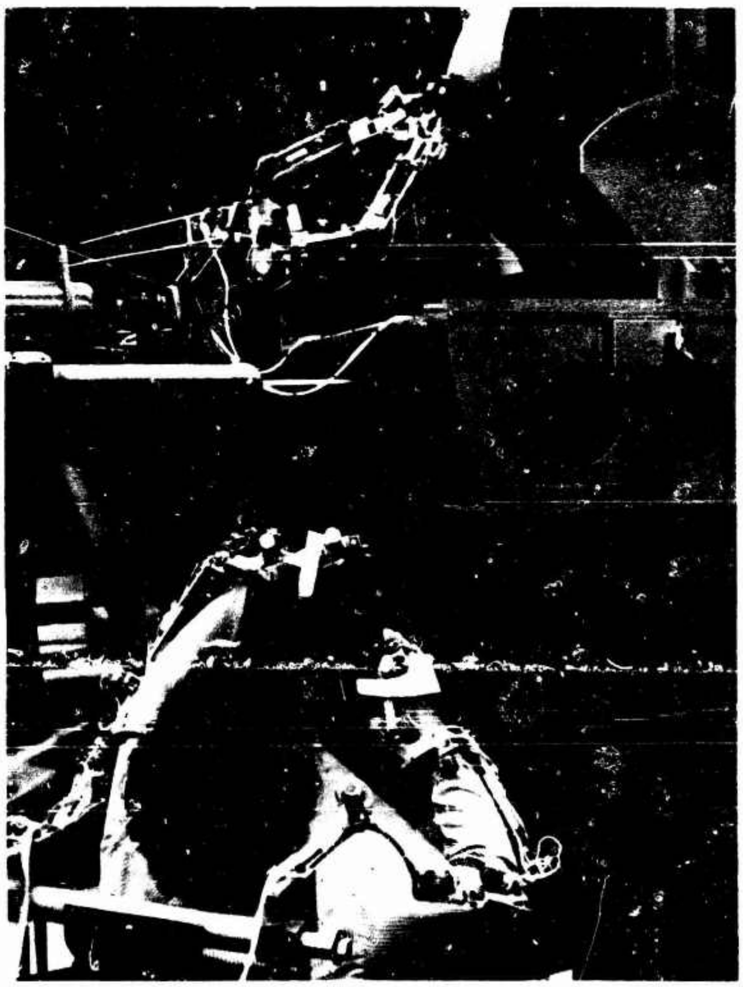


Figure 7

The Manned Spacecraft Center is developing design requirements for two manipulator booms attached to the front end of the space shuttle cargo bay. These booms would be used to emplace and retrieve satellites such as astronomical and other experimental payloads in low earth orbit. Currently, 50-foot long booms are being constructed to provide adequate coverage of areas inside and around the shuttle vehicle. They can be used to facilitate docking of two shuttles together, servicing satellites by exchanging experiment modules, resupply films and other expendables, and even effect repairs on the shuttle itself. Prototype booms with seven degrees of freedom are being developed to permit in-house studies at MSC. These experimental booms will be used to develop engineering design information for flight crew control of the boom attached manipulator system.

The technology developed is being applied to military programs. Remote manipulators are finding undersea operations application. This technology is also applicable to the development of prosthetic and other devices to aid the handicapped and may be used to increase safety in mining and firefighting.

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Proceedings of the Vth Hawaiian International Conference on Systems Sciences, Honolulu, Hawaii, Jan. 11-13, 1972. Page 63

DISCUSSION

THOMAS

How are the X-rays scaled to yield three-dimensional coordinates of the selected points on the heart?

JONES (with supplementary data from H. Sandler, NASA Ames Research Center, USA)

Under ordinary circumstances, relatively short spray tube-to-film distances are used in obtaining clinical angiocardiographic X-ray studies (less than 6 ft). Under such conditions, one must correct for magnification (geometric distortion) due to the short X-ray tube-to-film distances. In addition, when using an image intensifier with its slightly curved input surface and lenses to obtain X-ray motion pictures, there is spherical distortion that must also be corrected. By using fine line lead on centimeter cross-hatched grids, photographed at varying levels from the face of the intensifier, one can obtain correction factors for such changes. The level of placement for such a grid is obtained by photographing the object (subject's chest) in an orthogonal (right angled) view from which the level of grid placement can be placed accurately. Data from such grids will provide average correction factors for the material. Point scaling can also be realized by placing all recorded grids into the memory of a computer or during mathematical equations for distortion from the resultant grid pictures which are subsequently used to correct the actual data. It must be realized that X-ray recordings represent shadows and even though they may be recorded in two simultaneous planes, they may not uniquely define a three-dimensional structure. Only points which can be uniquely defined in both planes simultaneously can be so defined. In practice, this is true for valve planes (e.g., aortic or mitral) or markers placed in or upon the heart

NON-FATAL EJECTION VERTEBRAL FRACTURE AND ITS PREVENTION *

by

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Non-fatal ejection vertebral fracture has been a common injury in aviators since ejection seats came into use. (1) The injury is defined as any fracture of a vertebra due to the force of ejection itself, in an individual who survives the ejection and all subsequent hazards of his emergency escape.

While many individuals who were killed, drowned or died during ejection and its sequelae may have suffered vertebral fracture, it is improbable that many of them died as a result of the vertebral fracture alone.

EXTENT OF THE PROBLEM

Several studies of the nature and extent of the problem have been made. Jones et al showed that 21% of 165 U. S. Navy aviators suffered vertebral fracture using a gun-type ejection seat over a 4 1/4 year period 1958-1963. (2) Of these, six were retired on disability and one additional died. Fryer found a 19% incidence in 220 R.A.F. ejection using a similar seat. (3) Hirsch found a 25% incidence in 55 Swedish Air Force ejections using a different seat. (4). More recently, Shannon found that in the U.S.A.F. during CY 1967 and 1968, there were 390 noncombat ejections with 116 persons suffering major nonfatal injury. (5) Forty-one of the major injuries were fractures due to ejection force, and 97% of these were vertebral fractures. In the combat ejections, 89% of major injuries due to ejection force were vertebral fractures, and 80% of all vertebral fractures suffered were due to ejection force.

In all, 31% of noncombat and 25% of combat major injuries on ejection were non-fatal ejection vertebral fractures. In both cases the ejection vertebral fractures were the largest single category of major injury.

As Shannon points out, vertebral fractures and other injury on ejection has been the primary factor in the capture of a substantial number of United States aviators.

DISTRIBUTION OF FRACTURED VERTEBRAE

Table I presents the distribution of the vertebrae fractured in 78 aviators, representing 100% of those suffering ejection vertebral fracture in the U. S. Navy during the period 1 July 1959 through 30 June 1965. These data while previously unpublished have a considerable overlap with those of Jones. (2) The method of collection of these data is outlined. (6) Vertebral fracture was diagnosed only on the basis of x-ray, thus avoiding some of the diagnostic uncertainties mentioned by Crooks. (7)

The principle feature of interest is that the distribution is bimodal with equal distributions around T8 and around T12. This is most interesting in view of the studies reported by Charles, Shannon and Smiley. (8, 5, 9).

Charles examined the fractures due to crashes (not ejections) and made the statement that "...the majority of fractures were concentrated in the lower thoracic and upper lumbar region. This is of course the area where the spinal column has the least support and where compression fractures would logically be expected to occur". (8) Shannon's study of emergency ejection injuries in 1970 states, "As expected, the vertebrae most frequently involved were T12 and L1 which accounted for 23% and 22% respectively". (5) (Emphasis supplied) Smiley states "... the distribution are clustered in the area of spinal flexion". (9)

DISTRIBUTION OF VERTEBRAE FRACTURED

	#	%
C1	1	0.7
C2	2	1.4
C6	1	0.7
T2	1	0.7
T3	1	0.7
T4	5	3.6
T5	7	5.5
T6	7	5.5
T7	4	2.9
T8	20	14.4
T9	18	12.9
T10	11	7.9
T11	9	6.5
T12	21	15.1
L1	19	13.7
L2	6	4.3
L3	3	2.2
S1	1	0.7
Coccyx	2	1.4
TOTALS	139	100.8

TABLE I

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* Opinions or conclusions contained in this report are those of the author and do not necessarily represent the views or endorsement of the U. S. Navy.

Table II presents the U. S. Navy distribution 1959-1965 broken down into single fractures and multiple fractures. It is interesting that 40 persons suffered single fractures, and an almost equal number suffered multiple fractures. Similar data are available for Swedish, Canadian and Greek Air Forces. (4,9,10)

TABLE II

	DISTRIBUTION OF SINGLE FRACTURED VERTEBRAE		DISTRIBUTION OF MULTIPLE FRACTURED VERTEBRAE	
	#	%	#	%
C1			1	1
C2	1	2.5	1	1
C6			1	1
T2			1	1
T3			1	1
T4	1	2.5	4	4
T5	2	5.0	5	5
T6	1	2.5	6	6
T7			4	4
T8	5	12.5	15	15
T9	6	15.0	12	12
T10	2	5.0	9	9
T11	1	2.5	8	8
T12	7	17.5	14	14
L1	8	20.0	11	11
L2	3	7.5	3	3
L3			3	3
S1	1	2.5		
Coccyx	2	5.0		
TOTAL	40	100.0	99	99
PERSONS	40		38	

Comparison of fractured vertebrae distribution must be made on the basis of the percentage distribution rather than the absolute number, for obvious reasons. Such a comparison is presented in Table III for U. S. Navy, and published data for Swedish, Canadian, R.A.F. and Greek Air Forces.

DISTRIBUTION OF TOTAL VERTEBRAE FRACTURED

	U.S. Navy		Swedish AF(1)		RCAF (2)		RAF (3)		Greek AF (4)	
	#	%	#	%	#	%	#	%	#	%
C1	1	0.7								
C2	2	1.4								
C6	1	0.7								
T2	1	0.7	1	3.1						
T3	1	0.7	2	6.2						
T4	5	3.6	2	6.2			1	1.2		
T5	7	5.5	5	15.6	1	1.8	2	2.5		
T6	7	5.5	5	15.6	1	1.8	5	6.2		
T7	4	2.9	2	6.2	3	5.4	4	5.0		
T8	20	14.4	2	6.2			6	7.5		
T9	18	12.9	1	3.1	2	3.6	7	8.8		
T10	11	7.9	1	3.1	3	5.4	10	12.5	1	8.3
T11	9	6.5	1	3.1	8	14.2	9	11.2	2	16.7
T12	21	15.1	3	9.4	14	25.0	18	22.5	3	25.0
L1	19	13.7	2	6.2	12	21.4	10	12.5	5	41.7
L2	6	4.3	3	9.4	5	8.9	2	2.5	1	8.3
L3	3	2.2	2	6.2	1	1.8	1	1.2		
S1	1	0.7			1	1.8				
Coccyx	2	1.4					4	5.0		
Other					(5)	8.9	(1)	1.2		
TOTAL	139	100.8	32	99.6	56	100.0	80	99.8	12	100.0
PERSONS	78		13		30		40		5	

1. Hirsch, C. and Nachemson, A., Aerospace Medicine 1963 (Ref. #4)
2. Smiley, J. R. Aerospace Medicine 1964 (Ref. #9)
3. Fryer, D. I., F.P.R.C. 1166, 1961 (Ref. #3)
4. Symeonides, Pon P., AGARD 1971 (Ref. #11)

TABLE III

The U. S. Navy ejection vertebral fracture distribution by aircraft type for FY 1959 - 1965 is presented in Table IV. From these data, it is now possible to discern that the distribution of fractured vertebrae is different for each aircraft/seat type. While this fact is well known, presentation of vertebral fracture data for an entire Air Force as given in Table III would appear less useful in determination of the causes of fracture than presentation by aircraft/seat type. Several investigators have come to this realization.

VERTEBRAE FRACTURED DURING EJECTION BY A/C TYPE

	F3		F4		F8		F9		F11		T2		A4		Misc. A/C		TOTAL	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
C1															1	5.9	1	.7
C2											1	20			1	5.9	2	1.4
C6							1	1.8									1	.7
T2							1	1.8									1	.7
T3							1	1.8									1	.7
T4	1	4.8					3	5.4	1	11							5	3.6
T5	2	9.6					4	7.3					1	14.7			7	5.0
T6							4	7.3	1	11			1	14.7	1	5.9	7	5.0
T7	1	4.8					2	3.6							1	5.9	4	2.9
T8	5	24.0			3	25.0	5	9.1	2	22			2	29.4	3	17.6	20	14.4
T9	6	28.8	1	7.6	3	25.0	5	9.1	1	11			2	29.4			18	13.0
T10	3	14.4	2	15.2	1	8.3	3	5.4	1	11					1	5.9	11	7.9
T11			1	7.6	2	16.7	3	5.4	1	11	1	20			1	5.9	9	6.5
T12	2	9.6	4	30.4	3	25.0	7	12.7	1	11	1	20			3	17.6	21	15.1
L1	1	4.8	3	22.8			9	16.4	1	11	1	20			4	23.5	19	13.7
L2							4	7.3			1	20			1	5.9	6	4.3
L3							3	5.4									3	2.2
Sacrum													1	14.7			1	1.4
Coccyx			2	15.2													2	.7
TOTAL	21	100.8	13	98.8	12	100	55	99.8	9	99	5	100	7	102.9	17	100	139	99.9

TABLE IV

EFFECTS OF MULTIPLE EJECTIONS

In examining all cases of U.S.A.F. pilots who have made multiple ejections, Smelsey found a total of 116 cases through 31 December 1968. (10) Of this number, six sustained vertebral fractures on their initial ejection. Of the six, only one sustained a vertebral fracture on any subsequent ejection, and the vertebra fractured on the second ejection was not the same. The result in this case was return to full flying duties.

There is a possible source of bias in these data when attempting to calculate rates, since persons suffering an initial vertebral fracture on ejection may have left the service due to disability and therefore not been exposed to a second ejection; or may have transferred into a unit flying a non-ejection-seat aircraft ; or may have voluntarily left flying for other reasons. Thus the population at risk for a second ejection has the possibility of being a selected sample.

Ewing found that of 69 Designated Naval Aviators (DNAs) who suffered ejection vertebral fracture on initial ejection, only one suffered a vertebral fracture on a subsequent ejection. (6) It also involved a different vertebra. The number of those individuals making a second ejection is unknown. The result of the first fracture in this case was return to full flying duties (Service Group I). The result of the second fracture was return to permanently limited flying duties (Service Group II). The source of bias noted previously applies equally to this latter study since the number of DNAs leaving the service and thus no longer at risk following an initial ejection vertebral fracture is not well defined.

There is, therefore, insufficient evidence to allow prediction of vertebral fracture probability in a second ejection, given an aviator who suffered a vertebral fracture on a previous ejection; nor is it possible to give a prognosis of the ultimate effect on the individual (or his flying career) of a second vertebral fracture due to a second ejection. However, in neither of the two reported cases did the previously injured vertebra suffer a second fracture, nor did either case become disabled as a result of either fracture.

COSTS OF EJECTION VERTEBRAL FRACTURE

The study by Jones et al in 1964 noted that six aviators were retired for disability as a result of their fractures, out of a total of 34 persons who suffered ejection vertebral fracture. (2) Ewing's study shows all U. S. Navy DNAs retired for disability, and arranged by military rank. (6) These data are presented as Table V for the period 1959 through 1965, which partially overlaps the data of Jones, et al.

COSTS DUE TO PERMANENT REMOVAL OF DESIGNATED NAVAL AVIATORS FROM SERVICE GROUP I, FOLLOWING EJECTION VERTEBRAL FRACTURE

Rank	Disability Retirement	Limited Flying Duties	Total
CAPT			
CDR			
LCDR	2	2	4
LT	4	2 *	6 *
LTJG	5	1	6
ENS			

* Including one bilateral leg amputation

TABLE V

The cause of disability in five cases was paraplegia; intractable back pain in an additional five cases, and L5-S1 herniated disc in one case. As noted in Table V, five additional DNAs were never returned to the unlimited flying duties which they were performing at time of injury. They were returned to limited flying duties but were lost to the Navy as Service Group I aviators.

It should be noted that 16% of all DNAs suffering ejection vertebral fracture in the period 1959-1965 were retired for disability. If those restored only to permanently limited flight duties are included the percentage rises to 23%. Fryer's statement that permanent disability is rare, is not true for the U. S. Navy. (3) Crooks' statement "... the clinical importance of these crash fractures is negligible in the long term view" does not appear to apply to the U. S. Navy experience either. (7) A possible source of bias always exists in that non-disabled aviators are easier to locate and examine for follow up studies.

Another cost of ejection vertebral fracture is time lost from flying in Service Group I by the injured aviators. The definition of lost days is contained in the Appendix. Table VI presents the data by rank for the 70 DNAs. (6) When an aviator is not available to fly his mission, someone else must do it for him. Obviously, such normal time-loss events as leave, official travel and other illnesses and injuries cause any group of aviators to be somewhat overmanned. The time lost due to ejection vertebral fractures simply makes this manning requirement (commonly called the "seat factor") larger. This costs money for training of replacement pilots.

MAN-DAYS LOST DUE TO EJECTION VERTEBRAL FRACTURES, BY RANK FY 1959-1965, DNAS ONLY

Rank	Hospitalization	Total Days Absent from SG I	Number Individual DNAs
CAPT	93	178	2
CDR	302	754	3
LCDR	880 *	2,788 *	10
LT	2,132	4,833	29 **
LTJG	2,077	4,635	23
ENS	229	424	3
TOTAL	5,713	13,612	70 ***

* These figures include only known data. Duration of hospitalization and absence from SG I, when unknown, were determined by averaging for the particular fracture for this series. If such data were included, LCDR hospitalization would be increased 49 days; LCDR absence would be increased 59 days and CAPT absence would be increased 125 days.

** No hospitalization or days absent from SG I included for the bilateral leg amputation case.

*** While only 69 individuals suffered injuries, one suffered injuries in two separate accidents and is therefore counted as two persons for this table.

TABLE VI

In this study, 70 aviators lost a total of over 37.3 man years from their cockpits. This loss of operational capability may be as important as the losses due to disability retirement. The permanent loss of 16 jet fighter pilots in addition to the loss of 37.3 man years of jet fighter pilot time is not an inexpensive matter.

PREVENTION OF FRACTURE

An hypothesis of the mechanics of causation of non-fatal ejection vertebral fracture has been presented elsewhere. (12) It is hypothesized that certain movements of the individual vertebral bodies under $+G_z$ impact acceleration cause the characteristic fracture. If these motions can be prevented, fractures could only occur at markedly higher levels.

In the previous study (6), only one posterior vertebral fracture occurred out of 79 cases. The remainder were anterior compression fractures. It would therefore appear that there may be a mechanism limiting posterior compression, while <u>not</u> limiting anterior compression of the vertebrae.

The posterior compression limiter (or spring limiter) is seen to be the articular facets of the vertebrae, held together by ligamenis as demonstrated in Figure 1. The facets serve as a posterior hinge for adjacent vertebrae, as demonstrated in Figure 2, allowing the anterior lips of the vertebral body to touch, but preventing contact of the posterior lips.

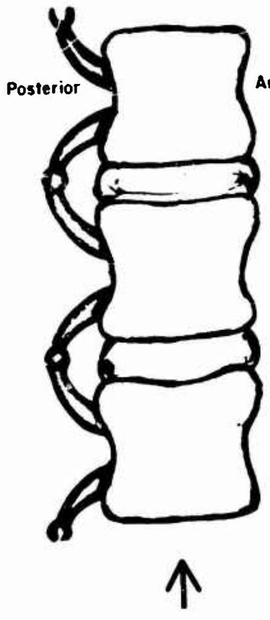

Fig. 1 Diagram of an erect spinal segment showing the relative postion of the articular facets and spinous processes.

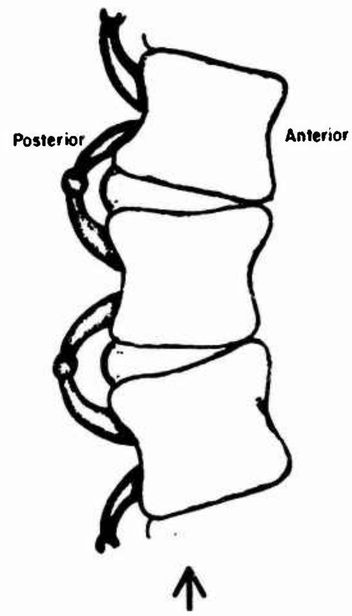

Fig.2 Diagram of a spinal segment showing relative positions of the vertebral bodies during flexion.

The hypothesis is therefore more specifically expressed: Posterior compression of the vertebral column in the thoraco-lumbar area is limited by the articular facets, while anterior compression is not.

If true, a means of preventing anterior compression fracture is suggested.

If the adjacent vertebrae could be forcibly restrained during $+G_z$ impact acceleration in a position of relative hyperextension, as demonstrated in Figure 3, by compressing the posterior spinous processes, anterior compression would be limited. In such an event, it would be necessary to fracture the posterior spinous processes, or the articular facets or tear the ligaments (as shown in Figure 4) in order to cause an anterior compression fracture. The acceleration forces required to cause such fractures should be markedly higher than those necessary to cause anterior compression fractures as normally restrained. Thus, the vertebral fracture threshold should be markedly increased.

Experiments were performed using cadavers and a vertical accelerator to attempt to prove or disprove the hypothesis. (12, 13).

In these experiments, cadavers were restrained to a seat, on a vertical acceleration sled in three modes: erect, flexed, and extended (or "hyperextended"). Each cadaver served as his own control, and was x-rayed to rule out pre-run vertebral fracture. The cadaver was then accelerated to a low level in one of the three restrained modes selected at random. If no fracture occurred, the exposure was repeated in a different mode, and so on. When no fracture occurred at a particular peak $+G_z$, the peak acceleration was increased by 4G and another series of three runs performed. Fracture, determined by x-ray, was the end point.

The "flexed" mode was obtained by using a tight lap belt with loose shoulder harness. The "erect" mode was obtained by using a tight lap belt and tight shoulder harness. The "extended" mode was identical to the erect mode except that a 2" x 4" wooden block was fixed between the posterior spinous process of L1 and the steel seat back.

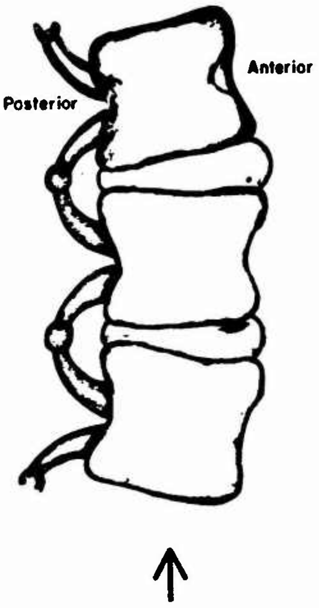

Fig. 3 Diagram of a spinal segment showing relative positions of the vertebral bodies during extension.

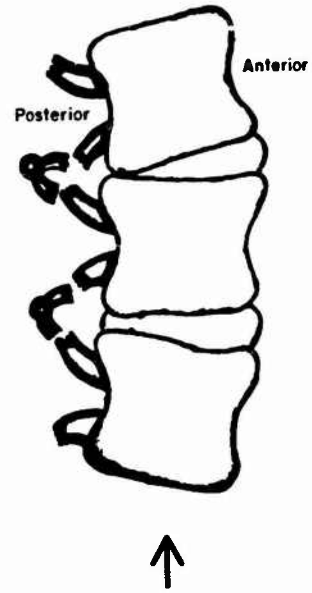

Fig. 4 Diagram of a spinal segment showing the mechanism required to permit posterior compression fractures of the vertebral bodies.

A summary of the results is contained in Table VII.

SUMMARY OF PEAK ACCELERATION VALUES
AT FRACTURE IN THE THREE SPINAL MODES

	Fracture level (g)	No. of Cadavers	Average age (yrs)
Extended	17.75 ± 5.55	4	61.5
Erect	10.4 ± 3.79	5	61.0
Flexed	9.0 ± 2.00	3	54.3

TABLE VII

Table VIII presents an analysis of variance that was possible despite the small sample size.

STUDENT'S t TEST OF FRACTURE g-LEVELS
BETWEEN THE SPINAL MODES

Modes	Sample size	t	P
Extended and erect	9	2.36	0.05
Extended and flexed	7	2.56	0.05
Erect and Flexed	8	0.58	>0.50

TABLE VIII

The differences in G level between the extended mode and the other two modes were found to be statistically significant ($P = 0.05$).

Comparison may be made of the fracture levels presented in Table VII with those presented by Ruff. (14) His work showed maximum tolerance of the individual vertebra in the T12 - L1 area in approximately the erect mode to be 24.5G and 23.0G respectively.

It is believed that the discrepancy can be resolved on the basis of age. Ruff's specimens were obtained at least in part from accident victims. It is presumed that those accident victims were youthful, whereas the average age of cadavers in the erecr and extended modes of the present study was 61 years. The study by McElhaney and Roberts shows that strength of the vertebral body in the sixth decade of life is approximately half that in the second decade. (15) Empirical data from aircraft accidents indicate that the majority of individuals suffering ejection vertebral fracture are in their twenties.

If this relationship holds true, therefore, the average fracture level for the erect mode at age 20 would be roughly 20 G - 25 G and for the extended mode would be 35 G - 44 G. Since cadaveric bone is not as strong as living human bone or fresh cadaveric bone, the comparison becomes potentially even more meaningful.

CONCLUSIONS

It is considered that: (1) the hypothesis proposed has been supported by the data collected and presented; no data were observed to indicate that it was incorrect; and it is possible, for these particular data, to reject the null hypothesis at an acceptable level of statistical significance.

(2) Moderate forced hyperextension of the cadaveric vertebral column in the area of L1 by a 6" x 4" x 2 1/4" wooden block necessitates an increase of 50% in the peak sled acceleration level required to cause anterior compression fracture of the lumbar vertebrae over that required in the erect mode, and the difference is statistically significant.

(3) No posterior vertebral fractures resulted from any of these experiments.

(4) There is a preferred position, therefore, of the lumbar portion of the vertebral column during exposure to $+G_z$ acceleration from any source. This position can be achieved artifically by forcibly restraining the shoulder and pelvis of a cadaver to a rigid seat back and forcibly extending the lumbar vertebral column in the area of L1.

(5) This series of experiments, therefore, has considerable implications both for ejection-seat design and restraint-systems design for any human being subjected to $+G_z$ impact acceleration.

(6) It would appear from the evidence presented here that the internal structure of the vertebral column can be so arranged by restraint devices that it can withstand considerably greater loads without fracture than the same vertebral column not so restrained. This implies that the orientation of each vertebral body relative to those adjacent determines in part the sled peak-acceleration value in the $+G_z$ vector at which fracture occurs. Therefore, the characterization of the orientation of the entire vertebral column relative to the applied acceleration vector by a single direction is inadequate to explain the vertebral fracture threshold limits determined experimentally.

APPENDIX A

Definitions:

Service Group I - Aviators under 45 years of age who meet the physical standards for Service Group I. These aviators may be assigned to flight duties of an unlimited or unrestricted nature.

Service Group II - Aviators under 45 years of age who meet the physical standards for Service Group II, and aviators of Service Group I who temporarily meet only the physical standards for Service Group II. Aviators of Service Group II are restricted from carrier operations except in helicopter.

Service Group III - Aviators 45 years of age and over who meet the physical standards of Service Group I, II or III and those aviators under 45 years of age who (1) are recovering from illness or injury or (2) meet the standards of Service Group III but are not physically qualified for the other service groups when the needs of the service and individual's flying experience specifically justify their employment in such a limited status. Those aviators assigned because of temporary physical defects are retained in Service Group III for a period up to 6 months, at the end of which time they are re-examined for classification. Should the temporary disability warrant a longer period in order to fully recuperate, they can be retained in this group for additional six (6) month periods before final classification is effected.

DNA - A designated naval aviator.

NFO - A naval flight officer.

Hospitalization Day - One in which the individual was listed by the hospital as a patient.

Absent from Service Group I Day - One in which the individual was hospitalized, grounded, or in any other Service Group (II or III) as a result of an ejection vertebral fracture. These periods are terminated when an individual dies of his injuries, is placed either on the temporary or permanent disability retirement list, or returns to SG I.

Grounded Day - One in which an aviator is discharged from the hospital but has not yet recovered from his injuries sufficiently that he may be returned to flying duties in any service group.

Service Group III Day - One on or after that date on which the aviator is found physically fit by the Bureau of Medicine and Surgery to perform duty involving flying in Service Group III, and prior to being returned to either Service Group I or II.

ACKNOWLEDGEMENTS

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DISCUSSION

PERRY

Are all ejectees X-rayed and, if so, at what time interval are serial pictures made?

EWING

No, they are not. There is no system established to do this. I personally feel it is important that every ejectee be examined at the time (immediately post-recovery), and then three weeks later. We have found numerous cases where low-power X-ray at the time of fracture revealed no fracture, but the use of high-power X-ray three weeks later revealed the callus of the fracture.

SAUNDBY

Did you use any head restraints in your ejection trials?

EWING

We used a very light piece of paper tape simply to hold the head up at the instant of applying the ejection. The paper tape broke during the power stroke so that the head did flop over. No attempt was made to hold the head back and achieve an actual head restraint.

MANAGEMENT OF ASYMPTOMATIC CARRIERS OF HEPATITIS-ASSOCIATED-ANTIGEN (HAA) IN HELLENIC AIRFORCE PERSONNEL

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SUMMARY

A large-scale investigation among Hellenic Airforce personnel has been instituted in January 1971 aiming at detecting the asymptomatic HAA carriers and recommending means of prevention, medical disposition and/or elimination from flying and certain specialties. This systematic screening is justified by a high correlation of positive HAA and cases of acute viral hepatitis in our series. A disquieting incidence of 5.2% of asymptomatic HAA carriers has actually been demonstrated. The experience gained through careful study of these carriers is presented in this paper.

Tangible results may be summarized in the following recommendations :
a. HAA carriers with normal transaminase levels should complete a regular tour of service, but it is recommended that they be eliminated from certain specialties which might facilitate the spread of viral hepatitis.
b. Those with abnormal transaminase levels should be subjected to a thorough examination for active hepatic disease, their further management depending entirely on the results of this examination.
c. Applicants for flying training, in particular, should be eliminated if found harboring the HAA and showing abnormal transaminase values.

INTRODUCTION

The discovery of the Australia antigen (Hepatitis-Associated-Antigen, HAA) and its association with viral hepatitis by Blumberg and al. (1968) (1) marked the dawn of a new era in the quest of this disease. A great number of papers, especially during the last years, appeared both in the foreign and the Hellenic medical journals, and new data were obtained mostly on the epidemiology of the disease (2, 3, 4, 5). Research was also directed towards the exploration and the establishment of preventive measures. Individuals repeatedly exposed to the HAA, have been shown to develop antibodies against it, but there exists no evidence that these antibodies exercise any preventive role (6). At the present, the hope for prevention should be searched into epidemiological grounds, by locating the risk sources, namely the carriers of the antigen (7). Their prevalence varies from one country to another, being 0.1% in the U.S.A. whilst in the tropics it rises up to 20% (Table 1). Greece shows the highest incidence of HAA carriers in Europe, according to the latest statistics (5).

Accepting the existence of the problem and getting acquainted with it will facilitate its confrontation. The Armed Forces, being the best organized group of our country, possess the capacity to successfully implement a management program of the HAA carriers.

In the Hellenic Airforce, the research for the most appropriate means of controlling viral hepatitis was instituted in January 1971 and it consisted of (a) the detection of HAA on the day of enlistment of Airmen and Airforce cadets, and (b) the enforcement of certain preventive measures (8). These measures are related, on one hand, to the protection of the environment against HAA carriers, and on the other hand, to the follow-up and medical treatment of the "healthy" carriers, many of whom are suffering with sub-clinical and/or chronic liver disease (9, 10).

I. PROTECTION OF THE ENVIRONMENT

A. Search and Follow-up of H.A.A. Carriers:

Individuals harboring the H.A.A., either in association with chronic liver disease or as chronic asymptomatic carriers, should be searched for, studied and placed under continuous medical control. In the Armed Forces, the identification of the carriers is feasible by a general blood sampling from all recruits on the first day of their entry into the training centers. Blood samples are collected by a medical team consisted of one experienced medical officer and 2-3 technicians. The blood samples, or following seperation of the clot, their sera, are immediately sent to the laboratory, under appropriate maintenance conditions.

In the Hellenic Airforce, HAA was detected in 5.2% of recruits. There was a significant geographical variation in the frequency of HAA carriers, the lowest figures being obtained in the Islands and Greater Athens area ($<3\%$), while the highest ones in northern Greece ($>8\%$) (5). The prevalence of HAA was higher in recruits from rural (5.9%) than urban (4.7%) areas (11). An association was also found between HAA frequency and socioeconomic level (Table 2). It is felt that the hygienic and socioeconomic conditions prevailing during the early life are of great importance for the establishment of the "healthy" HAA carrier state (5, 11).

TABLE 1.

Incidence of HAA in Europe

Country *	HAA (%)
1. Great Britain	0.1-0.60
2. Scotland	0.10
3. Finland	0.10
4. Norway	0.16
5. Switzerland	0.19
6. France	0.28
7. Denmark	0.30
8. Spain	0.30
9. Austria	0.46
10. Germany	0.46
11. Italy	0.5-1.50
12. Poland	0.90
13. Greece	1.8-5.20
14. Turkey	3.0-4.30
15. Yugoslavia	4.08

* In U.S.A. 0.10%,
in tropic regions up to 20%.

TABLE 2.

Incidence of HAA "healthy" carriers according to the socioeconomic level (from Kissoulis and al., ref. 11)

Social class	N° examined	HAA carriers N°	HAA carriers (%)
I.	85	1	1.2
II.	653	26	4.0
III.	944	47	5.0
IV	2,468	163	6.6
Total	4,150	237	5.7

B. Measures related to Blood Transfusion:

It has already been known by recently published investigations (12, 13, 14) that 55-75% of the recipients who are transfused with HAA positive blood, develop hepatitis. Consequently, in the U.S.A., unless transfusion of HAA positive blood is excluded, it is estimated that, in 1972, 11,000 individuals will manifest clinical (overt) hepatitis, 40,000 more will be affected by anicteric hepatitis, and 500-1,000 of them will die (15). In Greece, due to the lack of reliable statistical data, any estimate is unfeasible. However, the demonstrated high incidence of HAA carriers in our country (5), exceeding the 40-fold of the respective incidence of U.S.A., may well account for the observed high incidence of post-transfusion icteric hepatitis, which has arisen to 11.19% (16). Bearing in mind that most of the blood to be transfused is being provided voluntarily by the young Army, Navy and Airforce recruits, the magnitude of the problem created by the asymptomatic HAA carriers becomes obvious. Accordingly, these subjects should be eliminated as donors for both direct blood transfusion and production of blood derivatives.

C. Prevention of the transmission of the disease:

Transmission of the homologous serum hepatitis by the parenteral route, even with minute amounts of blood, has been known for many years (17). Experiments on human volunteers (14) have demonstrated that a minute quantity of plasma, with a low titer for complement fixation (1:10), is capable of causing clinical hepatitis, whilst a dilution in the order of 1:10,000,000 may cause a temporary HAA carrier state in the recipient. Self-explanatory is therefore the requirement for up-dating certain obsolete methods and procedures,e.g. substituting disposable lancets for the needle of Frank, still in use in several Hospitals, for the determination of blood group and W.B.C. Proper sterilization of medical, dental and biopsy instruments is an essential preventive measure. Likewise, it is indispensible to prohibit the sterilization of the multiple use needles by boiling and definitively substitute them by the single use ones, not only for mass immunizations or blood donations but for the routine everyday medical practice as well. Especially for mass immunizations at the recruiting centers, the use of specific pistol is strongly recommended, since it combines proper administration with saving of time and money.

The Barbershop constitutes a noticeable source of transmission of the disease, in our country. Transmission through razor blades is possible not only through shaving but also during the final phase of the haircut. Therefore the employment of shavers with disposable single use blades cannot be overemphasized.

Since the epidemiology of the homologous serum hepatitis (which in the opinion of several investigators should be identified with the HAA positive hepatitis) has not yet been fully elucidated, handling the carriers as if potentially transmitting the disease through contact as well as by the oral route, is warranted (2, 18, 19). Rigid personal cleanliness as well as general hygienic measures are mandatory.

II. SELECTION OF SPECIALTY

Upon completion of their basic training, recruits receive another training for their specialization in certain disciplines, according to their knowledge, experience, and the projected requirements of the Airforce.

The criteria for the selection should be amended to take into consideration the small group of HAA carriers. They should be assigned into specialties which appear unlikely to create conditions favoring the transmission of the disease and/or the deterioration of a potential hepatic lesion. Such a solution, far from ideal, reflects the magnitude of the problem in Greece (8).

There are numerous as yet unanswered questions. We must be conservative in imposing a vocational change on the carrier, if, due to his profession, he creates hazards for the environment (dentist, surgeon, nurse, etc.) (15,20). Considering the fact that in the U.S.A. and certain other countries, where the incidence of H.A.A. carriers is exceedingly low, the question of their vocational re-adjustment remains unanswered, in Greece the answer is explicitly negative, since an eventual revocstion of licence from highly trained professionals, like physicians, dentists etc. would lesd to s social turmoil mucb less manageable than the question of hepatitis proper (8).

For the Armed Forces, the selection of a specialty, at least for the draft-eligible personnel, is fscilitated by the placement of the "bealthy" HAA carriers in any specialties except food handler, barber, male nurse etc., as well as by the avoidance of fatiguing assignments. From the hitberto findings of our investigation (10), there seems to be no doubt that s considerable percentage of the carriers exhibit serious liver lesions, occasionally progressing to cirrhosis. By inference, we are considering tbe expediency of legislatively arranging the elimination of HAA carriers as candidstes for tbe productive Military Schools.

III. PROTECTION OF HAA CARRIERS

Many of the "bealthy" carriers present hepatic lesions of varying intensity (1, 9, 10, 21, 22). Tbe severity of tbe hepatic lesions ranges from the normal liver to tbe acute anisteric bepatitis, to the chronic persistent or aggressive hepatitis snd, finally, to the insctive post-necrotic cirrhosis (9, 10), (Table 3).

TABLE 3

Histological findings of 104 asymptomatic HAA carriers
(From Vissoulis and al.,ref. 10)

Group	Histological diagnosis	N° of cases	(%)
I.	Acute hepatitis	5	4.8
II.	Chronic aggressive hepatitis	3*	2.9
III.	Cbronic persistent bepatitis	6	5.8
IV.	Minimal non specific cbanges	53	51.0
V.	Normal	37	35.5
	Total	104	100.0

* In one case, post necrotic cirrhosis was also found.

In patients with attendant disorder of liver biology and, particularly, in the presence of elevated serum transaminases, the incidence of the histologically proved aggressive hepatitis is high (21). Using the criterion of the serum transaminase level, HAA carriers are separated into two main sub-groups snd trested differently from tbe very first day of their enlistment at the recruiting centers.

Those csrriers with normal transaminase levels, carry on their basic training and serve tbeir fixed tour of military service in specialties under tbe above mentioned restrictions. In addition, during the semester physical examinations of personnel at Base level, HAA carriers are re-examined for both antigen and serum transaminases.

Carriers of the second sub-group (abnormal transaminase values), are hospitalized for a thorough investigation to determine the nature and extent of a given hepatic disease. Tbis second sub-group, according to tbe clinical, laboratory and histological findings from the liver is furtber devided into 3 cstegories:

a. Pstients witb "normal" liver, in wbom clinical findings are lacking, the biology of the liver remains essentially normal, except for slight increase of transaminases, and the histological picture fsils to reveal any particular hepatic damage. It should be mentioned, at this point, thst liver biopsy material from our patients, examined by tbe immunofluorescent technique (23, 24), has invariably disclosed the fixation of HAA in the cytoplasm of the hepatic cells. Hans Popper (20), having reviewed our histological preparstions (1971), remarked that immunofluorescence is observed in hepatic cells, the cytoplasm of which has lost its normal granulation. These findings, although suggestive of s histochemical disorder, cannot, at the present time, fully ascertain the magnitude of the existing hepatic lesion. Persons belonging to this category are considered fit for a regular tour of service, following sub-group I.

b. Patients with anicteric hepatitis, witb slight manifestations only. These patients are handled similsrly as those affected with acute viral hepatitis.

c. Patients with chronic hepatitis. Tbe hepatopathy of tbese patients is distinguished into two forms, (i) persistent and (ii) aggressive chronic hepatitis (25). This distinction is of particular importance inasmuch as their therapeutic management and prognosis are dissimilar (26). Thus, in the case of chronic persistent hepatitis, the prognosis is generally good and the patients need not be subjected to any medicinal treatment. Avoidance of excessive fatigue and follow-up st 6-month intervsls sre sufficient recommendations.

In opposition to the above, the chronic sggressive bepatitis, also referred to as chronic active hepatitis (27), is of special significance on the ground of its grave prognosis, usually progressing to cirrbosis (28, 29), often requiring vigorous and sustained medicinal therapy by immunosuppressive drugs, like corticosteroids snd/or azothioprine (30, 31). In either form of chronic hepatitis, we recommend a one-year or two-year deferment of the diseased recruit, at the end of which a finsl conscription arrangement ensues.

Tbe problem of hepatitis in Greece is an acute one. Its investigation, ssisted by the research of tbe HAA, will certainly cast light on several new epidemiological aspects, possibly overruling some of tbe sctually valid concepts. There should be no doubt, however, that tbe spplication of the recommended measures, will contribute in confronting the problem, will assist in improving our knowledge and illuminate many obscure pliee of the disease,in our country.

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SYRINGOMYELIA AND FLYING FITNESS

by

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SUMMARY

It was the mission of an F 104G pilot to fly simulated attacks on a concentration of tanks. During the third run the aircraft struck the ground and was destroyed. The investigation revealed no technical failures. At the autopsy of the pilot, who died from crush fracture of the skull and decerebration, the spinal cord was included in the histological examination of the organs. Signs of degeneration indicative of syringomyelia were found. Serial sections revealed that the cavity formation extended from the cervical to the upper dorsal part of the medulla with a partial loss of the anterior commissure. Besides the histologically proved dysrhaphic phenomenon of syringomyelia the pilot showed other signs of developmental defects. The extent to which the existing syringomyelia had contribution to the fatal accident and the question of specific flying conditions being conducive to an exacerbation of syringomyelia are discussed.

Histological examinations of organs of pilots involved in fatal accidents have often revealed diseases, in particular those involving the heart, which may have limited flying fitness (',9). The following is a presentation of a case in which histological examinations uncovered a nervous disease in a pilot.

In September 1970 an element of two Starfighters (F-104G) were on a mission of simulated FA, controlled rockets, and strafing attacks on a concentration of tanks in a training area in northern Germany. The first two attacking runs were successful. During the third run the intended simulated rocket attack could not be completed because of an unfavorable position. The tactical number two changed into a simulated strafing attack but the tactical number one, flying in front, pulled up to the right and made another steep angled approach towards the target. When the latter aircraft intercepted the course of the other at an altitude of approximately 800 feet in a dive angle of 20° to 25° without any sign of the initiation of a recovery the tactical number two transmitted the warning "watch it". The recovery maneuver, however, was initiated too late. The tail end of the aircraft made contact with the ground and the aircraft exploded.

Aircraft debris was scattered over a distance of about 750 meters. The pilot was killed. Later investigations of the wreckage revealed no technical failures.

The autopsy of the corpse of the 26 year old pilot, a First Lieutenant, performed by Division V, Aviation Accident Pathology, of the German Air Force Institute of Aviation Medicine, revealed signs of a severe vertical compression in sitting posture, signs of transverse body contusions with control-stick injuries of the right wrist and the right costal arch, as well as injuries caused by explosion.

The skull showed crush-fracture and decerebration, the spinal column showed multiple fractures, and the heart and the aorta were torn. Macroscopically recognizable acute or chronic illnesses, which might have had a bearing on the events of the accident, were not found during the autopsy. The only conspicuous finding was a slight enlargement of the thyroid with an elongated pyramidal lobe.

In addition to specimens taken from other vital organs, part of the spinal cord from the cervical and upper thoracic region was removed during the autopsy for histological examinations. At first sections of the middle of the intumescentia cervicalis were prepared and stained with haematoxylin-erythosin. A study of these sections under the microscope revealed an unexpected finding.

To the right and left of the central canal were two cavities, oval in shape, with a longitudinal diameter of approximately 1 mm each. The cavities gave a stamped out impression and extended to the base of the posterior horn and displaced the posterior as well as the anterior commissure. The central canal was lined with regular cubic, occasionally detached, ependyma.

The central canal was lanciform with a longitudinal diameter of 0,29 mm and a transverse diameter of 0,04 mm and was thus somewhat wider than normal and appeared to have a slight eccentric displacement. The anterior median fissure with its portion of connective tissue was bent to one side and the anterior commissure was interrupted at this spot. The right hand cavity was only covered with connective tissue of the anterior median fissure. In the regions of both cavity formations, especially on their walls, there were several relatively wide vessels surrounded by profuse slack connective tissue. The walls of the remaining vessels of the spinal cord were thickened by connective tissue. Special staining for glial tissue according to HOLZER's method showed clearly that the cavities were surrounded by dense walls of neuroglial fibers. Cross sectional views of the upper parts of the dorsal regions of the cord showed the presence of cavities even in these places, although they were smaller and unilateral. Here too the thickening of the vascular walls by connective tissue is clearly evident in a specimen stained according to the method of van GIESON. In order to determine the longitudinal extent of the alterations in the cord, serial sections were performed on the entire portion of cord removed during the autopsy and the specimens stained with haematoxylin-erythrosin. A study of the serial sections showed that cavities had developed throughout the intumescentia cervicalis down to the upper parts of the dorsal regions of the cord. The shape, extent and location of the cavities varied. Tracing the development of cavities in a caudal to cranial direction, starting from the third dorsal segment, cavity formation was seen to exist on one side only. This formation was characterized by two small spots of missing tissue. In a cranial direction the cavities increased in size, with the smaller one being displaced more into the posterior horn. Finally the cavity formations combined unilaterally and formed one big cavity. In the lower portion of the cervical part the cavity was again a little smaller but closer to the central canal and the anterior commissure. In the region of the seventh cervical segment the cavity interrupted the anterior commissure and joined with the anterior median fissure and a cavity was also observed on the other side. In a cranial direction, in the vicinity of the seventh cervical segment, both cavities increased in size and combined with a complete absence of the commissure. In the fifth cervical segment there was a cavity extending to both sides and combining with the anterior median fissure with a longitudinal diameter of approximately 3 mm. The central canal always remained closed and was not connected with the cavities. In the cervical parts of the cord in proximity to the cavities there were also signs of partially diffuse necrosis of ganglion cells in the gray substance.

The histological findings thus demonstrated correspond to those of syringomyelia (2,5,6,7,8). Syringomyelia is a disease leading to a tube-like degeneration of the spinal cord and causing dysfunctions in the sensory, and also in the motor and autonomic systems. Current opinion is that the disease must be classified as a dysrhaphic anomaly and will only become manifest after the 20th year of age. The disease has a marked progressive character. Under given predisposing conditions and under the influence of additional harmful influences such as shocks or stress on the spine there will be a softening of the tissue in the spinal cord and the development of tube-like, liquid-filled, cysts with proliferation of vascular connective tissue. The cavities are usually produced in the gray substance, particularly at the base of the posterior horn. This preferred location explains the characteristic symptom of syringomyelia, the dissociated anesthesia, i.e. the diminution or loss of sensation of pain and temperature with the preservation of touch. Depending on the location and the extent of the process this disease may lead to various forms of nervous dysfunction. Affected anterior horns, for instance, may result in neurogenic muscular atrophy, and an extension of the process to the posterior columns in turn results in a disturbance of the sense of touch, deep sensitivity, and coordination.

Such lesions produce the first symptoms of early syringomyelia (8). The involvement of the autonomic nervous system is frequently manifested by anomalies of sweat secretion in the form of hyper- or anhydrosis. Since the preferred site of the disease is in the cervical part of the medulla the upper limbs are predominantly affected. As a dysrhaphic phenomenon syringomyelia is frequently accompanied by other developmental defects (2,5,6,7,8). In this case the autopsy revealed that the dead pilot had a pronounced lobus pyramidalis of the thyroid gland. Furthermore the medical history indicated that an excision of an encysted hydrocele of the spermatic cord was performed on the pilot approximately three and a half years prior to the fatal accident. The lobus pyramidalis and similarly the hydrocele funiculi spermatici must be considered defects of development (1,3,10,11).

Judging from the histological appearance of the examined spinal cord segments the pilot must already have been affected by disturbances of nervous functions. With the loss of the anterior commissure in several segments it is safe to assume a dissociated anesthesia of limited extent in some regions of the upper limbs. As a result of the spread of the degenerative process to the anterior horns, with partial diffuse necrosis of ganglion cells, paresis of single muscle groups in the upper limbs is to be expected, although not to a considerable degree. The involvement of the spino-cerebellar tract should have caused some disturbance of deep sensation and muscle coordination. Possibly the sensation of touch was also impaired.

Even though the nervous dysfunctions in general may not have been of any real significance in the early stages of syringomyelia, such disturbances of sensory and motor functions nevertheless exert an adverse influence on the flying fitness of jet pilots. Bearing in mind the possible implications of the histologically proven syringomyelia in the cervical and the upper dorsal part of the medulla there is a good chance that, in spite of the warning, the pilot was unable to recover from the dive in time as a result of nervous dysfunction accompanied by loss of precise muscle coordination. During the concealed progress of the disease nervous dysfunction may have gone unnoticed by the deceased pilot himself, as well as by the people around him, and had evidently escaped detection in earlier examinations. If continuous shocks to the spinal column and the spinal cord of stone-cutters(5) and workers in similar occupations are apt to exacerbate the development of the process of syringomyelia, then specific flying stresses on the on the spinal cord such as vibrations and G-forces should also induce the progression of a latent syringomyelia within a short period of time. This explains why the last flying fitness examination, performed on the pilot during his training in the USA one year before the crash did not reveal any neurological anomalies as did all other previous medical examinations. Within a period of one year constant flying operations may have caused syringomyelia to become manifest in this pilot.

Rare as syringomyelia may be in a pilot the possible development of a neurological disease of this or a similar nature in pilots should never be excluded. More frequent investigations and neurological examinations of pilots by Flight Surgeons, especially during a decrement of flying performance, can contribute to aircraft accident prevention. Special emphasis should be placed on defects of development. In autopsies involving aircraft accident victims it should become standard procedure to open the spinal canal and to obtain spinal cord tissue for histological examinations. The histological examinations of all vital organs of aircraft accident fatalities may be of paramount importance in the clarification of the causes of an aircraft accident.

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DISCUSSION

JONES

Was there any indication that the pilot had a motor deficiency on any objective examination prior to the accident? Did he disclose any impairment?

APEL

No, but his performance had become degraded slightly.

THE BIOSTACK EXPERIMENT ON APOLLO 16

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SUMMARY

The objective of the BIOSTACK experiment, flown on board of Apollo 16, is to study the combined action of individual heavy high energy loss nuclei of cosmic radiation and space flight factors on biological systems in resting state. The results will give information on the mechanism of heavy particles on biological matter.

The BIOSTACK experimental package contains a series of monolayers of selected biological objects (Bacillus subtilis spores, Arabidopsis thaliana seeds, Vicia faba radiculae, Artemia salina eggs) with each layer sandwiched between several different physical track detectors (nuclear emulsions, cellulose nitrate, polycarbonate). Individual local evaluation methods have been developed which allow to identify each biological effective particle and to correlate the individual hitting particle with the produced biological effect. A variety of biological effects due to a single penetrating particle is being analysed: influence on cellular and tissue development, nuclear damages, and mutation induction.

The heavy ion flux ($Z \geq 4$) during the Apollo 16 mission has been determined preliminarly as 33 particles/cm^2 of REL$\geq 0.8 \times 10^3$ MeV cm^2/g and 67 particles/cm^2 of REL $< 0.8 \times 10^3$ MeV cm^2/g. A cosmic background radiation of 505-622 mrad was measured by LiF thermoluminescence dosimetry.

1. INTRODUCTION

The problem of hazards from primary cosmic rays during space flight has obtained increased attention (1), since during the flight of Apollo 11 the astronauts experienced light flashes when the space ship was in darkness (2). This light flash phenomenon seen by the astronauts of Apollo 11 and confirmed during subsequent moon missions has been suggested with little doubt to be caused by cosmic nuclei, that interact with the visual apparatus (3).

From this observation the severe question arises what injury induced by cosmic nuclei may occur in other parts of the organism. Special attention is to be laid on the nervous system, especially during long time space flight. Radiobiological studies in space are necessary to clarify the effect of heavy ions on cells, especially of nondividing tissues.

The appraisal of the radiobiological effectiveness of the heavy nuclear component of cosmic radiation needs identification and evaluation of the local events produced by each penetrating ion, especially for particles of very high charge and energy loss. To describe the radiobiological significance of such cosmic particles Schaefer has proposed the term "microbeam" (4), indicating that a single traversal of a heavy nucleus may produce an energy dissipation in the biological microstructure that can be likened to a beam of narrow cross section. Katz uses the term "ion-kill" (5) to describe the direct interaction of the penetrating ion with the biological matter. In the BIOSTACK experiment a technique has been used which allows to determine the effects of individual heavy ions at molecular, cellular and tissue level together with the physical data of the particle (6). The BIOSTACK experiment has been flown on board of Apollo 16, thus it was exposed in deep space for nearly 11 days.

2. DESIGN OF THE BIOSTACK EXPERIMENT

The biological objects, which were selected as investigative systems in the BIOSTACK, are suited for the detection of at least one radiation effect. The radiation effects under investigation are:

- Inactivation of germination, outgrowth and cellular division in Bacillus subtilis spores
- Influence on germination, growth and development and induction of mutations in Arabidopsis thaliana seeds,
- Nuclear damages in radiculae of Vicia faba,
- Inhibition of emergence and hatching and influence on further development in Artemia salina eggs.

The biological objects were exposed in resting state. Therefore they do not need any life support and have a relatively long shelf life. In the stack they are arranged in monolayers, embedded in foils of polyvinylalcohol (PVA). These biological layers are sandwiched between sheets of visual track detectors, which are nuclear emulsions K2 and K5 and plastics such as cellulose nitrate (CN) sheets and polycarbonate sheets (fig. 1). By using this arrangement and specially developed localization methods it is possible to identify an individual incident particle and the biological region which has been hit by that particle. This gives the opportunity to correlate the obtained biological effects with the special physical data of the incident particle.

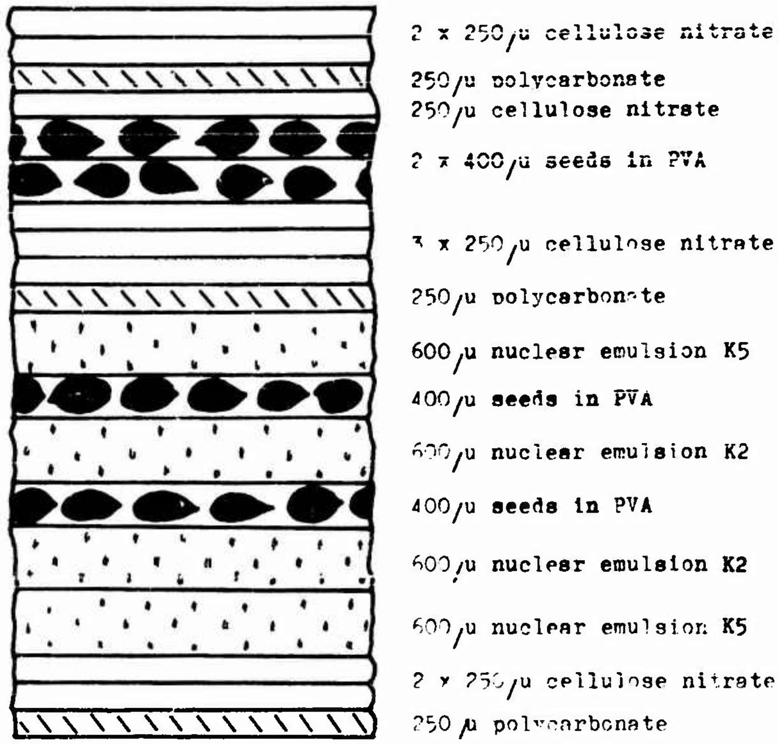


Fig. 1

Typical arrangement of a biological unit of the BIOSTACK: Unit with Arabidopsis thaliana seeds.

3. IDENTIFICATION OF THE HIT BIOLOGICAL REGION AND THE CHARACTERISTICS OF THE PARTICLE

3.1 BIOLOGICAL LAYERS IN CONTACT WITH NUCLEAR EMULSIONS K2

Nuclear emulsions K2 which were positioned below a biological layer carry on their upper side a weak negative photograph of these biological objects in the geometry of exposure. The pattern of the objects in natural size was reproduced on the emulsion by weak optical illumination during disassembly of the stack. The bottom side of the emulsion carries a weak photo of a coordinate grid. After development the same emulsion shows the tracks of the penetrated particles, the pattern of the biological objects and the coordinate grid (fig.2). Microscopical analysis of this emulsion gives the exact region of the biological object that has been hit by a particle.

Fig. 2

Nuclear emulsion K2, showing the negative of an Arabidopsis thaliana seed, that has been hit by a heavy ion during the Apollo 16 mission.

Evaluation from measurements of the track length, photometric analysis and grain count along the track give the required information on charge and energy loss of the biologically significant particles. The emulsions were previously calibrated by balloon flight experiments and by radiation experiments in a C- and a Ne-beam of 2.1 GeV/Nuc at Berkeley.

3.2 BIOLOGICAL LAYERS IN CONTACT WITH CN SHEETS

The CN sheets were used as carriers during the preparation of the biological PVA-layers, resulting in a fixed contact of the biological objects with the physical track detector. This contact is maintained during the exposure as well as during etching and analysis of the detector and - for Bacillus subtilis spores - even during the biological analysis.

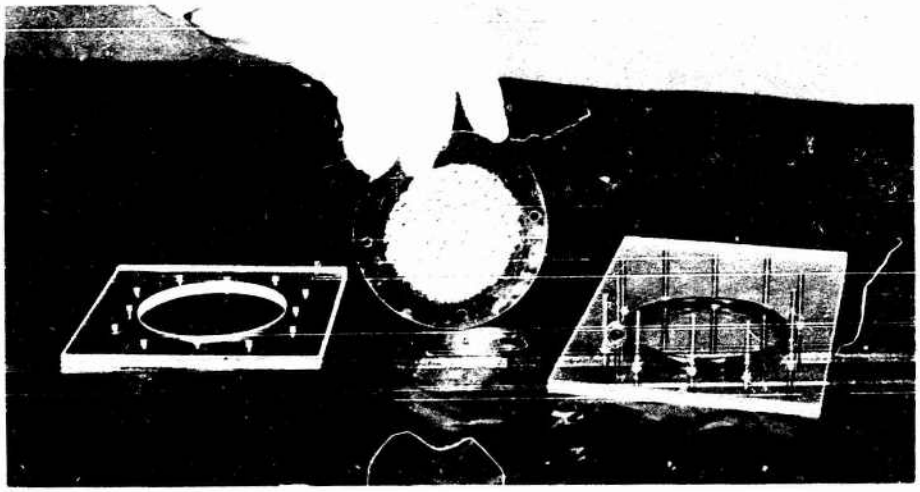
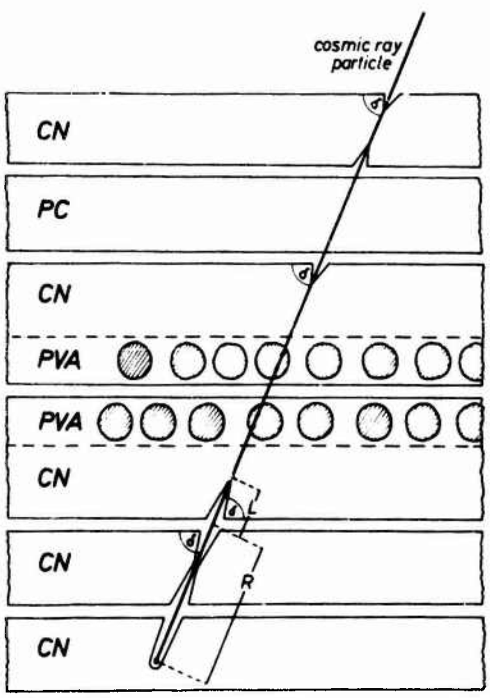


Fig. 3

Etching frame for CN sheets carrying biological layers in order to protect the biological matter from the etching liquid NaOH

During etching in NaOH solution precautions are taken to protect the biological objects from the noxious liquid. Using a special etching frame it is achieved that the sheet is sealed at the biological PVA side so that no etching solution can attack the biological objects. The other side of the sheet is etched to get etching cones. The etching is done at 30°C in a well stirred 6n NaOH solution for 4,5 hours.



The location of the path inside the biological layer can be found by measuring all coordinates of the etch cone in the CN and extending the path of the particle into the biological layer (fig.4). A more detailed description of this method has been given earlier (7).

The energy loss near the biological object can be determined from the length L of the etch cone on the CN-side of the sheet (fig.4, sheet 3,4), because the track etching rate is a function of the energy loss of the particle. The biological analysis is restricted to those objects hit by particles producing etch cones above a certain length. To determine the charge of the particle, the place where the particle stops has to be known. Etch cone length L and residual range R (fig.4) of the particle's path indicate the charge of the particle (8). This has been calibrated previously.

Fig. 4

Part of a biological unit with biological layers in fixed contact with the CN sheets.

4. EVALUATION OF THE BIOLOGICAL DAMAGE

The evaluation of the biological damage pays special attention to the hit biological object and - for multicellular systems - to the hit area in the biological object.

In Bacillus subtilis spores the effect of the individual particles on germination, outgrowth and first cellular division of hit spores is being investigated. For this purpose special incubation chambers are used. Germination is indicated as full phase darkening in phase contrast microscopical examination (fig.5a,b), subsequent outgrowth of the spores to vegetative cells (fig.5c) and first cellular division (fig.5d) are being observed.

The hit Arabidopsis thaliana seeds are divided in three groups comprising seeds which are hit either in the radicula, or in the cotyledons, or in the vegetative cone. After solving the hit seeds out of the PVA-foil, the kinetics of germination are being observed (fig.6), growth and development of the whole plant are being measured periodically.

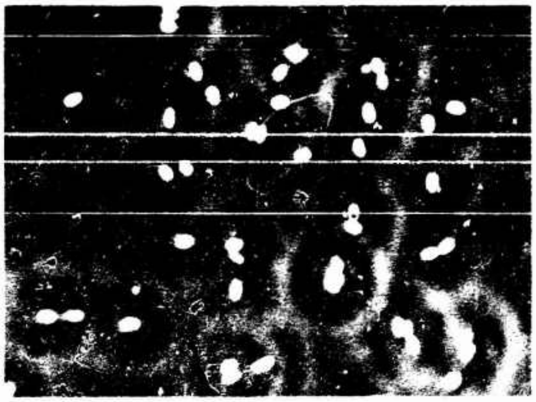


Fig. 5a

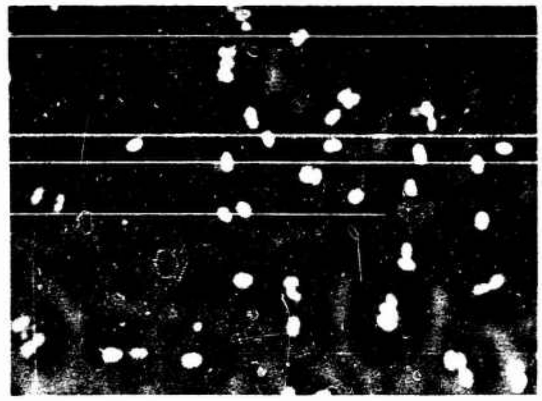


Fig. 5b

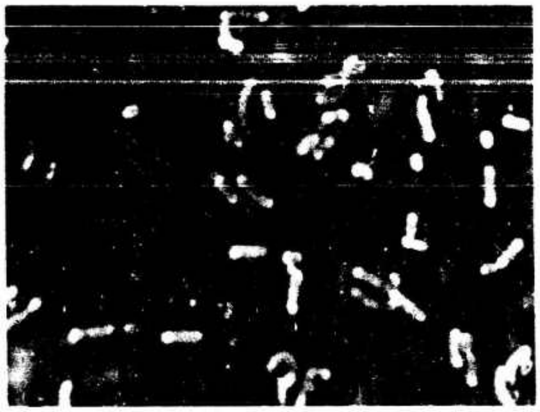


Fig. 5c

Fig. 5d

Fig. 5 Steps of analysis of Bacillus subtilis spores (phase contrast micrographs)
a) spores not germinated (full phase bright)
b) spores germinated (phase dark), 70 min incubation on nutrient agar
c) outgrowth, 130 min incubation
d) first cellular division, 200 min incubation

Induced mutations, for instance in shape and colour of the shoot, will be recognized in the F2-generation (9).

In the hit eggs of Artemia salina the embryonal development is being studied up to the hatching of the nauplius. The excystment proceeds in two stages: the emergence with the partially developed larva still enclosed in a membrane and the hatching with a swimming larva called nauplius coming out of the membrane (fig.7). The studies include macroscopic observations and histological examinations using a light microscope and an electron microscope.

Fig. 6

Processes of germination of Arabidopsis thaliana seeds
a: nongerminated seeds
b: outgrowth of radicula
c: seedling

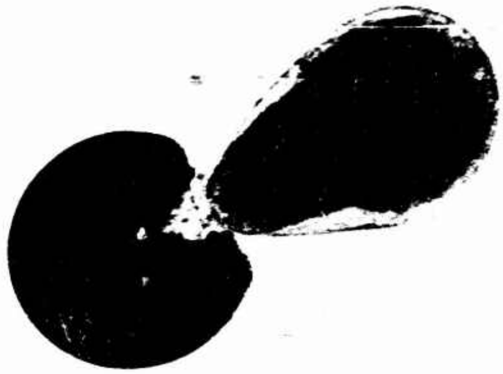


Fig. 7

Artemia salina, hatching

5. FIRST PRELIMINARY RESULTS ON COSMIC RADIATION

5.1. COSMIC BACKGROUND RADIATION

The LiF thermoluminescence dosimeters (TLD) were arranged at the bottom and at the top of the stack. They measure properly the background radiation, which is composed of the electromagnetic part of cosmic radiation and of the high energy protons. The local dose of cosmic background radiation was measured between 505 mrad and 622 mrad (table 1). The TLD layer at the bottom of the stack indicated a higher dose than the TLD layer at the top of the stack.

Sample	Layer no.	Dose (mrad)		
		read$^{x)}$	ground control dose substracted	correction for thermic neutrons
FLIGHT	A 1-0	680	645	575-622
"	A 9-15	610	575	505-552
ground control	B 1-0	35	0	
" "	B 9-15	35	0	

x) mean value, calculated from 10 measurements, precision ± 2%

Table 1 Dose of cosmic background radiation during the Apollo 16 mission measured by LiF-TLD.

5.2 HEAVY PARTICLES OF COSMIC RADIATION

The CN sheets which were not in contact with biological layers were etched in a mechanically stirred 6 n NaOH bath at 40°C during agitation with ultrasonic. Fig. 8 shows the etch cone of a high energy loss particle's trajectory. A total flux of

Fig. 8

Etch cone of a high energy loss particle's trajectory (total projected length 2.300 mm) in CN flown in the BIOSTACK on board of Apollo 16

33 particles/cm^2 of REL $\geq$ 0.8x10^3 MeV cm^2/g was determined for the whole Apollo mission. These particles have been roughly grouped in four categories depending on the etch cone characteristics (table 2). As the track etching rate is a function of the energy loss of the penetrated particle, particles of the same category are of the same range of energy loss.

In nuclear emulsions about 100 particles/cm^2 of Z $\geq$ 4 were observed. Therefore the total flux is composed of 33 particles/cm^2 of REL $\geq$ 0.8x10^3 MeV cm^2/g and 67 particles /cm^2 of REL < 0.8x10^3 MeV cm^2/g.

Category	characteristics	particles/cm^2
I	1 etch cone	7
II	2 etch cone	8
III	etch hole	13
IV	stopping particle	5
I-IV		33

Table 2 Particles/cm^2 during Apollo 16 mission from CN analysis.

6. INVESTIGATION PROGRAM TO DETERMINE THE MECHANISM OF HEAVY IONS IN BIOLOGICAL MATTER

This experiment BIOSTACK, flown on board of Apollo 16, is part of an investigation program to determine the mechanism of heavy ions in biological matter. Besides cosmic radiation exposure during space flight, as performed during the Apollo 16 mission, it comprises irradiation experiments with cosmic radiation during balloon flights, with heavy ions from accelerators and with other types of radiation from laboratory sources including alpha-particles, protons, electrons, X-rays, and gamma-rays. The data obtained from these experiments may yield information to understand the mechanism of single heavy particles of high energy loss that penetrate biological matter and produce a damage in this living material.

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BREEDING MONKEYS FOR BIOMEDICAL RESEARCH

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SUMMARY

The rhesus monkey shows many characteristics similar to man and is the animal of choice for a variety of biomedical studies. However, wild born rhesus monkeys show considerable histopathology, especially in the skeletal muscle. This makes them of doubtful value for experiments in which histopathological changes are expected in various organs and tissues.

Captive bred rhesus monkeys show much less pathology than wild born animals. The monkeys may be bred in cages or in an outdoor compound. Cage bred animals are not psychologically normal which makes them unsuited for some types of space related research. Compound breeding provides contact between mother and infant and an opportunity for the infants to play with their peers which are important requirements to help maintain their behavioral integrity. Offspring harvested after a year in the compound appear behaviorally normal and show little histopathology. Compound breeding is also an economical method for the rapid production of young animals. The colony can double its size about every two and a half years.

INTRODUCTION

For some time in this laboratory there has been an interest in the histopathological changes that take place in the various organs and tissues of the body under different types of stress. Of special interest have been ground based experiments which could yield information that may be of significance to manned space flight, particularly those which affect muscle. The loss of substance which occurs in this tissue in bed rest and apparently also in weightlessness, raises a number of questions to which answers are required.

Rhesus monkeys were selected for this work for a number or reasons. In many respects the rhesus monkey (Macaca mulatta) shows similarities to man, eg., in the blood chemistry and hematology. In addition the histology and histochemistry (including enzyme histochemistry) of their tissues are virtually the same as in man.

BLOOD CHEMISTRY

	RHESUS MONKEY	MAN
CALCIUM	9.6 - 10.2	9.5 - 11.5 mEq
PHOSPHORUS	5.0 - 6.2	2.5 mgms. %
SODIUM	141 - 157	138 - 146 mEq
POTASSIUM	4.1 - 6.0	3.8 - 5.1 mEq
CHLORIDE	97 - 111	95 - 106 mEq
CO_2	10 - 16	20 - 29 mEq/L
CREATININE	1.1 - 1.4	0.8 - 1.3 mgms. %
URIC ACID	1.0 - 1.4	2.6 mgms. %
CHOLESTEROL	152 - 170	150 - 270 mgms. %
TOTAL PROTEIN	7.8 - 8.7	6.0 - 8.0 gms. %
ALBUMIN	3.0 - 4.0	3.5 - 5.6 gms. %
GLOBULIN	4.3 - 5.2	1.3 - 3.2 gms. %
SGOT	29 - 44	8 - 40 units
SGPT	15 - 20	5 - 35 units
LDH	393 - 713	100 - 350 units
GLUCOSE	71 - 122	80 - 120 mgms. %
BUN	9.0 - 20.0	8.0 - 20 mgms. %

Table I

HEMATOLOGY

	RHESUS MONKEY	MAN
R B Cs.	4.46 - 5.60	4.5 - 5.5 millions
W B Cs.	5.3 - 12.3	6 - 10 thousands
HEMOGLOBIN	11.0 - 19.0	14.0 - 16.0 gms.
LEUCOCYTES:		
NEUTROPHILS(segmental)	20.0 - 55.0	65 - 75 %
LYMPHOCYTES	40.0 - 76.0	20 - 30 %
MONOCYTES	1.0 - 2.0	1 - 2 %
EOSINOPHILS	1.0 - 6.0	2 - 3 %
BASOPHILS	About 1.0	About 0.5 %

Table II

SEROLOGY

LACTIC DEHYDROGENASE: ISOENZYMES OF RHESUS CLOSER TO CHIMPS AND MAN THAN THOSE OF ANY OTHER MONKEY STUDIED.

SEROLOGICAL TAXONOMY: RHESUS IS CLOSER TO MAN AND APES IN:

1. CHICKEN ANTI-HUMAN GAMMA GLOBULIN
2. CHICKEN ANTI-HUMAN CERULOPLASMIN
3. RABBIT ANTI-HUMAN ALBUMIN
4. RABBIT ANTI-HUMAN TRANSFERRIN
5. RABBIT ANTI-HUMAN GAMMA GLOBULIN

For some of these antigen reactions another species of monkey, not rhesus, may be closer to man but there is no other one species that has so many of these antigens so close to man.

Table III

In a preliminary study of a large number of wild born "normal" rhesus monkeys, the amount of pathology present especially in the skeletal muscle, was astonishing. Observations on skeletal muscle were extended to a number of other primate species and some degree of muscle pathology was found in all of them. The squirrel monkey was particularly bad in this respect and it was difficult to understand how some specimens examined could function properly in view of the extensive pathology found. The types of pathological changes found in the rhesus monkey muscle included necrosis of individual and groups of muscle fibers with heavy phagocytosis of some necrotic fibers. Infiltration with phagocytes was present, not only in areas where degeneration was taking place, but also around intra-muscular blood vessels, between muscle fasciculi and interstitially between individual fibers. Fat invasion of the muscle was also seen. Other changes included muscle fibers with lognitudinal splitting, with centrally placed vacuoles and variation in shape and size of individual muscle fibers. There was also flocculation and hyalinization of fibers and central migration and "rowing" of nuclei. Sarcosporidia (parasitic protozoa which invade the muscle fibers) have also been seen in some rhesus monkey tissues.

The origin of these changes is not known, they may be of nutritional, virological, parasitological or even of a traumatic nature. Their presence, however, indicated that a wild-born rhesus monkey was not a suitable animal model, especially for the use in experiments in which possible changes in the muscles were being looked for.

An examination of rhesus monkeys bred in the laboratory under controlled conditions indicated little or no pathology of the kind seen in the wild born animals and it was decided that specimens of this type should be used in future experimental studies. It was then found that captive bred rhesus monkeys were very difficult to obtain and the necessity for establishing a breeding program became imperative.

TYPES OF BREEDING PROCEDURES

To obtain a completely clean animal microbiologically speaking, probably gnotobiotic (germfree) procedures would be best; the animals of course, have to be bred in specially designed facilities. However, one of the problems of gnotobiotically-born animals would be that each of them would have to be delivered by cesarean section and expensive germ-gree equipment would be required for raising them. The question should also be asked as to whether the experimental studies done on animals that were so different from those which have the normal complement of micro-organisms would be significant. Furthermore, the gnotobiotic method of production of animals would result in depriving the infant of interaction with its mother. Over the past ten years observations at the Yerkes Primate Research Center have been made of chimpanzees deprived of their mothers at infancy and raised isolated under conditions similar to those of gnotobiotic animals. These observations have shown that behavioral abnormalities occur. Dr. Harry Harlow of the Wisconsin Primate Center has also published many papers in which he has stated that rhesus monkeys bred in a similar fashion were affected in the same way. The symptoms included stereotypy (a stereotyped series of movements) and lack of motivation, the monkeys would remain huddled and withdrawn. Such animals would be very unsatisfactory for many experimental purposes.

Unfortunately, if the animal is left with the mother, even briefly, it is prone to acquire some infection, particularly infections of the intestine such as Shigella and endopathogenic E. coli. If they are taken away from the mother at birth, this infection remains minimal, but the infant still suffers from the behavioral abnormalities indicated above, and many, if subsequently given tasks to perform under stressful circumstances, withdraw and fail to work. If the mother is allowed to raise her baby, we have a better psychological situation. But the animal, in addition to requiring attention from its mother, which it would receive in a cage-bred raising situation, still requires at least a year of play with peer infants if it is to be psychologically intact.

In addition to the problem of deciding whether psychologically and pathologically normal animals can be born and raised in captivity, the rate of reproduction has to be considered. It is known that success of reproduction in rhesus colonies is a function of the living conditions to which the animals are exposed. Not only conception, but the course of pregnancy, successful delivery and proper post-natal care of the infant, are all affected by the environment in which the animals are kept.

Individual laboratories in the U.S.A. and abroad have bred monkeys in captivity under controlled conditions and much of the information given below is derived from their experience.

The female rhesus monkey has a menstrual cycle resembling that of human females: it lasts 26 to 32 days with a mode of 28 days. Extremes vary from 16 to 50 days. MacDonald (1) found a mean of 29.2 days. The extent of the menses normally ranges from two to five days (2). The menstrual cycle stops when the animal becomes pregnant. Following the termination of the pregnancy it takes about three months for the menstrual cycle to be reestablished. At the Bionetics Laboratories in Virginia where an extensive breeding program of rhesus monkeys has been established for a long time (2) all the babies are removed at birth so that they are not able to study the effects of lactation on the menstrual cycle. The period of normal pregnancy has been established as 165.7 + 5.15 days (1,3). In the wild condition, most rhesus monkey births occur in March, April and May. Monkeys bred in cages, however, tend to breed all through the year. Although those held by MacDonald had some seasonal breeding, they appeared to be moving towards all the year round breeding. There is some evidence (1) that the period of fertility during the menstrual cycle is from day 11 through day 15 of the cycle, with day 1 as the first day of menstruation.

In a mixed group of macaques (1) it was found that 43% of all the females in the colony gave birth and that 74% of the births which went to term were live. The experiences of the Bionetics Laboratories (2) is that housing two or four females, even in a commodious cage, with a single male was not satisfactory for breeding purposes, but that a "gang" cage was better. For their purpose, single pairs of animals were caged together. Their breeding schedule was prepared once a week and all mating was planned in advance and based on the menstrual history of each female. Over a three-year period, the Bionetics Laboratories found that most of the births took place in February, March, April and May, which placed the mating season from September to October.

One of the best known free ranging groups of rhesus monkeys are those on the island of Cayo Santiago, a small 40 acre island off the east coast of Puerto Rico. This colony was established by Carpenter in 1938 (4) and in 1965 there were 400 monkeys living there, descendents of the original group. A substantial number of monkeys is still there, but over the preceeding years, according to Koford (5), several hundred animals had been removed for laboratory studies. Koford (5) had stated that there were 277 monkeys on the island in mid-1959, and that they increased at the rate of about 15% a year from then on. One-fifth of the population is normally composed of infants, two-fifths are immature animals (1-3 years old), and two-fifths are sexually mature (four years old or more). It was found that reproduction was seasonal and practically all the infants were born during the first six months of the year. In 1960 there were 70 births; in 1961, 70; and in 1962, 88 births. The ratio of males per hundred females was as follows: 1960--81, 1961--102, 1962--89. The mortality rate of live births was five to ten percent.

BREEDING PROGRAM AT THE YERKES PRIMATE RESEARCH CENTER

In order to obtain animals which were psychologically normal, which were also largely free of pathology, and to ensure a reasonable rate of reproduction, it was decided to establish an open air breeding colony of rhesus monkeys at the Yerkes Field Station. Although the best arrangement would be to keep the animals in an enclosure which was large enough for the vegetation to survive their depredations, this would have required an extremely large area for the number of animals to be used and would be impractical for many reasons. The size of the compound was set at 125 feet square and the walls, 14 feet high, were constructed of chain link fencing wire with the top 8 feet lined with sheet metal to prevent the animals climbing out. There is no roofing. To one side of the compound was attached a mobile house 40 feet long, 8 feet high and 10 feet wide which serves for sleeping quarters. This was lined with fiber glass finished in epoxy paint and has two swinging doors opening into the compound. It is equipped with a heat pump to provide air conditioning and heating.

In the compound used, all vegetation was destroyed by the animals within a few months; even the bark of the trees was eaten. Occasionally, some rye grass seed is thrown on the grounds; some of it germinates and provides a partial grass cover for a portion of the year. Most of the time, however, apart from the monkeys, only the bare trunks of the trees can be seen inside the compound.

Inside the compound were placed a number of cement culverts about three feet in diameter; these provide cover in the compound for the animals most of which like to be out in the open all day. Some of the culverts had one end blocked by a sheet of wood so that in the winter the animals can still sit outside and be protected from the wind.

The animals have access to the open all through the winter when temperatures can fall over short periods to as low as 5°F. Only rarely there is a light fall of snow. The animals go outside even on the coldest days and occasionally have been known to get frostbite on the tips of their tails and fingers. If an animal is prevented from entering the heated quarters during cold nights, as a result of tension with other animals, warmth is provided in the open by a metal pipe, 18 inches in diameter, which projects 20 feet into the compound and is heated by a kerosene space heater placed at one end, outside the compound, which projects very hot air down the pipe. The animals can sit on or near it for warmth.

NUMBER OF ANIMALS

It was initially decided that a group of 50 animals would be desirable for the size enclosure to be used. This was to be composed of 45 females and 5 males. Most of these animals were collected from the Brooks Air Force Base in San Antonio, Texas and the Davis Primate Center, University of California. They were quarantined for thirty days in individual cages and tuberculin tested three times at two week intervals before being released simultaneously into the compound. Then followed some days of turmoil and fighting, resulting in many injured animals and a few deaths; the latter mainly due to injuries inflicted by the long canines of the males. These canines were subsequently removed from all the adult males, reducing the incidence of fatal injuries.

As in most monkey groups, these animals established themselves in hierarchies with an alpha male and various subdominant males; the females are similarly organized. Once the hierarchy is formed, the rigid organization with the alpha male remaining in control usually lasts for a long period of time (until the leader is challenged by one of the lower rated males). The closeness of the community with its rigid social structure made it impossible to add other animals to the colony. Males which were subsequently added were mangled within a very short time and some males required the removal of a testicle because of extensive scrotal injury. Females that were added were also badly injured. On two occasions females taken our for cesarean delivery because of dystocia were severely injured after reintroduction to the group and had to be removed from the colony. In these cases, the females had only been absent from the colony for a few weeks. For such animals and other newly acquired monkeys, which could not be placed in the main group, two subsidiary breeding colonies were set up near the compound in "corn cribs" which are cylindrical structures made of a meshwork of thick metal wire and a solid roof. Those used in these studies were 10-12 feet in diameter; they were set in a concrete foundation and equiped with a small heated box attached to one side for sleeping. They provide good housing accommodations for small groups of animals.

When the infants are born, they remain with the mothers for one year. They have an opportunity to play with their peers as well as having intimate contact with the mother. The weaning process is not completed in the rhesus monkey until a few weeks before the next delivery, so these animals are just weaned when they are finally separated from their mothers at the end of a 12 months period. For a variety of reasons, it has been decided to use males for the experimental studies which have been planned and special attention is paid to them.

Once the male infants are removed at the end of a year, they are placed in a special "corn crib" which is reserved for such animals. Usually about 7 or 8 males are harvested at a time. They remain together for another six months to a year and are subjected to biological and physical tests to establish them as good sound animals. If they are satisfactory they are moved from the open air housing at the Field Station to a specially constructed mobile house structure at the main Yerkes Center where they are placed in pairs in spacious cages 6 feet tall by 30 inches by 24 inches. They receive minimum contact from humans to reduce additional infection and then become available for detailed studies.

One of the many problems in wild-born animals is that they are usually heavily parasitized and parasite eggs drop to the ground. In tropical climates the ground in a compound would soon be so infested with eggs that they would be picked up by all animals including the young. The parasitologists at the National Center for Disease Control in Atlanta advised that the winters are cold enough at the Yerkes Field Station area to kill parasite eggs outside the animal's body. The animals are however treated annually with a broad spectrum antihelmintic, as a result very little parasitism has been seen. In addition to the antihelmintic the animals are given a yearly tuberculin test and general physical examination, at this time their weights are also recorded.

NUTRITION

Food provided in the breeding compounds and in the various stages following the removal of the animals is fundamentally the same. Conventional "Purina Monkey Chow" is served ad lib; in addition they receive half an orange each day per animal, together with vegetables such as carrots and cabbage. The "Purina Chow" contains added vitamins A and D and because it contains whole ground grain, it is adequate in vitamin B complex and also in vitamin E.

The infants so far produced by this procedure appear to be in fine physical condition and do not show the extensive pathology found in wild-born animals.

Although most of the original animals were collected by November, 1969 the compound was not in full operation until January, 1970. Some of the animals, when they were received, already had young infants and others were pregnant and gave birth during November and December. Existing young and those born in November and December 1969 are excluded from the figures for our births which are shown below.

BIRTH DATA

Number of Births

Year	Number Male	Number Female	Unidentified as to sex	Total
1970	9	4	1	14
1971	14	7	2	23
1972 (to 5-18-72)	8	1	2	11
Totals	31	12	5	48

Table IV

Number of Conceptions	Number of Females	Total
0	13	0
1	25	25
2	7	14
3	1	3
		42
	Unidentified as to mother	6
	Total	48

Table V

MORTALITY

Live Births

Total conceived 48
Total live births 41
Aborted or Still- 7 born

14.5% aborted or stillborn

Table VI

BIRTHS PER MONTH

1970	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10												
9												
8												
7												
6												
5												X
4												
3												
2					X	X	X				X	
1								X				
0	X	X	X	X					X	X		

1971	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10												
9												
8												
7												
6						X						
5					X		X					
4												
3												
2			X	X								
1		X						X	X			
0	X									X	X	X

1972	Jan	Feb	Mar	Apr	May (to 5-18-72)
10					
9					
8					
7					
6				X	
5					
4					
3					X
2			X		
1					
0	X	X			

TOTAL	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10					X							
9												
8				X		X						
7							X					
6												
5												X
4			X									
3												
2								X			X	
1		X							X			
0	X									X		

Table VII

COMMENT ON TABLES

Table IV indicates that the breeding colony has produced 48 young between January 1970 and mid May 1972, which represents an average of 21 animals per year, the original estimate prior to setting up the project was 20 infants a year. This number is expected to increase in future years. Another interesting fact from this table is that there have been 31 males and 12 females born. A neighboring colony of rhesus monkeys at the Yerkes Field Station belonging to another project showed a preponderance of female births. The Cayo Santiago Colony(5) produced over a four year period, a ratio of 81-118 males for each 100 females.

Table V indicates that 13 of the females have not yet given birth in the colony situation although three of them had given birth prior to January 1970. Twenty-five females have so far given birth to only one baby. It is believed that when these animals have their second infants, and some of them were pregnant at the time this paper was written, and when the 13 mothers who have not conceived yet begin to produce, we will improve substantially upon our 21 babies a year.

Table VI shows that 7 out of the 48 infants were aborted or stillborn. This represents a 14.5% mortality figure. This is almost identical with the figure of 15% given by Valerio(2) for the cage bred rhesus macaques of the Bionetics Laboratories. Koford(5) estimated only a 4% stillbirth rate for the Cayo Santiago free ranging group of rhesus, the observed figure was only 2.7%, but he points out that some mothers have their dead babies at sites where they are difficult or impossible to find. He is thinking only of stillbirths and it is possible that if we add losses of infants at an earlier stage of development which would be impossible to assess in their colony, the figure would probably be much closer to the 14-15% recorded by our colony and by Valerio(2).

Table VII shows the months when most births occurred during each year of the project. During the first year, 1970, the greatest number of births took place in June with another 7 born in the succeeding months. In 1972 the greatest number of births, 6, has been so far in April with 3 in May. More are expected in May and with the births in the succeeding months, the estimate of the total number of births for 1972 will be close to 20.

CONCLUSIONS

The procedure of breeding rhesus monkeys in 125 feet square open air compounds, has been found to be the most economical way to produce animals of high quality, relatively free of histopathology and behaviorally adequate. This procedure has also been successful in the number of animals it has produced. At the time of writing, two and a half years after establishment, the colony has nearly doubled its original number.

This appears to be a desirable method for the production of rhesus monkeys for biomedical investigations such as space related research where pathological changes may be small and difficult to distinguish from pre-existing pathology.

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HYBRID COMPUTING - A TECHNIQUE FOR THE IMMEDIATE ANALYSIS OF PHYSIOLOGICAL DATA

by

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SUMMARY

The archives and shelves of almost all aviation medical laboratories contain, in one form or another, volumes of experimental data for which there will never be a use. This situation stems in part from the difficulty of deciding how little data is sufficient to prove an experimental point, in part from poorly designed experiments, and in part from our inability to use data as easily as we can acquire it: it is with the last of these problems that this communication is concerned.

The essence of the solution must include a means for rejecting that part of the data considered to be of little importance; a technique for establishing the probable difference between two possibly similar recordings, or the probable similarity between two apparently different recordings; and the speedy processing of data, preferably but not necessarily carried out during the experiment. Much can be done with simple and easily understood statistics, a small hybrid computer, and the allocation of a little thought to the problem as a whole rather than to its isolated parts.

These processes will be illustrated by considering the real-time analysis of a multichannel electrophysiological recording, using uncomplicated mathematics and the parallel-serial hybrid computing installation at the RAF Institute of Aviation Medicine.

Multichannel continuous recordings have always been very much a part of physiological experiments, and hitherto the assessment of their meaning has been partly a matter of experienced opinion and partly a consequence of painstaking measurement with a ruler and pencil. The reputation which has been built around the abilities of modern computers leads almost everyone to believe that these machines must be capable of dealing quickly and objectively with recordings of this nature. Whilst computers - and in using this word most people are referring to a digital computer - can carry out their basic functions extremely quickly, those functions are on the whole of a kind which most of us could not use in attempting to read meaning into multichannel recordings. The execution of a single useful instruction on a digital computer may require the repetition of a few basic operations several thousand times. As a well understood example of the kind of record for which we should all wish to have some computer assistance, perhaps we could take the ordinary EEG; although a specific problem, the same considerations would apply to a variety of recorded data.

On the assumption that each EEG channel covers a frequency band extending from D.C. to 100Hz, then as a prudent investigator with a digital computer, we should expect to sample at a rate between 500 and 1000 samples per second; thus for an eight channel recording, which may reasonably occupy some 30 minutes, there would be 1000 x 60 x 30 x 8 separate measurements. Clearly this 16 million is by any standards a very large number, even though such an experiment would be a modest one. Extend the investigation to cover a night's sleep and several subjects, and we find ourselves faced with the problem of dealing with a volume of data which would not only cost a great deal to store, but would occupy much expensive computer time to acquire. One of the great contributions which computers ought to be able to make to the conduct of an experiment is to provide results so quickly that the immediate conduct of the experiment is determined by measurements which are being made at the time. If to our previous calculations we add this requirement too, then we should reach the surprising conclusion that the digital computer, for all its advertised speed, is incapable of dealing adequately with our problem.

Digital computers are probably in the public eye because of their impact on the commercial world or on those departments of science where relatively slow but extremely involved and precise calculations have to be made on very little data. There is however another potentially useful machine, the analogue computer; it will deal easily with almost unlimited quantities of fast on-line continuous data, but suffers from the disadvantage that it possesses no storage capacity and has only a limited accuracy, of the order of 1%. It treats inadequately many statistical calculations, and is poor at the solution of algebraic equations of the higher orders; but in a simple manner it is capable of solving simultaneously several high order differential equations which on a digital computer would be tedious to programme and difficult to execute quickly: moreover the analogue machine would deal with such problems at solution rates of 20,000 per second, a speed which not even the fastest digital computer could approach. Clearly it would be advantageous if the desirable characteristics of both these machines could be combined in one system: they can, and the combination would be called a "hybrid computer". Fig 1.

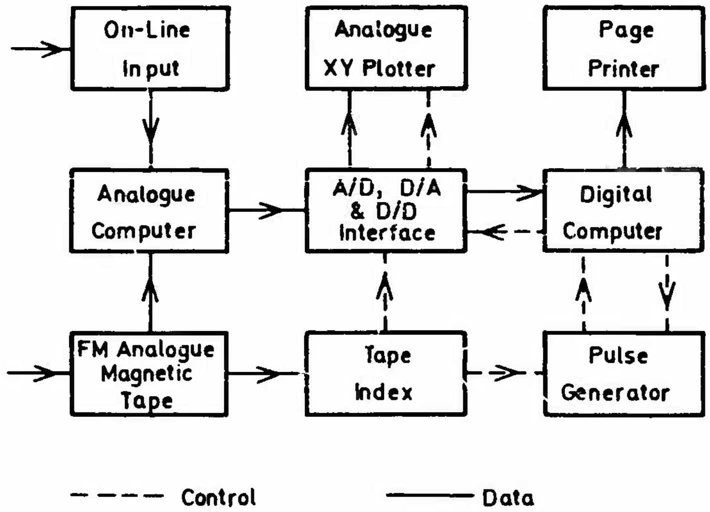


Fig 1.

Such a computer retains if required the individual abilities of both machines, but either section may pass to the other any function which its partner might carry out more competently. To this computer combination special purpose external devices, timers, analogue magnetic tape, trace recorders, and similar equipments may readily be added, the whole forming either a special purpose or a general purpose machine whose functions are determined by hardware and/or software.

As an example of a purely analogue operation, we may consider an analysis of the EEG during an experiment designed to assess the way in which cerebral electrical activity is affected by controlled hyperventilation (Byford, Hay & O'Connor (1)). From a bottled supply the subject is constrained automatically to breathe air at a steady 40 litres per minute through a standard RAF oxygen mask. Control is such that his respiratory rate is held at 20 beats per minute, but before an EEG recording is commenced the expired air PCO2 must have achieved a plateau level, usually 2 - 3%. Recording continues for one minute after the cessation of hyperventilation: left and right occipital and frontal leads are employed. The requirement is to display the time course of the EEG, to identify any features common to a group of subjects, and to make a quantitative assessment of changes within or between channels. The computer programme gives its output in the form of curves of signal variance, the slopes of which are an indices of the level of activity in each of five frequency bands into which the EEG is commonly divided (Byford (2)).

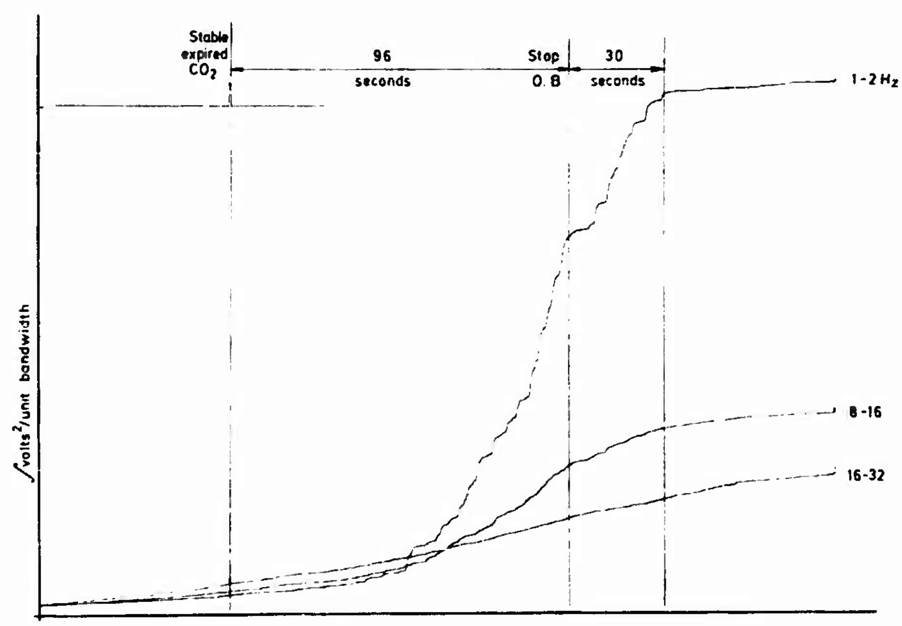


Fig 2. Time course of EEG activity in 3 frequency bands during controlled hyperventilation
Frontal electrode

From Fig 2 it will be seen that the expected delta activity (1 - 2 Hz) rises with increasing rapidity and is briefly inhibited following the instruction to cease overbreathing; delta rhythm is subsequently reactivated at approximately the level existing before the interruption. Some 30 sec after the instruction to stop, delta rhythm ceases abruptly and the resting state is restored. This finding has been shown to be maximal in the frontal region, as was expected, and to apply to about half the subjects tested: subjects either exhibited this pattern in full, or nothing at all.

The process which we have considered so far has in essence discarded a substantial part of the input data and summarised the remainder in pictorial form; this we believe may contain useful information in a more easily understood form. It would now be possible, with ruler and pencil, to make measurements which assist the usual experienced opinion; the curves lead also to a subjective assessment which might suggest possible lines of future development. Both the ruler and pencil calculations and the future development may demand some statistical process which would allow us to make comparisons between activities in the several frequency bands, within one frequency band, or between the same bands in different EEG channels. In any of these cases the calculations are best carried out in a digital computer, for which purpose we should convert to their digital equivalents, at a relatively low rate, the analogue electrical outputs from which the variance curves were produced. Activity thereafter will be centred around the digital computer, which is considerably more competent to carry out our statistical instructions.

An application of a different kind would be an on-line continuous analysis of certain characteristics of the electrocardiogram. For this purpose the electrocardiogram may be considered to be composed of a number of straight lines, arranged so that positive peaks would represent P, R and T waves, and negative troughs Q and S waves. We should require to know the time course of the amplitudes of R and T and of the durations P-Q, Q-R, R-S, S-T, and R-R. (This would leave four measurements which are sometimes attempted on the electrocardiogram but which in general would seem to have little justification. The amplitude of P is small and is contaminated by biological electrical noise of a similar amplitude; the beginning and end of P is equally difficult to assess for the same reason. The commencement of T is only on rare occasions as well defined as the illustrations in the text books would have us believe, there being in reality a gradual change following the S to the peak of T; and gradual changes are subject to large measurement errors.) All these values are readily obtained from each complex as it occurs, they involve the use of analogue computer components which will follow an electrical waveform and store the peak value

PROGRAMME A5

STARTING INDEX = 2103

******ABNORMALITY INDEXES******

R>T	2109	2137	2151
RT>RT'	0		
RP>RT	2113		
RQ>RP/8	2143	2213	
RS>RP/8	2197		

LIST OF INDEX NOS. AT WHICH PROGRAMME DEFINED ABNORMALITIES OCCURRED.

*****DATA HISTOGRAMS*****

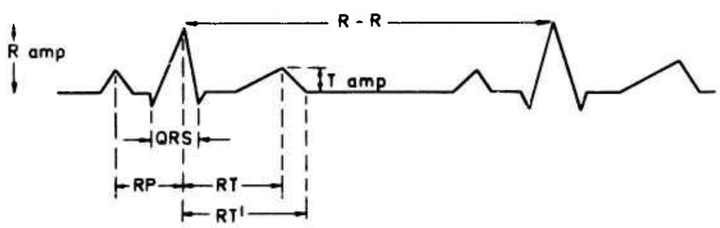
R-R	0	0	0	0	0	0	0	0
	12	33	147	21	19	17	7	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0

32 COLUMN HISTOGRAM OF 256 DATA VALUES FROM +0 TO +127 INCLUSIVE.

N = 256 MEAN = 84 S.D. = 5

SIMILAR HISTOGRAMS FOR:-

R-T'; R-T; R-P; RSx8; RQx8; T AMPLITUDE; R AMPLITUDE;



NON PARAMETRIC STATISTICS ARE USED TO PROVIDE AN OVERALL INDEX OF SIGNIFICANCE. EACH OF THE 8 DISTRIBUTIONS IS COMPARED WITH A PRE-ARRANGED STANDARD OR ANOTHER SERIES OF E.C.G. COMPLEXES.

E.C. 7A = OIII1OIO

Fig 3. A continuous on-line analysis of the electrocardiogram.

when asked to do so, integrators which produce a uniformly increasing voltage (an indirect measure of time) whose rise can be arrested on command, and simple electronic logic. The result of this analogue exercise is to produce for each complex, eight analogue values:-

RR interval
RT interval - T peak
QR duration
PR interval
RS duration
RT' interval - T end
R amplitude
T amplitude

which represent in condensed form one ECG complex. The arrival of the following complex causes the production of a transfer signal which moves these eight values simultaneously into the digital computer; here they are sorted into their appropriate categories, assembled into histogram form, and compared with standards previously set into the digital computer. If a comparison shows that any one of the measurements differs significantly from the standard, the digital computer takes note of this fact, and of the position of that complex along the analogue tape (indicated by a magnetic tape index). On completion of the analysis the digital computer prints in condensed form a comprehensive list of all those measurements it regards as "non-normal" together with their locations on the analogue tape, Fig 3. In addition, the "normal" measurements are combined with the standard so that the accumulated statistical reliability of the standard is improved.

These two short examples are illustrations which do less than justice to the flexibility of a complete hybrid system. Since digital input and output facilities are easily provided there is no problem in extending the system to include special purpose hardware which would not normally form part of the computer. Many commercial instruments are now available with facilities which allow them to be controlled by, or to control, a digital or analogue computer; the installation at The Institute of Aviation Medicine is for instance now capable of dealing automatically with several channels from an analogue tape recorder and to analyse this data without operator intervention. This may point the way to the solution of one of the most formidable problems associated with the analysis of electrophysiological data, since the next clear step in the programme is to continue the operation but at several times realtime in order that complete physiological examinations may be analysed either on-line as they progress, or off-line at a speed that permits a reasonably economical use of computers.

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AEROMEDICAL EVALUATION OF THE PHASED-DILUTION CONCEPT FOR OXYGEN BREATHING SYSTEMS

by

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SUMMARY

A phased-dilution oxygen breathing system which provides a bolus of oxygen followed by ambient air has been described by others. This series of studies was designed to compare the relative effectiveness of phased-dilution with current demand-diluter oxygen delivery systems in artificially ventilated dogs and in seated, quietly breathing humans.

The arterial oxygen tension approximately doubled in the canine model with the phased-dilution oxygen delivery when compared with comparable quantities of premixed oxygen at ground level and at simulated altitudes of 10,000 and 18,000 feet in a decompression chamber.

Arterial oxygen tensions in humans breathing in a random fashion have been higher with the phased-dilution oxygen delivery system than with comparable quantities of premixed oxygen. Human arterial oxygen tensions measured with the phased-dilution technic at ground level and in a chamber at subatmospheric pressures equivalent to altitudes of 10,000 and 18,000 feet have been less than predicted from the canine work. It appears that this more limited effectiveness is closely related to a "respiratory dead space effect" and is influenced by frequency and depth of breathing with a fixed bolus.

INTRODUCTION

New developments in both electrochemical and adsorption-desorption technics for the limited extraction of oxygen from air during flight has prompted new efforts to determine the most effective and economical system for oxygen delivery to the flyer. The concept of phased-dilution delivery, stemming originally from the rationale underlying the BLB oxygen mask (1), has suggested new approaches for the development of such oxygen delivery systems. As proposed and studied by the RAF group at Farnborough, particularly Roxburgh (2) and Ernsting (3), and the FAA study by McFadden, et al (4), this concept hypothesizes that "with a fixed rate of oxygen flow, a breathing system which delivers at the mouth and nose a volume of oxygen at the beginning of each inspiration and in which the remainder of the inspirate is air, should produce a higher oxygen tension in the lungs than a system which delivers the same volumes of oxygen and air thoroughly mixed to the respiratory tract" (3). The present effort has been to examine further the effectiveness of this concept and its potential for application in aircraft oxygen systems.

ANIMAL STUDIES

Methods. During the first portion of this evaluation, the anesthetized dog was used as a physiologic analogue for pulmonary ventilation and gas exchange in the lung. A delivery system was developed for use in the laboratory whereby a precise volume of oxygen could be delivered in the form of a "bolus", immediately followed by a precise volume of nitrogen or air, to the respiratory tract of the anesthetized dog. This could be accomplished on a breath by breath basis. The instrumentation basically included two synchronized volume displacement pumps, a 700 ml Harvard respirator pump and a 100 ml syringe driven by a modified servospirometer. Each could be preset within their limits to any desired volume and with appropriate microswitches, solenoids and valving, would deliver oxygen in the bolus form prior to air or nitrogen delivery. In this way, it was possible to compare the arterial oxygen tension (P_{aO_2}) resulting from "phased" delivery with that resulting from "premixed" gas delivery, providing the tidal volumes and frequencies of breathing were held constant in each case. Comparisons were initially made at ground level using oxygen/nitrogen mixtures approximating the physiological altitude equivalents of sea level, 10,000 feet and 18,000 feet. The equivalent percentages were calculated on the basis of saturated inspired tracheal oxygen tensions (P_{IO_2}). The arterial oxygen tensions resulting from exposure to these gases at ground level were subsequently compared to values obtained at subatmospheric pressures of 10,000 and 18,000 feet.

Five mongrel dogs, ranging in weight from 20-30 kg, were deeply anesthetized with sodium pentobarbital (Nembutal) and intubated with a hard rubber cannula. An inflation cuff near the distal end of the tracheal tube was filled with saline to effect an air-tight seal. In later studies, experimental conditions were repeated using a mask molded to provide a gas tight seal about the dog's muzzle instead of the endotracheal tube. The use of the tracheal tube in the earlier studies decreased the respiratory dead space below normal while the mask increased the dead space to about twice normal.

An indwelling arterial catheter was inserted into the femoral artery for collection of arterial blood samples. Blood gas determinations were made with an Instrumentation Laboratories Instrument, Model 313, at 37° C and corrected to the animal's rectal temperature. Arterial blood gas measurements were obtained using a wide variety of tidal volumes, breathing frequencies and respiratory minute volumes, both at ground level and at subatmospheric pressures equivalent to 10,000 and 18,000 feet. Thus, a large number of possible breathing situations have been tested with the canine model.

Results and Discussion. Arterial oxygen tension data are shown graphically in Figure 1 in which oxygen/nitrogen mixtures simulating air at ground level, 10,000 feet and 18,000 feet were breathed with a fixed tidal volume of 300 ml at a constant respiratory frequency of 12 breaths per minute. It is interesting to note in this figure that not only is the arterial oxygen tension about twice as great with phased-dilution compared to the premix values, but also the arterial oxygen tension with phased-dilution at the simulated hypoxic altitude of 18,000 feet is higher than at 10,000 feet when breathing the premixed oxygen/nitrogen.

Figure 2 shows the effect on the arterial oxygen tension with a fixed tidal volume of 200 ml, when the frequency of breathing was changed from 8 breaths/min up to 32 breaths/min resulting in different respiratory minute volumes from 1.6 liters/min to 6.4 liters/min. The faster the frequency, with a constant tidal volume, the larger the respiratory minute volume and pulmonary ventilation and the higher the arterial oxygen tensions with phased-dilution. In contrast, using the conventional premix condition, the arterial oxygen tension remained about the same at all frequencies tested.

Figure 3 shows the effect on the arterial oxygen tension when the tidal volumes and frequencies are changed in such a manner as to maintain a constant minute volume (tidal volume X frequency) of 3.2 liters/min. In this situation with phased-dilution, when the anesthetized animals were being mechanically ventilated through an endotracheal tube (smaller than normal respiratory dead space), the smaller the tidal volume and the faster the frequency, the higher the arterial oxygen tension. On the other hand, with the premix delivery method, the arterial oxygen tension remained essentially the same regardless of the combinations of tidal volume and frequency used to ventilate the animal.

Previous data having suggested a substantial potential savings in oxygen when the phased-dilution delivery method was used (Figure 1), the data in Figures 4 and 5 were acquired at subatmospheric pressures of 10,000 and 18,000 feet, respectively, using 50% less oxygen from the supply during the phased-dilution portion of the study. Air instead of nitrogen was used to follow the oxygen bolus at the subatmospheric pressures. The amount of oxygen in the air was taken into account when calculating the size of the oxygen bolus. A sea level equivalent oxygen/nitrogen mixture was used in the premix portion of the study. Experimental runs were conducted at subatmospheric pressures simulating 10,000 feet and 18,000 feet, thus simulating the range of cabin altitudes in current aircraft. Using this experimental design it was possible to simulate performance of the ideal conventional diluter-demand system at altitude and compare its effectiveness and oxygen economy with that of phased-dilution in which the amount of oxygen taken from oxygen stores was reduced 50%. Tidal volumes and respiratory rates were again changed so as to maintain a respiratory minute volume of 3.2 liters/min. Phased-dilution, with the reduced amount of oxygen, still produced arterial oxygen tensions which were about equal to those obtained with the diluter-demand (premix) method. Again, with phased-dilution, the highest values were seen at the lower tidal volumes and higher frequencies. This effect was probably due to a minimal dilution of the oxygen bolus with air.

As mentioned above, the endotracheal tube substantially reduced the respiratory dead space and possibly produced a less turbulent gas flow than that seen in normal respiration. In order to determine the effects of a larger respiratory dead space and more normal flow pattern, silicone rubber face masks were fabricated for each dog and used in place of the endotracheal tube. This innovation significantly increased the respiratory dead space and provided a potential mixing chamber for the oxygen bolus and the following nitrogen. Figure 6 shows results obtained with tidal volumes of 400, 300 and 200 ml used in combination with respiratory rates of 16, 21 and 32 breaths/min, respectively. Identical volumes of oxygen and nitrogen were used in both phased-dilution and premix portions of the study. It is interesting to note that although arterial oxygen tensions were still approximately doubled with phased-dilution when compared to premix values, the slower frequencies and larger tidal volumes produced the highest values with phased-dilution. This is in contrast to results obtained with the endotracheal tube (small dead space), where the highest arterial oxygen tensions were seen with smaller tidal volumes and higher frequencies. Using the canine mask, the lowest arterial oxygen tensions were seen with a tidal volume of 200 ml and a rate of 32 breaths/min. This could possibly be attributed to a greater turbulence and mixing of the oxygen/nitrogen at higher frequencies and/or decreased alveolar ventilation since there was also a slight decrease in arterial oxygen tensions obtained with the premix method. Theoretically, when the respiratory tidal volume is equal to or is smaller than the dead space, only the nonfunctional dead space is ventilated and essentially no inspired gas reached the lungs and a decreased oxygen tension is reflected in the arterial blood. The larger the dead space, the larger must be the tidal volume for adequate pulmonary ventilation.

Figure 7 graphically depicts arterial oxygen tensions when the oxygen bolus was reduced 50% compared with ground level premix oxygen/nitrogen values. This portion of the study conducted with a canine mask and therefore a more normal flow pattern and larger dead space again demonstrated that the phased-dilution method produced a greater than 50% potential savings of oxygen at all combinations of tidal volume and respiratory rates used.

At the onset of this study, there was reason to believe that some benefit could be obtained from phased-dilution oxygen delivery, especially at lower cabin altitudes in the range of 10,000 feet to 18,000 feet. This primarily stems from saving the oxygen normally contained in the respiratory "dead space". If it is assumed that during quiet normal breathing, approximately 1/3 of the respiratory tract is taken up by conducting, non-diffusional airways (5), a savings of approximately 35% oxygen could be anticipated. The savings were actually higher than anticipated and cannot totally be explained on a "dead space" basis, i.e., if anything the dead space was reduced below normal in studies using an endotracheal tube. These savings of approximately 50% may, in part, be explained by a gradual build-up of oxygen in the lung resulting from the repeated phasing of pure oxygen with each respiratory cycle. In addition, this apparent effectiveness may have also been augmented by the slightly increased positive pressure in the lung that was generated intermittently by the respirator pumps.

HUMAN STUDIES

Methods. Studies are continuing with seated, resting human subjects at altitude with relatively uncontrolled breathing patterns to confirm the initial findings with the canine model. The instrumentation for this phase of the study basically consists of a 1-liter spirometer which serves as the reservoir for the oxygen bolus and an A-14 regulator which provides nitrogen or air as required for the second gas in phased delivery. An additional 28 liter Collins spirometer is used on the outflow for collection of expired gas. The breathing mixtures are delivered on demand through a low dead space Rudolph valve and mouthpiece, with appropriate microswitches and solenoids. In this way, a preset bolus can be delivered to approximate any oxygen percentage within the range of normal tidal volumes. No attempts were made to control the subjects' breathing patterns other than encouraging them to relax. With this technic, subjects with various breathing patterns can be evaluated and the general efficiency of phased delivery approximated. Arterial blood was collected from an indwelling arterial catheter which was inserted into the brachial artery. Normal resting tidal volumes were measured while the subject was breathing premixed compressed air from the phased-dilution breathing apparatus. These tidal volumes remained the basis for bolus size throughout the entire run even though tidal volumes did change slightly thereafter. During any one measurement, the bolus size could immediately be determined from the bolus reservoir spirogram while the mean tidal volume was calculated from the expired gas spirometer. In this way, the equivalent premixed percentage of oxygen, plus compressed air, could be determined for the specific collection period. Oxygen/nitrogen phasing was completed at ground level only with oxygen/compressed air being used at subatmospheric pressures of 10,000 and 18,000 feet. In all cases, the subject remained on each experimental gas mixture for 15 minutes. Arterial blood was also drawn for analysis with the subject breathing from the diluter-demand (MD-1) regulator. These data can be used subsequently to determine the efficiency of presently available oxygen delivery systems.

Results and Discussion. Eight experiments with human volunteers have been conducted to date. Table I gives data obtained from three subjects with different breathing frequencies and tidal volumes. Since the size of the oxygen bolus was determined on the basis of tidal volumes recorded during control runs on compressed air at ground level, the percentage of oxygen during each phase of the experiment varied in proportion to subsequent changes in tidal volume. Arterial oxygen tensions were calculated for equivalent premix delivery F_{IO_2}'s using the alveolar gas equation (6).

Table I demonstrates that phased-dilution is more effective at higher frequencies and smaller tidal volumes (a similar finding in the canine work using an endotracheal tube (Figure 3)). The relative effectiveness of phased-dilution is nevertheless lower than one might anticipate or extrapolate from work with the canine model. The relative effectiveness with humans appears to be closely related to a "respiratory dead space effect" and higher tidal volumes (lower relative dead space) and slower breathing rates result in a reduced relative effectiveness.

The apparent decreased relative effectiveness of phased-dilution at 10,000 feet when compared with ground level and 18,000 feet can be explained by taking into consideration the relatively much smaller size of the bolus required at 10,000 feet. A considerable amount of the calculated oxygen for a sea level equivalent mixture is contained in the air portion and is wasted in the "dead space."

Initial studies with the canine model indicated a potential savings of approximately 50% when phased-dilution is compared to an equivalent oxygen/nitrogen premix. This was larger than one would have predicted from previous RAF data (3, 7). It is possible that the increased positive pressure in the dogs' lungs from respirator pumps contributed to this effect as well as a more even ventilation/perfusion ratio in the supine position.

Table II shows arterial oxygen tensions obtained while the subjects were breathing from a diluter-demand (MD-1) regulator. The waste of oxygen using this system is obvious, particularly at ground level and 10,000 feet.

This study indicates that the economy achieved with phased-dilution appears to be closely related to the volume of the respiratory dead space (about 150-200 ml per breath). This amounts to a savings of approximately 30% during quiet breathing at rest with normal tidal volumes and rates. With larger tidal volumes and a proportionately smaller dead space, the relative effectiveness of phased-dilution became proportionately smaller. When large tidal volumes are combined with progressively slower breathing frequencies, the arterial oxygen tensions with both diluter-demand and phased-dilution would decline to lower and lower levels with prolonged breath-holding or apnea. The act of talking is, in a sense, one form of breath-holding, resulting in a low breathing frequency, but usually with an increased tidal volume to maintain an adequate minute ventilation and arterial oxygenation. Anti-G straining maneuvers would also result in this breathing pattern.

The effect of an oxygen mask with its increased dead space and possible inboard leakage and mixing will be studied.

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The animals involved in this study were maintained in accordance with the "Guide for Laboratory Animal Facilities and Care" as published by the National Academy of Sciences--National Research Council.

The voluntary informed consent of the subjects used in this research was obtained in accordance with AFR 80-33.

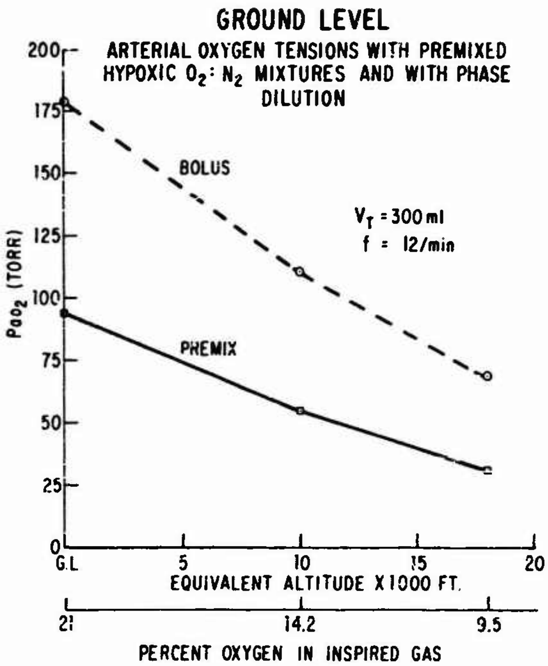

Fig. 1

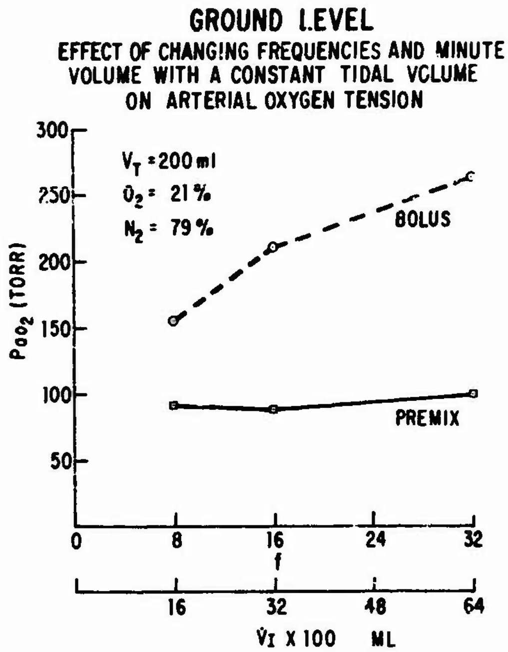

Fig. 2

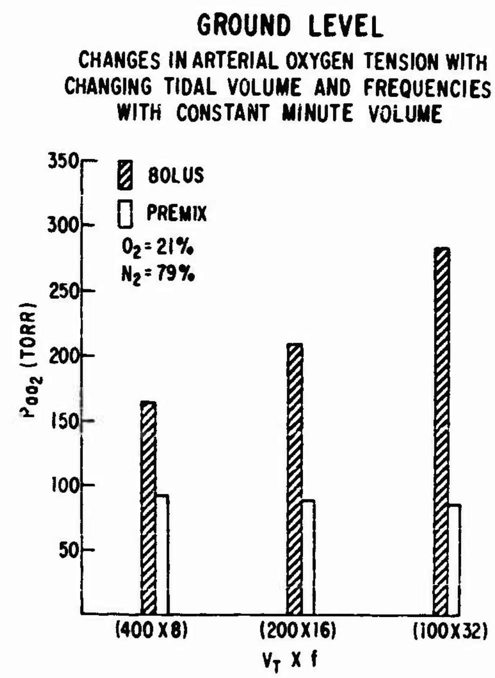

Fig. 3

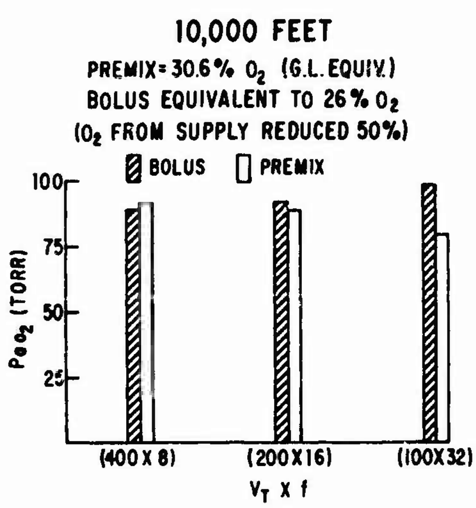

Fig. 4

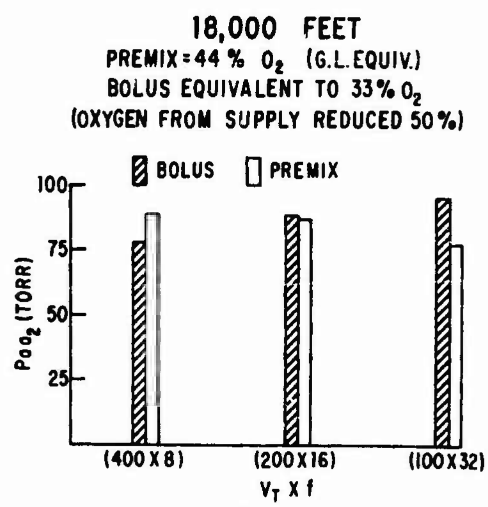

Fig. 5

DATA IN FIGURES 1 - 5 OBTAINED FROM CANINE PREPARATION USING ENDOTRACHEAL TUBE.

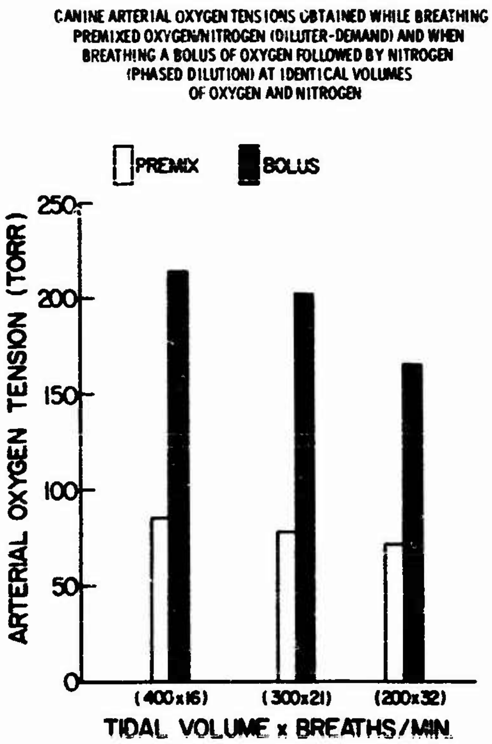

Fig. 6

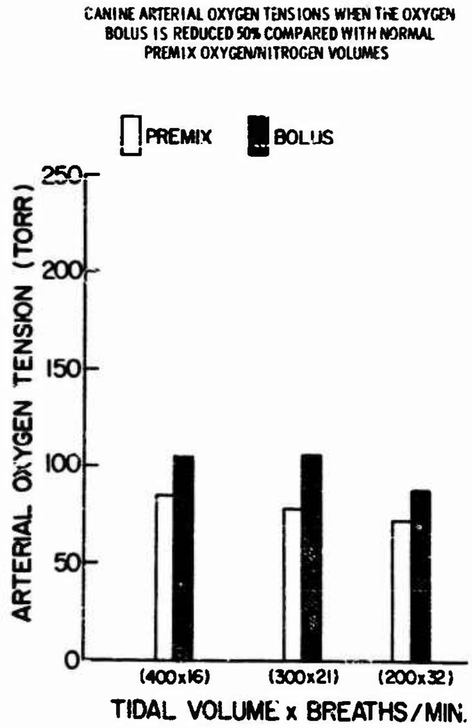

Fig. 7

DATA IN FIGURES 6 AND 7 OBTAINED USING CANINE MASK.

TABLE I

RELATIVE EFFECTIVENESS OF PHASED DILUTION IN INDIVIDUALS WITH DIFFERENT BREATHING FREQUENCIES AND TIDAL VOLUMES

Subject	Altitude (feet)	$F_{I_{O_2}}$	f	V_t	$P_{a_{O_2}}$ (torr) Calc Premix	Bolus	Increased Effectiveness (%)
I	G.L.	.21	5	975	* 90	-	-
	G.L.	.18	4	1139	70	80	13
	10,000	.30	5	1024	86	96	10
	18,000	.47	5	917	98	121	20
II	G.L.	.21	10	769	* 92	-	-
	G.L.	.23	10	735	110	150	26
	10,000	.31	10	777	93	116	20
	18,000	.48	11	702	104	142	27
III	G.L.	.21	13	412	* 83	-	-
	G.L.	.19	12	473	62	132	53
	10,000	.28	13	470	69	89	22
	18,000	.44	13	435	79	131	40

* Actual value with premixed compressed air through phased dilution apparatus

TABLE II

ARTERIAL OXYGEN TENSIONS WHILE BREATHING FROM DILUTER-DEMAND OXYGEN DELIVERY SYSTEM

Subject	Altitude (feet)	f	V_t	$P_{a_{O_2}}$ (torr)
I	G.L.	5	1007	285
	10,000	5	1016	200
	18,000	5	1055	148
II	G.L.	-	-	-
	10,000	-	-	173
	18,000	-	-	103
III	G.L.	10	522	275
	10,000	11	478	187
	18,000	13	464	139

DISCUSSION

JONES

Do you know if the U. S. Air Force intends to utilize this concept in oxygen regulators of the future?

KRUTZ

They are considering it. We still have to quantify the effects. The effectiveness of phased-dilution seems to be decreased in humans with large tidal volumes and slow breathing rates. This would make it difficult to use in fighter aircraft where one is pulling high g-loads, grunting, straining, and breathing very seldomly. Absorption atelectasis is another problem to be considered when using 100 percent oxygen delivery systems. Further tests on regulators of this type are continuing.

IRELAND

Is this system work being done in conjunction with the joint USAF/USN/NASA Project to develop advanced oxygen generation systems from ambient air?

KRUTZ

Yes. Current oxygen generating systems produce pure oxygen in limited quantities. It is necessary, therefore, to find the most economical and efficient method of delivering this oxygen to the aircrew member.

JONES (comment)

In the United States, to reduce oxygen logistics, there is a program to manufacture oxygen from the air inflight. This eliminates the need for refilling oxygen tanks on landing.

SPECIALIZED ANTHROPOMETRY REQUIREMENTS FOR PROTECTIVE-EQUIPMENT EVALUATION

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SUMMARY

Anthropometry has been considered from the point of view of its application to problems of protective-equipment evaluation, design of human impact-acceleration experiments, and description of flying personnel populations. The difficulties of supplying data for all three areas of endeavor are discussed. A three-dimensional anatomically referenced basis for recording anthropometric data is offered as an adequate approach. Coordinate systems for the head and the first thoracic vertebral body are described.

I. INTRODUCTION

Anthropometry has an extensive and diverse history as applied to the designs and specifications of practically every type of equipment used by man. The definition of anthropometry as a study of human body measurements is sufficiently broad to include the detail and diversity inherent within the history of anthropometry. One approach to understanding the history of anthropometry is to consider the evolution of anthropometric measurement techniques. Three major approaches can be noted. The first is a formal method, measuring various aspects of the size and shape of selected military populations, which was applied to the U. S. Air Force and reported by Hertzberg et al.[1] This basic approach has been subsequently reapplied to many other selected military populations. As a result, data on a large number of carefully defined measurements, taken with standard instruments, according to standard procedures have been developed. This data base serves as a set of statistical descriptors of the populations studied. The second approach is of necessity not formally defined. It involves small independent efforts in equipment design that require special measurements not previously defined and for which there is no data base. The types of measurements usually involve special functional motions required of an operator. Efforts to supply a broad base of data concerning functional motions of human subjects were reported by Dempster[2] and Damon et al.[3] Regardless of the extent of such measurements there is a continual requirement for data on the "unmeasured variable". The third approach encompasses a series of individual efforts to determine some of the mass distribution parameters of human anatomical segments. With consideration of the above approaches, it is the purpose of this paper to examine the requirements for certain specialized anthropometric data techniques and to propose methods of meeting these requirements.

II. ANTHROPOMETRY IN IMPACT PROTECTIVE EQUIPMENT

The detailed relationship of anthropometric data to impact protective equipment can be well demonstrated by two major types of equipment, the aviator's helmet and the aviator's restraint system. The aviator's helmet with some level of impact protection designed into the helmet can be evaluated and ranked sequentially for impact resistance by means of testing[4] based on the American Standard Specifications for Protective Headgear for Vehicle Users (Z-90).[5] Each of these procedures is critically dependent on anthropometric data of the human head. The position of the test helmet relative to the head form is standardized in relation to an anatomical plane dependent on Reid's base line, which is in the Frankfort horizontal plane. Reid's base line is derived from a line from the external auditory meatus to the floor of the bony rim of the eye socket. Also, the mass, center of gravity, and the mass moment of inertia of prospective protective helmets can be tested.[6] Using these test procedures, helmets have been compared.[4,6] The understanding of the implications of these data is limited by the lack of data available on the center of gravity and mass moment of inertia of the human head. To completely specify the difference between the unhelmeted head or head and neck, and the helmeted head or head and neck, the mass, center of gravity, mass moment of inertia, and principle axes of the human head and neck must be known. Furthermore, the data must be expressed relative to a reference frame that can be related to the test procedure. The degree to which human data are available is the limitation on interpretation of engineering test procedures already available.

The aviator's restraint system presents a requirement for even more detailed and comprehensive anthropometric measurements. In some respects if the restraint system is completely effective, the impact protective capabilities of the helmet are superfluous, since direct impact to the anatomy should be avoided. The ability to predict avoidance of direct impact is dependent on detailed knowledge of motions of the anatomy throughout the impact event. The motion relative to the aircraft structure must be known in sufficient detail to assure that no part of the anatomy impacts with the structure. It should be noted that sufficient space for an unhelmeted aviator to avoid cockpit structures may be insufficient for the helmeted aviator because of the added size of the helmet. Furthermore, the motions would have to be predictable based on the size and shape characteristics of the user pilot population.

The Naval Aerospace Medical Research Laboratory (NAMRL) Detachment in New Orleans, Louisiana, has adopted a basic experimental approach of measuring the exact kinematic response of selected anatomical portions of human volunteer subjects to impact acceleration. Each of the factors affecting evaluation of the aviator's helmet and restraint systems was of major consideration in establishing the experimental design and subject selection reported by Ewing et al.[7,8] Experiments have been completed for mid-sagittal planar motion of the head and neck for 236 runs conducted on human subjects,[7-9] during a U.S. Army-Navy program at Wayne State University. This experimental approach is being extended in order to conduct human experiments in which a three-dimensional response is anticipated. The kinematic measurements are considered to be basic observations that must be known to design and evaluate systems intended for the protection of man experiencing high, short-duration impact forces. From the kinematics it is theoretically possible to infer the dynamics. Knowledge of the dynamics is considered a necessary prerequisite to the design and validation of anthropometric dummies required for evaluation of protective systems.

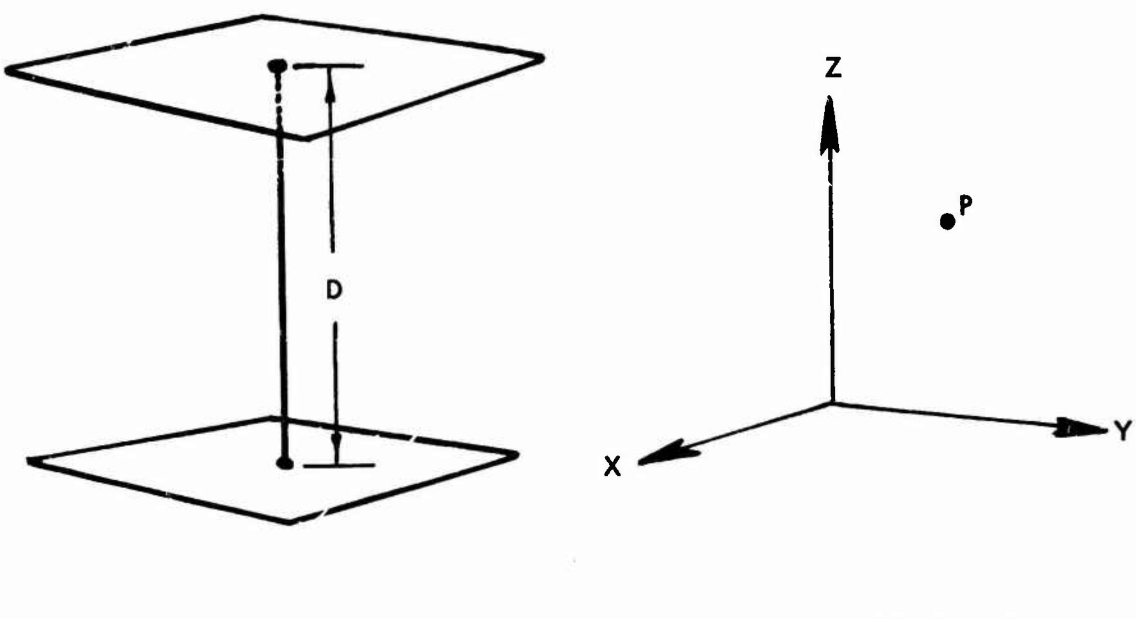
These examples of problems of impact-protection equipment evaluation and experiments to provide basic human data establish the basis for this review of the suitability of currently available anthropometric data.

III. CURRENTLY AVAILABLE ANTHROPOMETRIC INFORMATION

Impact protective-equipment design requires knowledge of the complete scope of human mechanics. To support this study of human mechanics, anthropometric data can be divided into three major categories:

1. Population descriptors
2. Three-dimensional anatomical descriptors
3. Mass distribution parameters

The first category, as applied to U.S. military aviation personnel, is best exemplified by two notable reports, one by Hertzberg et al,[1] and the other by Gifford et al.[10] The majority of measurements recorded in these reports were of two types. The first type involved the measurement of the distance between a plane established at one point on the anatomy and a parallel plane established at a second point. The second type was an arc-length measurement over the surface of the body. The measurement techniques and the descriptions of selected populations by these measurements have been extensively documented. The geometrical nature of the measurement between planes is illustrated by the left hand drawing in Figure 1 and can be contrasted to detailed three-dimensional measurements which are illustrated in the right hand drawing in Figure 1. Because this type of measurement between planes has no relationship to classical mechanics, I have called them population descriptors. They constitute the data base for statistical description of the size and shape of the sampled population but they cannot be used directly as an analytical basis for human biomechanics. Their value is evident from the fact that the measurements of stature, sitting height, and eye-sitting height have become well known to cockpit committees on cockpit design. Furthermore, the measurements serve a vital function in characterizing the range of size of the sample population. Without this information it would be impossible to select human subjects for experiments or equipment evaluation with any assurance that a representative sample had been selected.



Geometry of Straight Line Anthropometry Measurements (D)

Geometry Required for Expression of Reference Points (P) in Terms of X, Y, Z Coordinates

Figure 1. Comparison of Alternate Geometrical Approaches to Recording Anthropometric Data.

The second category of anthropometry can provide an analytical basis for human kinematics. Measurements in this category require three-dimensional descriptions of each rigid portion of the anatomy, along with a description of their interrelations in standardized measurement positions. Such a description involves many complications. Each portion of the anatomy of interest must be represented by a three-dimensional coordinate system linked to the anatomy. The relation of one part of the anatomy with respect to another requires a description of three coordinates and three angles. This concept is illustrated partially in the right hand drawing in Figure 1. General measurement techniques and standardized measurement postures for this category of anthropometry have not been worked out. However, specialized efforts which are of considerable scope and similar in concept have been reported.[2,3] What is primarily lacking are agreed upon three-dimensional coordinate systems derived from anatomical segments and methods of observing the landmarks necessary to describe these coordinate systems. The importance of such coordinate systems will become even more evident when mass distribution anthropometry is considered.

The last category of anthropometry requires the determination of mass distribution parameters of human anatomical segments. Various attempts to document the mass, center of gravity, and mass moment of inertia of anatomical segments have been reported in the literature. A selection of information from head and neck measurements is summarized in Figure 2. Figure 2 includes most of the data available up to 1967 on the head and neck. These data[2,11,12] render stable statistical estimates of population values extremely unreliable.

Head and Portion of the Neck

Source	Weight (gm)	Center of Gravity (cm)	Moment of Inertia*	Specific Gravity
Harless (1857)	4555	7.7 from crown 13.5 from chin		
Braune & Fischer (1889)	5350	In median plane near clivus, near basilar suture below slope of sella turcica		
	4040	In Fossa Tarin's behind the slope of the sella turcica in the median plane		
	3930	0.7 cm behind the slope of the sella turcica in the Fossa Tarin's and in the angle formed by the upper edge to the bridge with the posterior lamina perforata		
Dempster (1955)	3797	8 mm anterior to basion on the inferior surface of the basiocccipital bone or within the bone 24.0 ± 5.0 mm from the crest of the dorsum sellae. On the surface of the head a point 10 mm anterior to the supratragic notch above the head of the mandible is directly lateral	0.22×10^6	1.12
	5227		-------	1.13
	4348		-------	1.12
	5337		0.31×10^6	1.10
	4850		0.23×10^6	1.10
	4371		0.32×10^6	1.10
	4340		0.39×10^6	1.11

* Presumably in cgs units with moment of inertia about an axis normal to the mid sagittal plane through the center of gravity.

Figure 2. Summary of Human Head and Neck Mass Distribution Data from Various Sources.[2,11]

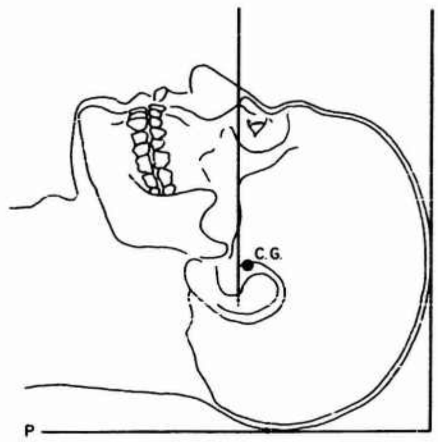
Attempts were made to locate the center of gravity relative to the anatomy. The locations are described in Figure 2 and serve as an approximate method of locating the center of gravity. However, the anatomical features that were used as references were distributed areas, and no attempt was made to derive three-dimensional anatomical coordinate systems from these features.

The moment of inertia measurements illustrated in Figure 2 are limited to one value of the moment of inertia tensor from each of 5 specimens. The values are in centimeter-gram-second units and are about an axis normal to the mid-sagittal plane through the center of gravity of the head. Due to bilateral symmetry the value presumably approximates one of the three principle moments of inertia. Information pertaining to the complete description of the moment of inertia tensor of anatomical segments is completely lacking.

Fujikawa[12] reported a series of measurements of human heads. His positions for the center of gravity of the head were described pictorially and were located approximately by description of anatomical features. Practical application of these data is limited because of the imprecision inherent in transferring the pictorially registered points to a live subject.

Clauser et al[13] reported on 13 cadavers tested under carefully controlled circumstances. The measurements of the head included the mass and position of the center of gravity. The head was positioned with the Frankfort plane parallel to a superior plane. The center of gravity coordinates are given in two dimensions along the superior and posterior planes relative to the origin formed by their intersection.

.he geometrical nature of the measurement is shown in Figure 3. No moments of inertia were reported. This approoch most nearly relates to the approach taken at our laboratory, and under an Office of Naval Research (ONR) contract performed at Tulane University[14] for the description of mass distribution characteristics of anatomical segments.



C.G. = CENTER OF GRAVITY OF HEAD
F = FRANKFORT PLANE
S = SUPERIOR REFERENCE PLANE
P = POSTERIOR REFERENCE PLANE

Figure 3. Illustration of Geometry of Head and Neck Data from Caluser et al.[13]

IV. P OPOSED METHOD OF DESCRIBING MASS DISTRIBUTION CHARACTERISTICS

To propose a systematic method for recording mass distribution parameters, it is first necessary to list the requirements for such a method. These requirements derive from previous consideration of the problem of engineering design and evaluation of impact protective equipment, currently available data on mass distribution characteristics of humans, and experimental design of studies to observe the kinematic response of humans. The one major requirement that has been well recognized is the one for a precise statement of the anatomical dissection of the segment to be measured, along with careful control of the dissection and measurement procedure to prevent changes in the specimen. Major additional requirements are:

1. Mass distribution parameters must be expressed in coordinate systems derived from the anatomical segment.

2. The coordinate system must be three dimensional and must be derived from specified points on the anatomy that can be visualized by a three-dimensional observation technique.

3. Anatomical segments that are not rigid must be held rigidly in a completely described geometrical position.

4. Additional anatomical features of importance for any engineering test and evaluation procedure must be expressed in terms of the three-dimensional anatomical coordinate system, which is used to describe the mass distribution parameters.

5. The basic anatomical coordinate systems should be derived from anatomical points that yield center-of-gravity-position coordinates and moment-of-inertia-direction coordinates with the least population variance.

The NAMRL Detachment has established a standardized three-dimensional anatomical coordinate system for observations on the human head. Four points on the head are labeled with radiopaque markers. The points are on the skin over the left and right infraorbital notches and at the superior edge of the left and right external auditory meati. The origin is at the midpoint of the left and right external auditory meatus markers. The +Z axis is from the origin in a cephalad direction perpendicular to the plane formed by the +X axis and the line between the auditory meatus markers. The +Y axis is from the origin toward the left ear perpendicular to the XZ plane. The XZ plane is considered the mid-sagittal plane and is illustrated in Figure 4. X-rays have been taken of live subjects with calibration of the +X, +Z plane. The subjects were volunteers used in 236 human impact-acceleration experiments conducted in 1968 and 1969. A sample x-ray is shown in Figure 5. Preliminary results of the kinematic response of the head anatomical coordinate system were reported by Ewing et al.[7] Furthermore, this is the precise anatomcial coordinate system that has been used in a determination of the mass distribution parameters of head and head and neck specimens under an ONR contract with Tulane University.[14]

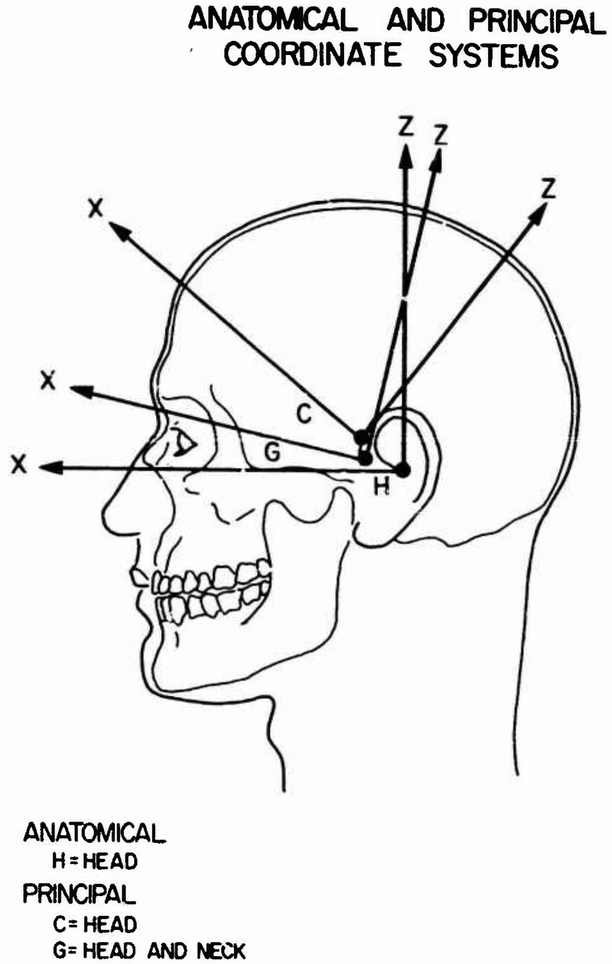


Figure 4. Illustration of Head Coordinate Systems.

Four of the five major requirements, previously enumerated, are met for this particular coordinate system. The first requirement is met by labeling points on the anatomy, the second by labeling sufficient points to construct a three-dimensional orthogonal coordinate system. The anatomical segment is rigid and can be viewed by x-ray, which meets the third requirement. The fourth requirement is met to the extent that future unanticipated engineering test and evaluation procedures can be supported by information available from existing x-rays.

Fulfillment of the fifth requirement requires extensive evaluation. It is possible that other coordinate systems would yield less variation of the average position of the center of gravity or average directions of the moment of inertia components. This can only be resolved statistically be repeated measurements on many specimens and an empirical elimination of other candidate anatomical coordinate systems.

In principal this approach, using x-rays and defined anatomical points to establish three-dimensional anatomical coordinate systems, can be extended to other anatomical segments. The NAMRL Detachment standard for the first thoracic vertebral body (T_1) has been defined. The origin is at the anterior superior corner of T_1 as seen from a lateral x-ray. The +X axis is defined by a line from a point midway between the superior posterior corner and superior inferior corner of posterior spinous process of T_1 to the origin of T_1. The +Y axis is through the origin of T_1, along a line parallel to a line from the center of the articular facet at the right transverse process, right first-rib articulation to the same point on the left. The +Z axis is from the origin of T_1 in the superior direction perpendicular to the XY plane. The lateral view of this coordinate system is illustrated in Figure 6.

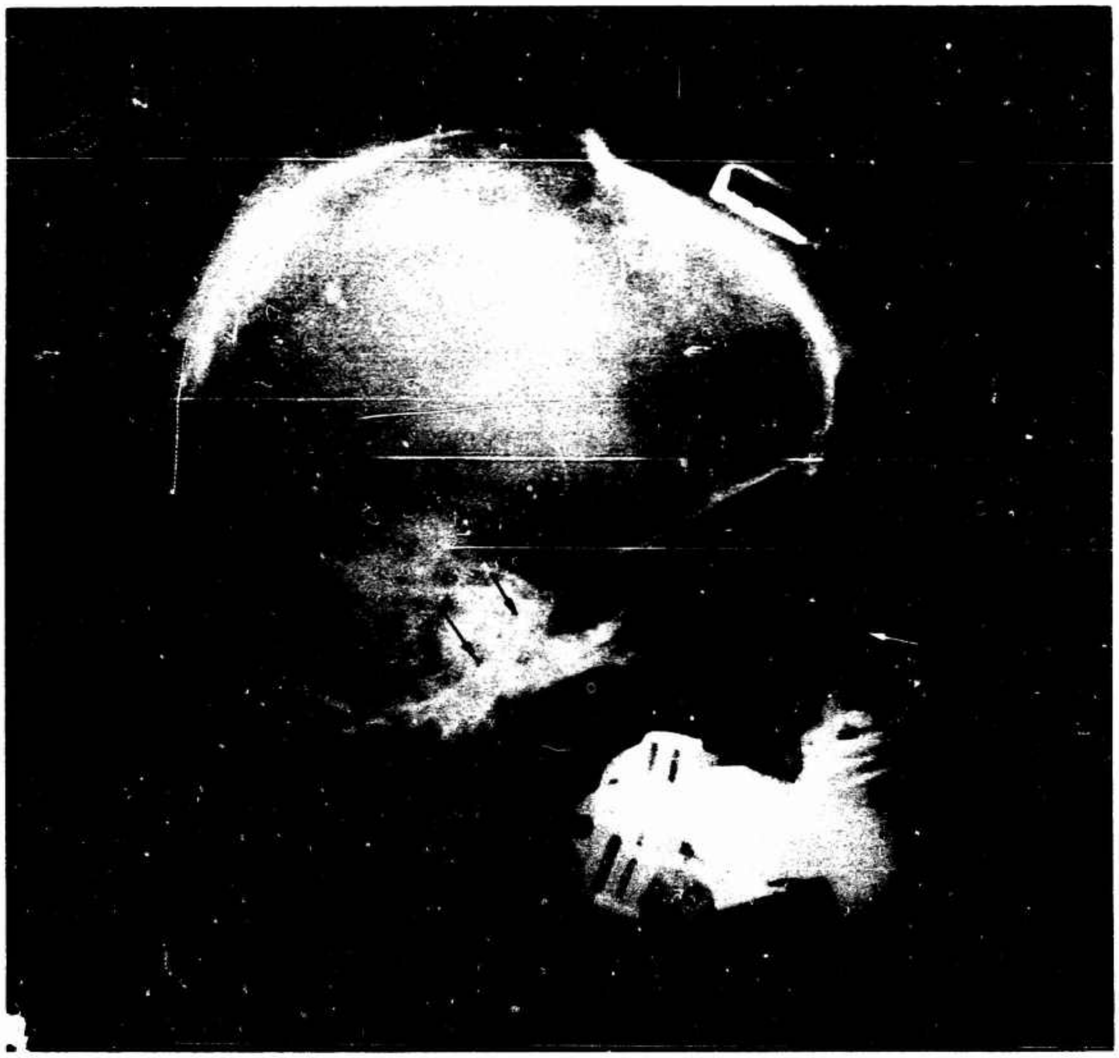
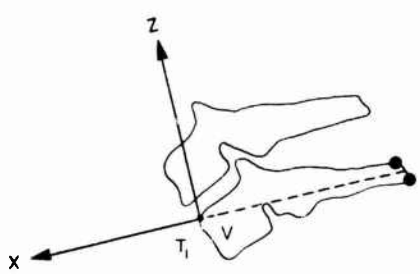


Figure 5. Sample X-ray of Head of Human Subject with Radiopaque Markers.

ANATOMICAL COORDINATE
SYSTEM (SPINE)



T_1 = SPINE (T_1) ANATOMICAL COORDINATE SYSTEM
V = FIRST THORACIC VERTEBRA

Figure 6. Illustration of the First Thoracic Vertebral Body (T_1) Coordinate System.

V. CONCLUSION

By discussing certain problems of protective-equipment evaluation and selected experiments on humans designed in part to meet these problems, a set of requirements for collecting specialized anthropometric data has been developed. The anatomically derived coordinate systems presented for the head and T1 can be observed by x-ray technique. The approach can be extended to any anatomical segment of interest. The basic reason for expressing anthropometric data within anatomically derived coordinate systems is that such data can be used in a wide range of circumstances to supply anthropometric data for protective equipment evaluation, design of human impact acceleration experiments, and description of selected human population.

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DISCUSSION

BYFORD

Is there any theory which would assist in the solution of problems in biodynamics where non-rigid anatomical structures are situated in a non-uniform dynamic force field?

THOMAS

Acceleration with time dependence and dependence as a function of position on an experimental body is non-uniform and is usually measured by judicious placement of accelerometers. To the degree that the mass distribution parameters of the body are known, the non-uniform forces can be inferred. If the experimental body is rigid, the number of measurements is reduced to a minimum and the transformations of rigid body mechanics can be applied. This has been our approach to studying the mechanics of rigid anatomical segments of man undergoing impact. If it is necessary to measure the non-rigid portion of the anatomy, the problem is much more complex and for certain measurements is impossible on a volunteer human subject. To measure non-rigid structures, it is necessary to take sufficient stress, strain, flow or pressure measurements to validate a model of the deformation of the segment. Due to the complexities of anatomical segments, a general approach to this problem remains to be demonstrated. Physically, the problem is one of stress, strain, or flow analysis.

BYFORD

In addition to this problem, there is also the problem that in much of our work, the g-field is non-uniform, on a centrifuge for instance. Under those conditions, there is no center of gravity; a center of gravity presupposes a uniform field. It seems one would have to develop a different concept for anthropometric measurements in dynamic situations.

THOMAS

I think it is best to use the term "center of mass." This avoids some of the confusion which I think may be semantic. A center of mass always exists for a rigid body regardless of the g-field. Many measurement techniques require a 1-g field provided the field is known.

HUMAN EXPOSURE CRITERIA TO LASER ENERGY

by

Major Donald I. Carter, USAF, BSC
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SUMMARY

The United States Air Force is adapting laser technology to many combat and combat support uses. Some of these uses include distance measuring to assist in aiming airborne guns in the AC-130 gunships, boresighting guns on fighter aircraft and target marking for accurate aerial bombing. The number of different lasers and their uses are increasing. Since these high energy monochromatic light beams can produce biological damage, safe exposure criteria are needed to assist in developing safe exposure distances, protective devices and medical surveillance programs.

1. BIOLOGICAL EFFECTS

The lasers currently in the U. S. Air Force operational inventory convert electrical energy into electromagnetic radiation at specific wavelengths (usually within or fairly close to visible light frequencies) and pulse durations, depending upon the working material in the laser cavity and the switching technique used. The energy focusing and collimating effects produce extremely high energy or power densities. The effect on the body is primarily through absorption of the electromagnetic radiation and results in thermal heating of the tissue at the site of absorption. The site of absorption is at the body surface other than in those situations in which the wavelength of the output electromagnetic radiation can be transmitted through or partially through the cornea of the eye. If the wavelength is such that the energy is focused by the lens of the eye onto the retina then the potential for damage is increased due to the increased energy density on the retina. Consequently, the eye is the most sensitive body organ, particularly for those wavelengths that can be refracted by the eye.

2. EXPOSURE CRITERIA DEVELOPMENT

The U. S. Air Force has actively investigated the biological effects of lasers since 1966. The USAF School of Aerospace Medicine at Brooks Air Force Base, Texas, has been the prime Air Force agency responsible for performing and monitoring these investigations. We are particularly indebted to Dunsky, et al., for developing the rationale for the current U. S. Air Force human exposure criteria (Reference 1).

In developing the exposure criteria for eyes, all eye damage data were considered, however, the only data accepted were that which were collected using minimal retinal spot size in rhesus monkeys and limited human exposures. The ED 50 (the energy or power level entering the eye which has a fifty percent probability of producing a minimum retinal lesion seen through an ophthalmoscope within 30 to 60 minutes post exposure) was determined for various wavelengths and exposure durations. As the macula is considered more susceptible than the paramacular area, ED 50s developed in the paramacular region were corrected (by multiplying paramacular ED 50s by a factor of 0.5) prior to grouping them with macula data. Additionally, ED 50s for neodymium exposures without chromatic abberation were corrected (by multiplying them by a factor of 0.75) to assure minimal spot size. The resulting ED 50 data were tabulated and plotted by time and wavelength. As there was no significant difference between the ED 50s in the visible wavelengths, the ED 50s were averaged for the 400-700 nanometer wavelengths. These values were divided by a factor of 10 to accommodate extrapolation of data from monkey to man, variation between subjects and other uncertainties. The resulting values were designated to be the permissible exposure level (PEL). The PEL for any particular wavelength and exposure time was always less than the minimum energy observed to cause a burn for that particular wavelength and exposure time.

Similarly, the ED 50s for neodymium lasers were tabulated and plotted. These curves were similar to the curves for visible wavelengths. Here, however, the data were corrected by a factor of 2.0 owing to the uncertainty of limited experimental data which were obtained using a laser with a multimode beam structure. The corrected ED 50 values were divided by a factor of 10 to account for the uncertainties mentioned previously in regard to the visible wavelengths. This value was then designated to be a PEL. It was noted that this PEL was a factor of 5 greater than the PEL for visible wavelengths in a similar operational mode. The visible wavelength PELs for normal pulsed and Q-switched lasers were therefore multiplied by a factor of 5 to arrive at PELs for neodymium under similar exposure durations. The permissible exposure levels thus established were published by the USAF on 27 September 1971.

Shortly after distribution of the September change, advanced data from an Air Force contractor indicated that ED 50 values obtained with a TEM_{00} mode laser were lower by a factor of 1.4 than ED 50 values obtained with multi-mode lasers. During this period, the U. S. Army determined that the ED 50 data for a 3 mm pupil was lower by a factor of 1.4 than that for an 8 mm pupil.

Because the data for visible wavelengths in the Q-switch had been obtained using a large pupil and s... -mode laser, we had not been considering the worse case situation. Thus, the data point which previously anchored the visible PEL line in the time frame of 10 to 100 nanoseconds could be lowered by a f... of 2.

Other newly acquired data points - one at 0.7 microseconds for neodymium and one at 10 microseconds for an argon laser - substantiated the above reductions.

Figures 1 and 2 depict final shapes of the curves as determined jointly with the U. S. Army and U. S. Navy. These same values shown in tabular form (Tables 1 and 2) were forwarded by the U. S. Air Force to the Department of Defense for publication as a DOD Directive. The values shown here are used in appropriate equations to compute ocular hazard distances, optical density requirements for eye protective devices or combinations.

3. HAZARD SURVEILLANCE

The basic U. S. Air Force philosophy regarding protection from laser energy is to design the system so that it presents the minimum hazard. Factors taken into consideration include keeping the beam enclosed whenever possible and using the minimum output energy to perform the particular task. Special measures employed in the field include high ambient illumination to decrease pupil size, nonreflective surfaces, warning lights, interlocks, "count-down" before operation, eye protection and approved "standard operating procedures." Once airborne laser systems are mounted on the aircraft and are aligned they are generally not operated again until airborne unless nonfunction of the laser system constitutes an abort mode. In this situation the laser is directed vertically into the air or, if this is impossible due to the mounting configuration on the aircraft, it is directed down the cleared runway or into a nonreflecting surface prior to takeoff. Generally, airborne lasers do not present personnel hazards during flight as they are mounted on the aircraft so that the output beam does not transit occupied portions of the aircraft. Mechanical blocks installed in the laser mounting and pivoting system prevent movement which could permit the beam to strike part of the aircraft and reflect into the aircrew compartment.

The physical examination program for laser workers includes the initial, periodic, and terminal physical examination of employees who work with lasers that have an output which could potentially cause eye damage. It is not felt necessary to examine visitors to laser installations when the visitor is adequately protected by goggles or other means or to examine workers using lasers whose output does not exceed the PEL. The pre and post employment examinations include an ophthalmologic examination (including visual acuity, complete funduscopic examinations under mydriasis, Amsler grid examination and color retinal photographs). Intraocular tension, central visual fields and other tests are at the discretion of the ophthalmologist. An accurate description and/or drawing of the fundus by an ophthalmologist may be substituted for the retinal photographs. Special provisions for performing the pre-employment examination are made if the laser worker is in an overseas area without access to an ophthalmologist. Annual examinations consisting of a complete funduscopic examination under mydriasis are conducted by a physician. Special ophthalmological examinations are conducted whenever overexposure is known or suspected.

The only case in which an accidental exposure has occurred in the U. S. Air Force was reported at Kirtland AFB, New Mexico, in early 1972. The individual, a civilian employee working in a laser research and development laboratory, received a brief exposure during a mirror alignment procedure. A 2-inch diameter collimated beam was swept across both of his unprotected eyes. The argon ion laser was operating at 514.5 nanometers at a power output between 10 and 20 milliwatts. The collimator and a beam splitter reduced the net power in the 2-inch diameter beam to between 1 and 5 milliwatts. The individual reported that he saw a bright flash and immediately closed his eyes. When he opened them again (a matter of a few seconds) he noticed everything "looked green (about the same shade as the laser beam) and dark." The effect faded gradually within 10 minutes after exposure leaving only a faint after-image for about 24 hours. An examination by two physicians and one board qualified ophthalmologist was conducted and color retinal photographs were taken. There was no damage observed and the individual has subsequently noted nothing untoward. Apparently since the exposure time was short and the eye lightly pigmented no permanent damage occurred.

Regardless of the validity of one's exposure standards the human element is ever present. Even with the best of safety procedures constant vigilance must be exercised to prevent an unfortunate incident.

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Dunsky, Irving L., et al.: Determination of Revised Air Force Permissible Exposure Levels for Laser Radiation. SAM-TR-72-11, USAF School of Aerospace Medicine, Brooks AFB, Texas, April 1972.

Table 1
.4-1.4 um Permissible Exposure Level

Time (Seconds)	Power into eye(watts)	Energy into eye(joules)	Irradiance at cornea(w/cm^2)	Radiant Exposure at cornea (j/cm^2)
10^{-8}	$2.0x10^{1}$	$2.0x10^{-7}$	$5x10^{1}$	$5.0x10^{-7}$
10^{-7}	2.0	$2.0x10^{-7}$	5.0	$5.0x10^{-7}$
10^{-6}	$2.0x10^{-1}$	$2.0x10^{-7}$	$5.0x10^{-1}$	$5.0x10^{-7}$
10^{-5}	$2.0x10^{-2}$	$2.0x10^{-7}$	$5.0x10^{-2}$	$5.0x10^{-7}$
$1.9x10^{-5}$	$1.1x10^{-2}$	$2.0x10^{-7}$	$2.7x10^{-2}$	$5.0x10^{-7}$
10^{-4}	$7.1x10^{-3}$	$7.1x10^{-7}$	$1.8x10^{-2}$	$1.8x10^{-6}$
$5x10^{-4}$	$4.8x10^{-3}$	$2.4x10^{-6}$	$1.2x10^{-2}$	$5.9x10^{-6}$
10^{-3}	$4.0x10^{-3}$	$4.0x10^{-6}$	$1.0x10^{-2}$	$1.0x10^{-5}$
$5x10^{-3}$	$2.7x10^{-3}$	$1.3x10^{-5}$	$6.7x10^{-3}$	$3.3x10^{-5}$
10^{-2}	$2.3x10^{-3}$	$2.3x10^{-5}$	$5.7x10^{-3}$	$5.7x10^{-5}$
$5x10^{-2}$	$1.5x10^{-3}$	$7.5x10^{-5}$	$3.8x10^{-3}$	$1.9x10^{-4}$
10^{-1}	$1.3x10^{-3}$	$1.3x10^{-4}$	$3.2x10^{-3}$	$3.2x10^{-4}$
$5x10^{-1}$	$8.4x10^{-4}$	$4.2x10^{-4}$	$2.1x10^{-3}$	$1.1x10^{-3}$
1	$7.1x10^{-4}$	$7.1x10^{-4}$	$1.8x10^{-3}$	$1.8x10^{-3}$
5	$4.8x10^{-4}$	$2.4x10^{-3}$	$1.2x10^{-3}$	$5.9x10^{-3}$
10	$4.0x10^{-4}$	$4.0x10^{-3}$	$1.0x10^{-3}$	$1.0x10^{-2}$

Note: 1. For $1.9x10^{-5}$ to 10 sec PEL(watts) = $7.1x10^{-4}t^{-1/4}$

2. A pupil area of .40 cm^2 (pupil diameter = 7 mm) was used to convert from power and energy into the eye to irradiance and radiant exposure at the cornea.

Table 2
1.06 um Permissible Exposure Level

Time (seconds)	Power into eye(watts)	Energy into eye(joules)	Irradiance at cornea(w/cm^2)	Radiant Exposure at cornea(j/cm^2)
10^{-8}	$2.5x10^{2}$	$2.5x10^{-6}$	$6.3x10^{2}$	$6.3x10^{-6}$
10^{-7}	$2.5x10^{1}$	$2.5x10^{-6}$	$6.3x10^{1}$	$6.3x10^{-6}$
10^{-6}	2.5	$2.5x10^{-6}$	6.3	$6.3x10^{-6}$
10^{-5}	$2.5x10^{-1}$	$2.5x10^{-6}$	$6.3x10^{-1}$	$6.3x10^{-6}$
$6.4x10^{-5}$	$3.9x10^{-2}$	$2.5x10^{-6}$	$9.9x10^{-2}$	$6.3x10^{-6}$
10^{-4}	$3.6x10^{-2}$	$3.6x10^{-6}$	$8.9x10^{-2}$	$8.9x10^{-6}$
$5x10^{-4}$	$2.4x10^{-2}$	$1.2x10^{-5}$	$5.9x10^{-2}$	$3.0x10^{-5}$
10^{-3}	$2.0x10^{-2}$	$2.0x10^{-5}$	$5.0x10^{-2}$	$5.0x10^{-5}$
$5x10^{-3}$	$1.3x10^{-2}$	$6.7x10^{-5}$	$3.3x10^{-2}$	$1.7x10^{-4}$
10^{-2}	$1.1x10^{-2}$	$1.1x10^{-4}$	$2.8x10^{-2}$	$2.8x10^{-4}$
$5x10^{-2}$	$7.5x10^{-3}$	$3.8x10^{-4}$	$1.9x10^{-2}$	$9.4x10^{-4}$
10^{-1}	$6.3x10^{-3}$	$6.3x10^{-4}$	$1.6x10^{-2}$	$1.6x10^{-3}$
$5x10^{-1}$	$4.2x10^{-3}$	$2.1x10^{-3}$	$1.1x10^{-2}$	$5.3x10^{-3}$
1	$3.6x10^{-3}$	$3.6x10^{-3}$	$8.9x10^{-3}$	$8.9x10^{-3}$
5	$2.4x10^{-3}$	$1.2x10^{-2}$	$5.9x10^{-3}$	$3.0x10^{-2}$
10	$2.0x10^{-3}$	$2.0x10^{-2}$	$5.0x10^{-3}$	$5.0x10^{-2}$

Note: 1. For $6.4x10^{-5}$ to 10 sec PEL(watts) = $3.6 \times 10^{-3} t^{-1/4}$

2. A pupil area of .40 cm^2 (pupil diameter = 7 mm) was used to convert from power and energy into the eye to irradiance and radiant exposure at the cornea.

FIGURE #1 - PERMISSIBLE EXPOSURE LEVEL

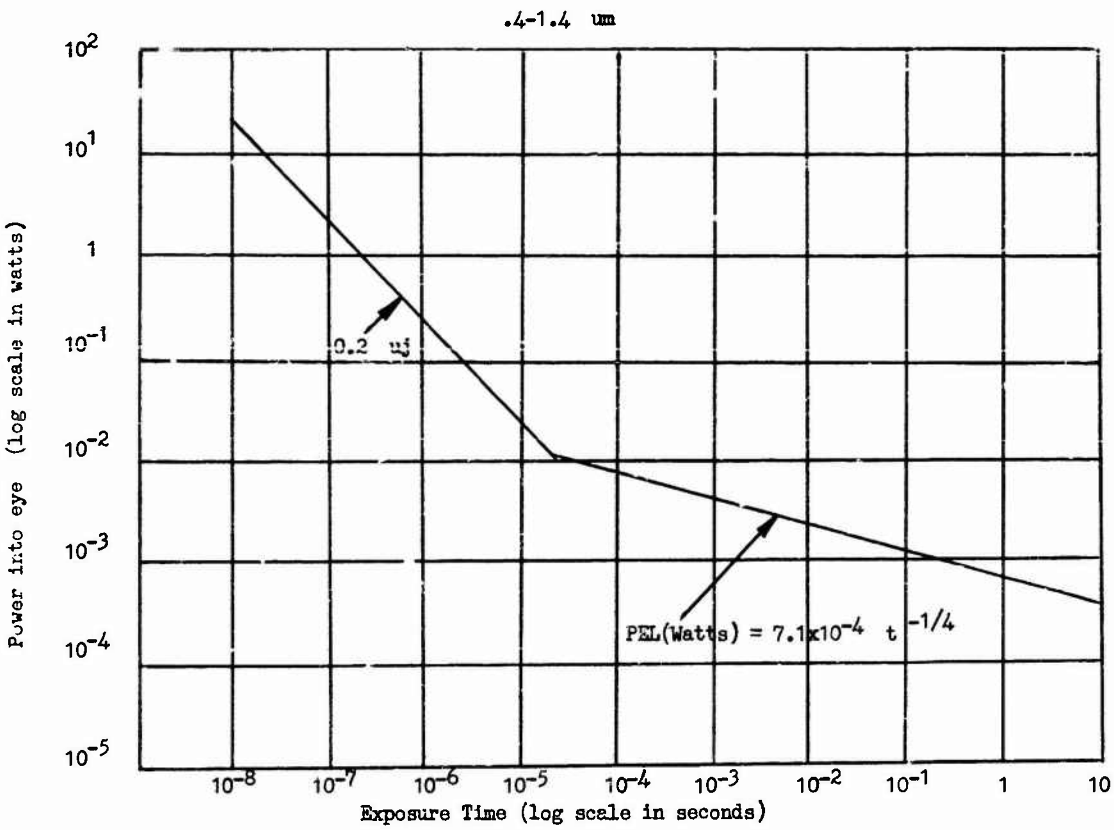
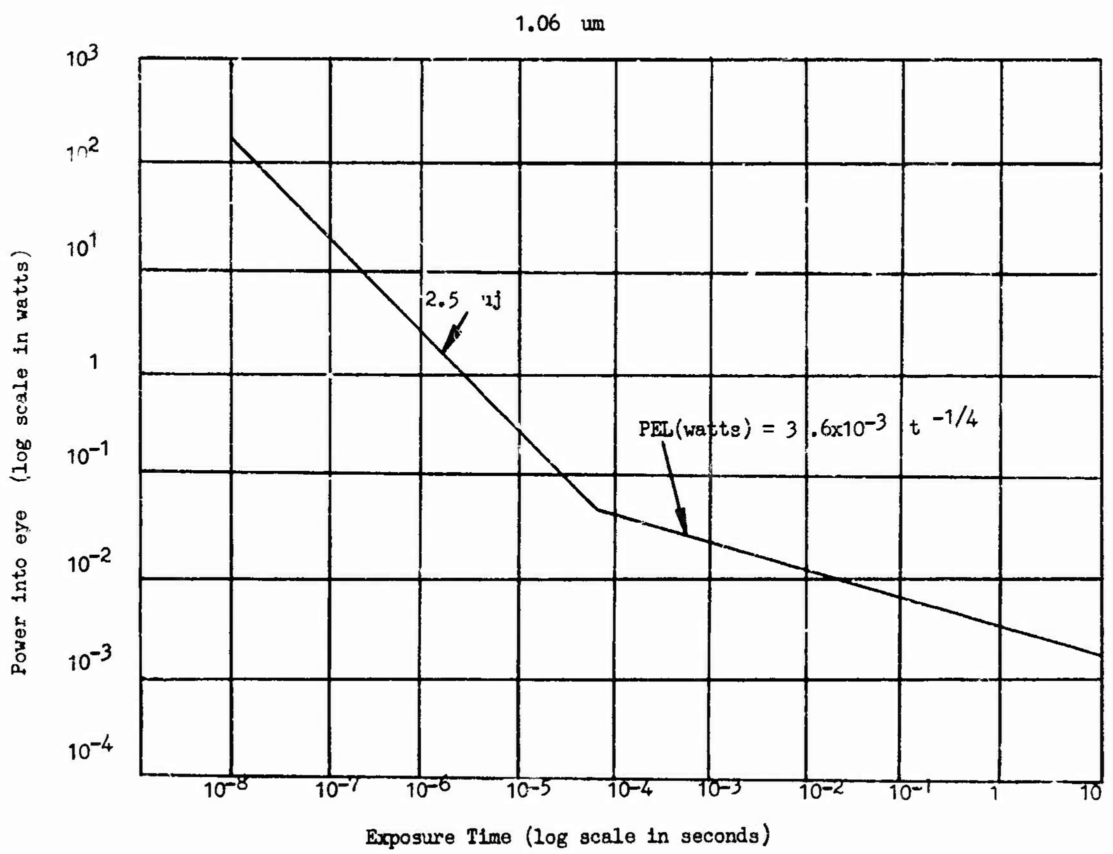


FIGURE #2 - PERMISSIBLE EXPOSURE LEVEL



STUDY ON SOME AIR FORCE OPERATIONAL ACTIVITIES IN ITALY, WITH REFERENCE TO THERMAL CONDITIONS AND THEIR EFFECTS ON ACCELERATION TOLERANCE AND PSYCHOMOTOR PERFORMANCE

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SUMMARY

Climate in Italy, in summer period, presents such characteristics that, in peculiar Air Force operational activities, performance of AF personnel can be affected. Because of this, a series of researches was carried out, in this field, which essential data are shown.

After a brief survey on main features of Italian climate, and summer climatic conditions in some AF bases, the results are reported of a research on microclimatic data recorded in the interior of the cockpit of aircraft of different types, and inside motor vehicles cabins, while parking in summer daylight period.

Physiological importance of these data, and the effects on working efficiency are discussed and evaluated by means of some heat stress indexes (WBGT, according to Yaglou and Minard; heat storage index, according to Blockley and Taylor; heat stress index, according to Belding and Hatch).

Results of experimental parallel researches are also reported, aimed to assess the effects on acceleration tolerance and psychomotor performance, of situations simulating scramble take off, in microclimatic conditions similar to actual ones.

The experiments were carried out recording complex reaction times, in response to visual stimuli, administered randomly and alternatively, on both lateral sides of binocular visual field, in different experimental conditions (neutral and hot environment, under normal and up to + 4 G_z acceleration, preceded or not by 3 hrs bed rest).

The results of such investigation point out that, inside some aircraft and motor vehicles cabins, microclimate reaches severe stressing values, in summer. The results of the experimental researches in centrifuge, evidence untoward effects on psychomotor performance, of heat and acceleration stresses, and possible effects of rest period.

PREFACE

Italian climate, in summer period, can present, in its different components of major physiological relevance (air temperature, humidity, wind, solar radiation), such characteristics that human performance to work can be affected appreciably. In particular, Air Force activities, as far as ground operations are concerned (aircraft check and maintenance, assistance to flight, aircraft taxing, take off and landing) are carried on in the open air, or in closed environments (motor vehicles and aircraft), highly affected with external ambient conditions.

Furthermore, low level flight, that is flight of relevant operational importance, causes aircraft to be exposed to environmental conditions close to ground ones, made worse, in case of high speed, by heating due to friction with low and more dense atmosphere.

Therefore, in different periods, in the I.A.F. Medical Service, researches were carried out, aimed to study the effects of summer climate in Italy, on personnel performance, in some peculiar Air Force operations.

CHARACTERISTICS OF SUMMER CLIMATE IN ITALY

Italian climate belongs to the sub-tropical Mediterranean area. The following eight climatic regions can be singled out (fig.1): 1) the Alps, 2) the Po river basin, 3) Liguria and North Tuscany, 4) Tyrrhenian versant, 5) North Adriatic versant,

6) Central-Southern Adriatic versant, 7) Calabria and Sicily, 8) Sardinia.

Considering the areas of major Air Force importance, due to air base density, in summer months noticeable uniform conditions of climate can be observed, characterized by long periods of clear sky, high solar radiation level, high air temperature lasting many hours per day (fig.2). The records of some weather stations, representative of the most important climatic regions, and reported in table I, put into evidence in July (central month of the meteorologic summer) monthly mean temperature 22 to 23°C, mean maximum temperature 27 to 28°C, and extreme maximum temperature 33 to 34°C. Mean relative humidity ranges between 65 to 70%, sunshine between 10 and 11 hours per day, and global radiation (comprehensive of sky and sun radiations) between 450 and 500 cal/ sq.cm per day. Wind situation is more variable, due to frequent periods of calm in Po river valley, and remarkable ventilation in insular and peninsular areas.

In order to compare Italy with other European countries, to evidence the characteristics of our climatic conditions, in figure 3 we reported comprehensively, the average monthly temperatures of July, sunshine hours and global radiation of some European stations. General climatic features, without entering into details beyond our specific interest, show that, at least in the NATO European countries, the problem is fully present in Italy and few other mediterranean areas.

MICROCLIMATIC STUDY OF AIR FORCE OPERATIVE ENVIRONMENTS

Because of the climatic conditions above lined, a series of researches was carried out (1), in the first days of August 1970, on microclimate of Air Force aircraft and motor vehiclos in some AF bases close to Rome.

The data obtained are presented, in this paper, divided according to the main operational and structural characteristics of the environments observed, as well as to cabin ventilation, as follows:

- Cockpits of aircraft with large transparent canopy (the study was carried out in light helicopters, but we think that can be partially applied also to one or two seated airplanes, with large canopy);
- Cockpits of aircraft with not transparent canopy (the study was carried out both in heavy aircraft of commercial type, being used by the IAF, and in military type, multi-seated aircraft);
- Motor vehicles cabins (the study was carried out in fire service vehicles of different types).

The above lined grouping is necessary for synthetical presentation of the data, to evaluate, at least approximately, the actual importance of the problem. On the other hand, this synthetical presentation can not take into account the specific structural characteristica of heach environment.

Evaluation of psychophysiological effects of these microclimatic conditions was based on air temperature, humidity, ventilation and solar radiation, which the following indexes of heat stress were calculated from:

1) Wet Bulb Globe Temperature Index (WBGT) (2).
   This index was calculated from wet bulb (natural convection) and globothermometer temperatures. It is concerned with severe work loads, and was proposed to study conditions of USA Marines in training. For piloting 85°F limit was proposed empirically, but 80° F limit should be more suitable (3).
2) Heat Storage Index (4).
   This index is based on heat balance and heat storage calculations. Heat balance, from the formula $M \pm C \pm R - E$, was obtained, for each given environmental situation, calculating theoretically (5) heat metabolic production M, convection C and radiation R exchanges, and evaporative heat loss E, for a medium size man, during the medium work load (74 Kcal/ sq.m hr)of a mechanic tightening a bolt. Ratio between maximum tolerable heat storage, and the actual heat storage (or theoric, as in this study) gives directly heat endurance in hours. This index is mainly to be applied in severe work and climate conditions, that allow only short tolerance time.
3) Heat Stress Index (6).
   This index is obtained from ratio between evaporative heat loss, being necessary to match heat balance, and the maximum actual evaporative heat loss. It was calculated, in this study, for the same work load and the same individual characteristics above reported. The index is concerning with hygienic and physiologic conditions of 8 hours work, with the following limits (percentual differences):
   - 10 to + 10 = thermal neutrality;
   + 20 to + 30 = mild to medium heat stress (mild decrease of mental and physical performance with severe work loads);

+ 40 to + 60 = severe heat stress (dangerous to people in normal heat conditions).

The microclimatic study was carried out in clear sky day, between 12.00 and 13.00 hrs local time, consequently with the highest solar radiation and air temperature (fig.2). Due to local climatic situation, fair ventilation was recorded in general. Ventilation system of aircraft and motor vehicles was not working, and separate data were recorded of cabins with closed or fully open windows.

We think this useful, for comprehensive exposition of the data, to report separately the data obtained in two different external conditions (with external air temperature in the range of the most frequent values of maximum mean temperature, 25 to 28°C; and the data recorded with higher external temperature, 29 to 32°C, in the range of extreme maximum temperatures of several Italian areas, in summer months).

In table II we report, this way grouped, main microclimatic data (air temperature, humidity, globothermometer temperature), and the three heat stress indexes calculated, giving, for heach situation, maximum and minumum values recorded.

Therefore, these values, that leave out of consideration specific climatic and environmental situations, have their significance to indicate the range of microclimatic situations that flight and ground personnel can possibly meet. The different indexes will be applied, with respect to the different type and duration of activity, that is, respectively, WBGT for flying activity, heat storage index for short lasting strenuous work, heat stress index for prolonged work on ground.

The data obtained put into evidence that, in almost every situation under study, values giving significant heat stress were found. However, this stress was of different importance, due to external conditions, cabin ventilation and radiant protection.

With respect to personnel performance, severe heat stress , though of short duration, can possibly intervene in flight, in low thermal protection aircraft. However, it can be found, in particular environmental conditions, in multi-seated aircraft, with more efficient thermal protection. This situation should be considered as possible in the first part of the flight, being the cockpit at least partly closed, and ventilation system not yet fully operating.

Ground situation of AF personnel (motor car drivers, maintenance technicians), in general working in ventilated environment (because of open windows or relative wind of vehicles in motion), is significant, with respect to heat stress, only in case of persistent hot conditions along the day, or strenuous work.

OPERATIONAL CONDITIONS IN SCRAMBLE TAKE OFF

The peculiar microclimatic conditions found in Italy, in summer periods, in Air Force operational environments, above lined, interest, without any doubt, personnel performance.

The full efficiency of flying personnel, mainly necessary in some specific operations, as scramble flight, requested the study of the effects of microclimatic heat stress, interacting with other environmental factors characteristic of this activity, in the Italian A.F.

In fact, scramble take off requests sudden transition from waiting condition, often of rest (but not in sleep), to aircraft piloting, this last activity being always demanding and dangerous, mainly in case of actual alarm.

Therefore, we thought useful to study the effects of waking rest in clinostatism, typical of waiting period preceding take off, and the effects of high ambient temperature of the cabin (that can be found, as we saw, in our summer climate, in parking aircraft and at the beginning of the flight), both per se and interacting (7).

Subject performance was studied, from psychomotor side, on the basis of manual response to complex visual stimuli, connecting, this way, to the task of aircraft piloting. From physiological side, tolerance level to $+G_z$ acceleration (head-foot) was studied, that is a peculiar stress of fighter aircraft.
The experimental study was carried out on Air Force technicians, both experienced and unexperienced with acceleration in centrifuge runs. Two green targets were presented, singly and irregularly, to the subject, under operator's decision, with

frequency of 30 stimuli per minute. The targets were situated at the lateral edges of binocular visual field. The subject had to response, at each target lighting, by pressing the homolateral push button, of the two ones held in his hands.

Targets lighting and subject responses were recorded photographically. Reaction times, errors and target vision fading due to visual field narrowing were studied. This method is close to the ones applied to study the effects of some environmental temperatures on G tolerance(8).

In a first experimental series, basal conditions of each subject were recorded, without and immediately after 3 hours bed rest. Behaviour during acceleration (+3 G_z per 2 minutes, followed by +4 G_z per 1 minute) was also studied. Centrifuge runs were carried out without and immediately after rest period. All these tests were conducted in thermal comfort (average air temperature 19°C, humidity 50-60%).

In the second experimental series, tests were carried out, in a first part, both in basal conditions and during acceleration, at 19°C air temperature,without any previous rest. Other two parts followed,each one comprehensive of basal and accelerative periods, respectively performed without and after rest. These last reasearches were carried out at 40°C air temperature. Rest period was spent at 19°C, in these last parts too.

Table III shows separately, for each experimental series,mean values of reaction times, mean standard deviation, the sum of errors made by the subjects in all the tests. Figure 4 shows, for each individual test, acceleration time necessary for visual field narrowing.

The data, as a whole, put into evidence positive acceleration and high environmental temperature effects in decreasing psychomotor efficiency of the subject. These effects, evidenced by reaction times lenghtening and errors number increasing , are repotted with the two conditions considered,both separately or contemporarily acting. Rest period preceding acceleration does not modify, per se, reaction times. Acceleration tolerance, as evaluated from visual field narrowing, is not affected, considering the global results of the tests, with previous rest period and high environmental temperature, yet separate or associated.

On the other side, we found, in a few individual responses, possible decreasing tolerance to acceleration, in connection with previous rest and high environmental temperature, likely depending on higher individual sensibility.

It is also interesting to point out that visual field narrowing during acceleration can not be foreseen from precedent psychomotor performance.

CONSIDERATIONS AND CONCLUSIONS

The data reported in this paper, that were obtained in a series of studies on the effects of climatic heat stress in the Air Force, point out possible microclimatic conditions of psycho-physiological relevance.

From the point closely related to microclimate effects, actual operational validity of the conditions we ascertained, depends, as above said, both on the task being performed and the exposition time. We are conforted, along this line,by a similar research,previously quoted (3). The investigators found, in helicopters in Viet-Nam, persistent adverse microclimate, because of on-board ventilation system inadequacy to high environmental temperature. We already stressed, as far as frequency and level of stress were concerned, importance of climatic behaviour along the day.

Evaluation of adverse microclimate, should be considered with respect to physical and psychological task to perform, by means of heat stress indexes. A large survey on temperature influence on mental performance (9),though concerning higher temperatures than the ones we studied,evidences adverse effect depending on exposition time, heat stress level and task complexity.

Simulate scramble take off conditions, in this adverse microclimatic environment, must be evaluated, in their experimental results, by considering their difficult application to actual operational situations. In fact various tolerance threshold, with respect to sensorial functions and psychomotor tasks involved, were found during acceleration (10).

Moreover, studies on mental efficiency, in transition from sleep to alertness (11,12,13,14,15), as well as the re 'arches on cardiovascular performance and previous prolonged bedrest (16,17), are cor rned with situations that can not be completely superimposed to conditions of scramble take off.

However, in spite of the above reported limitations, we think that the data obtained in this series of researches on microclimate, can lead to the following practical conclusions and suggestions:

1) Take into consideration, from aeromedical, operational and designing stand points, that in summer period in Italy, microclimatic conditions affecting AF personnel efficiency, can possibly intervene;
2) Consider, from the above mentioned standpoints, possible decrease of psychomotor performance of flying personnel, due to acceleration and high ambient temperature;
3) Consider that decreasing acceleration tolerance, mainly associated with previous rest and high ambient temperature, can be found in more sensitive individuals;
4) Consider that a given threshold of acceleration tolerance, can not be foreseen, on the basis of previous psychomotor behaviour.

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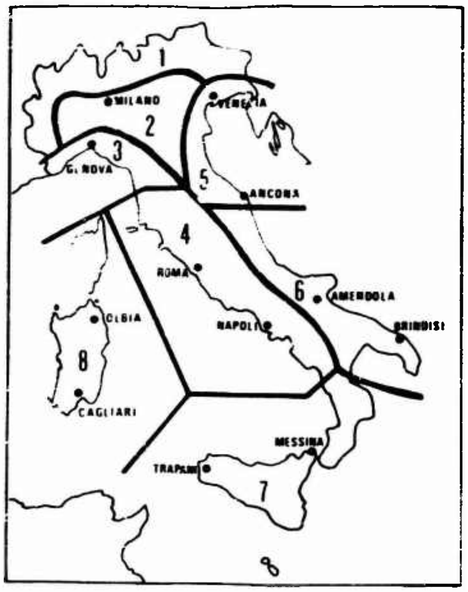

Fig.1 Italian climatic regions (refer to text for regions figure). Meteorologic stations of table I are also indicated.
(from 18, modified)

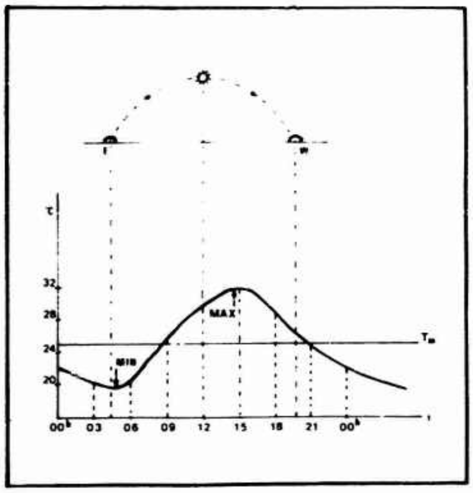

Fig.2 Temperature daily changes in July in Florence, and Sun height (Tm: mean temperature;MIN: minimum mean temperature;MAX: maximum mean temperature).
(from 19, modified)

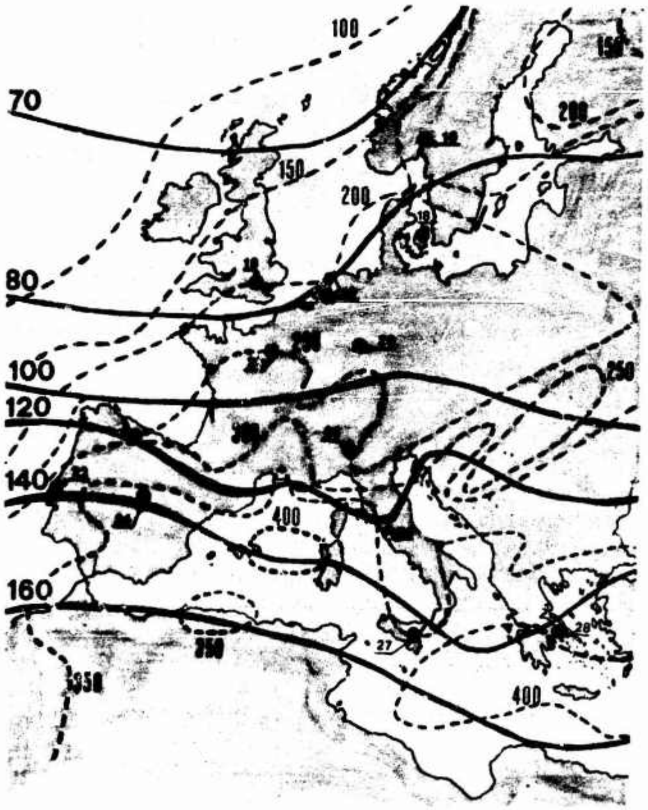

Fig.3 Europe climatic data. The following data are reported:
July mean temperatures(in C°) of some stations (underlined figures);
Isolines of annual global radiation (unbroken thick lines) in Kcal/sq.cm year (figures at left edge);
Isolines of mean July sunshine (broken thin lines),in hours (figures close to lines).
(Temperatures from 20,years 1941-50; isolines from 21, years 1957-59)

Table I Weather records of some Italian stations in July.

Climatic Regions	Stations	Temperatures			Humidity relat. mean %	Clear sky days	Sunshine hrs		Global radiation		Wind mean velocity	Calm No observ.
		mean max.	mean month	extr. max			mean day	max month	mean day	max month		
Po river basin	Milano	28,8	23,0	33,8	67	15	9,1	310,0	433	14790	3	50
Liguria & North Tuscany	Genove	24,7	23,8	32,0	73	13	9,6	317,1	460	16043	8	27
Tyrrhenian versant	Roma	28,7	22,1	33,5	66	13	10,8	356,5	532	17999	8	34
	Napoli	27,6	22,0	32,4	68	13	10,4	344,1	447	15974	7	31
N. Adriatic versant	Venezia	27,8	22,9	33,3	69	13	9,6	347,2	476	15398	6	17
	Ancona	25,9	22,8	30,2	67	16	10,4	365,8	527	19019	9	27
Central-S. Adriatic vers.	Amendola	30,3	23,8	35,3	48	15	10,6	352,8	480	16306	7	13
	Brindisi	26,6	23,4	33,0	74	19	11,2	365,8	470	17214	11	15
Calabria & Sicily	Messina	27,0	24,1	31,4	68	15	10,6	350,3	465	17407	7	21
	Trapani	27,3	23,2	31,0	80	21	11,6	374,5	512	15731	14	13
Sardinia	Olbia	28,1	22,7	34,0	63	19	12,1	398,0	513	17596	9	24
	Cagliari	26,8	23,2	30,7	65	17	10.7	368,9	518	18420	7	22

Data of temperature (in C°), humidity, sky conditions, wind mean velocity (in knot) in maximum frequency directions, observations of calm are recorded in July 1970 (22).
Sunshine hours and global radiation are recorded in July month, from 1958 to 1969, and reported respectively in hours and decimals and cal/ sq.cm per day or month (23).

Table II Microclimatic conditions, in external air temperature corrisponding to summer mean maximum and extreme maximum values.

External Air Temperature	Environment		Microclimatic data: Air Temperature	Microclimatic data: Humidity %	Microclimatic data: Globothermometer Temp.	Heat Stress Indexes: WBGT F°	Heat Stress Indexes: Heat Storage Ind. hrs	Heat Stress Indexes: Heat Stress Index
Mean Maximum 25-28 C°	Helicopter	O	39	36	41	81	8	+54
	Multi-seat Aircraft	O	27-33	26-52	28-38	73-78	8	-11 +41
		C	29-36	49-58	30-39	76-89	8	+19 +103
	Motor Vehicle	O	27	64	29	74	8	-20
		C	27	56	28	74	8	-10
Extreme Maximum 29-32 C°	Helicopter	O	40	57	45	88	2	+106
		C	43-45	28-35	47-50	87-95	1	+139 +217
	Multi-seat Aircraft	O	36-40	37-58	38-44	82-91	8	-49 +97
		C	40-42	35-54	42-43	86-90	2	+145 +148
	Motor Vehicle	O	32-36	30-40	34-38	77-82	8	+15 +38
		C	36	30-33	37-43	80-86	7	+60 +108

In each situation under study, range of values obtained in all the examinations are reported.
C: cabin windows closed; O: cabin windows open.

Table III Psychomotor tests in basal conditions and in acceleration, at different ambient temperatures.

	NO REST 19°C		AFTER REST 19°C		NO REST 19°C		AFTER REST 40°C		AFTER REST 40°C	
BASAL COND.	508 ± 113	7	508 ± 119	7	434 ± 96	0	441 ± 75	1	445 ± 120	2
$+3G_z$ 2 min	541 ± 99	21	540 ± 107	20	476 ± 83	8	466 ± 106	6	477 ± 94	5
$+4G_z$ 1 min	559 ± 97	9	550 ± 89	8	491 ±93	7	468 ± 81	8	484 ± 85	5

Reaction times mean, mean standard deviation (in thousandth of second) and total errors , for each experimental situation.
Total errors must be compared, considering the different number of responses at 3 and 4 G, due to different duration of the tests.

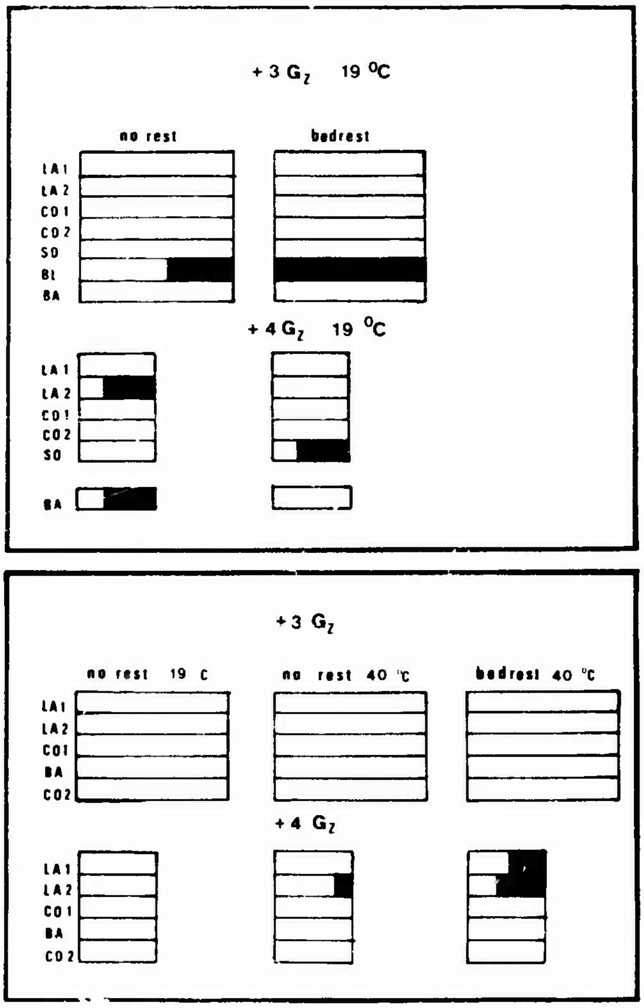

Fig. 4 Duration of acceleration exposition, necessary to visual field narrowing, without and with rest, at air temperatures of 19 and 40° C.
Complete exposition was 2 minutes at 3 G and 1 minute at 4 G (rectangules lenghts). Visual field narrowing is indicated by the black area.
Individual run results and subjects symbols are reported.

DISCUSSION

JONES

During tests of lifting bodies as part of the U.S. Space Shuttle Program, pilots have reported fatigue after long confinement in the cockpit under very warm ambient conditions. As a result, pilots have been issued liquid-cooling garments for use during lifting body tests. Do you use ground cooling units at all?

ROTA

No we do not.

JONES

I think you have made a good case for their use.