NOISE AND VIBRATION cont'd.

Laboratory simulators are available to produce the operational noise spectra (electrodynamic speaker systems, sirens) and vibration spectra (one- or several-degree-of-freedom shake tables) required for realistic human factors testing and biological research work.

Noise (20 to 20,000 cps) affects man primarily through the organ of hearing. At extremely high noise intensities instantaneous injury to the middle and inner ear can occur. At lower intensitities long-time noise exposure can result in temporary, or finally in permanent hearing loss. This reduction in hearing acuity is caused by damage to some of the receptor nerve cells in the inner ear. Even at relatively low intensities noise can interfere with the speech communication vital to performance. It also can be the source of annoyance. Quantitative criteria for these various effects are available and being used in system design. Protective equipment is available when necessary. Non-auditory effects of noise involve other organs than the auditory system but are important usually only at extremely high intensities. All effects of noise depend not only on the intensity but also on the frequency spectrum of the noise; noise control measures also are strongly frequency dependent.

Vibrations in the frequency range below 100 cps are those most troublesome for man. Unfortunately, this is also the range where vibration control by isolation is most space- and weight-consuming. The effects on man of vibrations in this region are strongly frequency dependent; mechanical resonances of various body parts and organs can occur at certain frequencies and amplify the effectiveness of the input energy with respect to the particular body region.

NOISE AND VIBRATION cont'd.

There is, for example, a resonance of the thorax and abdominal viscera in the 3 - 6 cps range and a resonance of the head compared to the shoulders around 30 cps (for the sitting subject). The first resonance can lead to pain symptoms at relatively low vibration acceleration levels, thus limiting physiological tolerance of the subject. The head resonance can result in blurred vision and decreased performance capability on exposure to relatively low levels in this frequency range. These are simplified examples to demonstrate how the body's dynamic response influences critically the physiological and performance tolerance limits. Human tolerance and performance limits depend in detail on the direction of application of the vibration, the body position and support, the exposure time, and many other factors. Only approximate criteria are available in this area and additional research to clarify the various mechanisms of biological action is required.

In actual flight, noise and vibrations are experienced in combination with other environmental stress factors, a fact requiring conservative application of the available criteria which have to date been derived from results of only one stressor at a time.

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Dr. Wilmot N. Hess

SPACE RADIATION AND MAGNETIC FIELD ENVIRONMENT

I. The Solar Atmosphere

A. The solar corona is unstable and blows a wind of protons and electrons at the earth at a velocity of about 400 km/sec.

B. The magnetic field of the earth which is roughly dipolar is pushed in by the solar wind and limited to existing inside a cavity called the magnetosphere. The shape of this cavity and of the distorted field lines inside it have been calculated.

C. Changes in the solar wind characteristics produced by eruptions on the sun cause effects at the earth. Changing the solar wind pressure on the magnetosphere causes it to change shape and size and as a result changes the magnetic field at the surface of the earth.

II. Cosmic Rays

A. Cosmic protons with very high energies with up to 10^9 ev continually arrive at the earth from deep space. We know their fluxes and energies relatively well but rather little about their origin.

B. When a magnetic storm occurs at the earth produced by an enhanced solar wind, this frequently decreases the flux of calculated cosmic rays arriving at the earth. This effect called the Forbush decrease can be roughly understood in terms of our understanding of the interplanetary medium.

C. We know that energetic protons are occasionally made near the surface of the sun. These particles are occasionally observed on sea-level detectors but more frequently on satellites and balloons. The energetic rays extend above 10^9 ev.

1. Solar cosmic rays, as far as we know, are always made in the region of large solar flares. Various schemes for the acceleration of the particles have been suggested but their mode of origin must be considered an open question.

2. The solar protons arrive at the earth some time after the flare. Flares near the west limb of the sun produce faster arriving protons due to the geometry of the magnetic field. The propagation process resembles fairly closely the diffusion of the particles.

3. When solar protons arrive at the earth, they produce several effects. At the polar cap regions they produce an increased ionization in the ionosphere and because of this a reduced influx of

cosmic radio noise to the earth. These polar cap absorption events are measured by a device called a riometer and can be used quantitatively now to study solar proton events.

4. There have been about one half dozen very large solar proton events observed in the past ten years. They frequently occur as multiple events from one sunspot group.

III. The Radiation Belt

A. Satellite measurements have lead to general knowledge of the spatial distribution of high and low energy protons and electrons in the radiation belt.

B. We understand quantitatively the source and losses of the energetic protons near the earth. The protons are made by decay of neutrons coming out from the atmosphere of the earth and are lost by interaction with the thin atmosphere present at very high altitudes.

C. A recent model explains several of the features of the low energy protons in the outer belt by assuming the protons are diffused into the magnetic field from the outside by a magnetic pumping process.

D. Significant radiation belts have been made in the past by explosions of high altitude nuclear bombs. These have enabled up to measure the lifetime of trapped electrons which was not previcusly possible. We understand reasonably well the decay of the starfish belt in terms of atmosphere scattering and whistler interaction.

E. From a knowledge of the electrons' lifetimes from studying artificial belts, we can understand qualitatively the natural electrons in the radiation belt.

F. From studying synchrotron radiation we are quite sure that Jupiter has an electron radiation belt substantially more intense than the earth's. Saturn shows no synchrotron radiation evidence of a radiation belt. The Mariner probe did not find a belt on Venus.

IV. Total Encountered Particle Fluxes

A. Solar proton events - We have a reasonably good idea of the total particle flux that would have been encountered in the several large solar proton events in the past 10 years. By various schemes of solar flare prediction, we can try to minimize the chance that an astronaut would encounter solar protons in a trip to the moon.

B. Radiation belt flux - the flux of particles that a satellite would encounter in traversing the starfish radiation belt and the inner radiation belt protons have been calculated for various circular orbits.

ENGINEERING ASPECTS OF SPACE MEDICINE

George Washington University

Radiation Biology - Lecture Outline

Douglas Grahn

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I. The Interaction of Radiation with Matter

A. Initial physical and chemical events

1. Electromagnetic radiation - photoelectron and recoil electron production; relatively sparce production of ion pairs.

2. Particulate radiation - recoil protons, mesons, neutrons, etc.; secondary γ and x-radiation; dense ion pair production along particle track.

3. Formation of radicals in water: H, OH, H_2O_2, HO_2; breakage of chemical bonds; events occurring in 10^{-12} to 10^{-6} seconds.

B. Molecular and cellular effects of radiation

1. Modification of DNA molecule, enzymes, and other proteins; disruption of biochemical processes.

2. Induction of genetic change - gene mutation and chromosome aberration.

3. Cell death; modification of cell function.

C. Tissue and systemic effects of radiation

1. Proliferating tissues (blood forming, intestinal wall) - reduction or inhibition of cell division; depression in cell number and tissue function.

2. Non-proliferating tissues (liver, kidney, CNS) - persistence of damaged cells; absence of immediate evidence of injury.
3. Systemic manifestations of cell and tissue damage.

D. Miscellaneous factors

1. Time-intensity variables - reduced biological effectiveness by dose protraction and fractionation.
2. Relative biological effectiveness (RBE) - recognition of differences in biological effect due to pattern of energy transfer and ionization density.
3. Partial body exposure.
4. Chemical and bone marrow therapy.

II Human Radiation Biology

A. Acute radiation injury

1. Central nervous system injury - dose range 1000r and up - survival time less than one week; death from shock, fluid loss, hemorrhage, widespread tissue destruction.
2. Hematopoietic injury - dose range: 50r - 650r - sublethal to lethal; death in one week to two months; minimum lethal dose ca. 150r. Death from hemorrhage, infection, anemia.
3. Prodromal responses - nausea, vomiting for several hours to one day; fever, loss of appetite, diarrhea; minimum dose probably 50r for most sensitive - 250r probably will produce prodromal reactions in all persons.
4. Subacute injury - protracted recovery in survivors or sublethally exposed; temporary sterility.

B. Chronic or long term radiation injury

1. Reduced life expectancy - extrapolation from animal data suggests a non-linear response to single doses and an estimate of 15 - 20% (~ 6 - 8 years) reduction by 400r - 500r; more linear response expected from continuous low intensity exposure and an estimated loss of 1 - 2 days per r accumulated.
2. Leukemia induction - probability of leukemia occurrence: $1\text{-}2 \times 10^{-6}$/r/year for 15 - 20 years post-exposure for doses of 50r or greater.
3. Other malignancies - present evidence indicates increased death rate from gastric, pulmonary and skin cancer.
4. Cataract formation - linearly increasing probability above 200r - may approach 100% above 1000r.
5. Genetic damage - mutation rate for recessive visible genes: $5\text{-}25 \times 10^{-8}$/r/gene; recessive lethal mutations per gamete: $1\text{-}20 \times 10^{-4}$/r.

III Determination of Radiation Safety Standards in Manned Flight Operations

A. Present ICRP and NCRP maximum permissible dose (MPD) values generally unacceptable

1. MPD's set for potentially large populations at risk - not small flight crews.
2. MPD's set to hold biological hazard to occupationally exposed group as "negligibly small".
3. MPD's set for assumed career of about 50 years.
4. Philosophy of standards inconsistent with problem of multiple risk situation of manned flight.

B. Radiation protection primarily a matter of "acceptable degree of risk" vs "mission failure"

1. Risk primarily a function of acute radiation injury endpoints - gastrointestinal, hematopoietic, skin damage.
2. Risk secondarily a function of long term effects and career limitation.
3. Acceptable radiation risk may vary with each mission profile.

J. Warren Keller

RADIATION SHIELDING IN SPACE

I. Introduction

II. Passage of Radiation Through Matter

A. Protons

1. Ionization Loss - loss of energy through inelastic collisions with bound electrons

2. Stopping Power - rate of energy loss in material - function of particle energy and medium being penetrated

3. Range - distance traveled in material before being stopped - function of particle energy and medium being penetrated

4. Nuclear Collisions - inelastic collisions with nuclei of the material being penetrated - cascade and evaporation processes - production of secondary radiations; neutrons, protons, gamma rays

B. Electrons

1. Ionization Loss - loss of energy through inelastic collisions with bound electrons

2. Scattering - elastic coulomb scattering from atoms of the material being penetrated - decreases range - affects angular distribution

3. Radiation Loss - gamma rays (or bremsstrahlung) produced in deceleration process - fraction of energy loss through radiation, energy of bremsstrahlung, angular distribution dependent on material

4. Range - distance traveled in material before being stopped - function of particle energy and medium being penetrated

III. Methods of Calculation

A. General Approach

1. Idealized Geometry - slab geometry used to approximate spherical shield for isotropic incidence

2. Complex Geometry - realistic vehicle geometry is complex - sectoring technique used - many possible errors

III. Methods of Calculation (Cont'd)

B. Protons

1. Primary Protons - simple calculation to determine energy and angular distributions and dose behind shield

2. Secondary Radiations - complex problem - good data on production lacking but being generated by both experiment and theory

C. Electrons

1. Primary Electrons - complex problem - many assumptions used - Monte Carlo techniques useful for generating data

2. Electron Bremsstrahlung - assumptions necessary for practical calculations - gamma ray shielding involves both exponential attenuation and build-up factors

IV. Shield Effectiveness

A. Protons

1. Geomagnetically Trapped Protons - dose decreases very slowly with increase in shield thickness - secondaries not important for thin shields - low Z materials most effective

2. Solar Protons - dose decrease more pronounced with increase in shield thickness because of soft spectrum - secondaries not important for thin shields

B. Electrons

1. Natural Electrons - rapid decrease in dose with increasing shield thickness for penetrating electrons - bremsstrahlung sets limit on practical shield effectiveness - heavy materials most effective for stopping electrons but also produce greatest amount of bremsstrahlung

2. Artificial Electrons - greater shielding problem than natural electrons

V. Summary

Dr. D. E. Beischer

Physiological Effects of Magnetic Fields

An outline

Why are magnetic fields of interest to manned space travel?

Strong magnetic fields are considered as protection against ionizing radiation similar to the shielding action of the geomagnetic field. Application of such fields is considered also in ion propulsion, magnetic docking, energy storage, and other applications. These applications would depend on light weight superconductive magnet systems.

Magnetic fields of low intensity (about 1/1000 of the geomagnetic field) are expected on the moon and their possible physiological effects are of interest in connection with manned lunar landings.

How do extreme magnetic fields affect man?

The only effect of a very weak magnetic field (1/1000 of the earth's field) was observed in the visual sector (strong decrease of the flicker fusion threshold).

No systematic physiological studies with humans have been made on the effects of strong fields. Occasional observations showed that magnetic fields up to 20,000 gauss can be tolerated by man without sensation in part or total body exposure for short periods of time. There seems to be no cumulative effect of exposure to fields of 5,000 gauss for three days per year per man. Occasional spells of dizziness were noticed.

However, animal experiments in strong magnetic fields advise to caution. Recently, an effect on the electrical processes of the heart, demonstrated in the ECG, was noticed in monkeys and effects on all electrical processes in living tissue are expected. A number of experiments with animals indicate a general effect of unspecified etiology on all growing tissue. Inhibition and stunting of growth has been observed in a number of biological systems including tissue cultures. A delay of wound healing belongs in the same category of observations.

Influences of magnetic fields on function and behavior have also been described. A directional effect of the geomagnetic field on migrating and homing birds has often been discussed and a directional influence on the movement of snails has been fairly well established.

Alternating fields have visual effects (magnetophosphorescence) and fast changing very strong magnetic field, used in metal forming, stimulates motoneuron action. Some biomagnetic oddities such as the amelioration of tissue damage by radiation observed recently in the flour beetle and the existence of a magnetocardiogram will also be discussed.

Magnetobiology is a typical field which found impetus by possible space applications to the benefit of a new physiological insight.

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(Lecture Outline for George Washington University College of General Studies series entitled "Fundamentals of Space Medicine")

Space Related Medical Aspects of Ultraviolet, Visible, and Infrared Radiation

by

John A. Buesseler, M. D.

I Introduction:

Although the beneficial effects of natural sunlight have been appreciated by man since early recorded time, fruitful efforts at studying the biological effects of radiation began with the description in the late 18th Century of a series of disorders demonstrably due to abnormal cutaneous responses to light. However, in the absence of adequate theoretical and technical tools, real progress in the field of photobiology had to await the 20th Century. It is the brief exploration of this recently acquired knowledge, as it relates to space flight, with which this presentation is concerned.

II The Electro-Magnetic Spectrum:

Electro-magnetic disturbances which propagate themselves through space exhibit an unusually wide range. The center of the spectrum is usually taken to be the small band of radiations recognizable to the human eye as visible light. From this as the center, the spectrum extends in both directions, on the one hand, electro-magnetic oscillations several miles in length and, on the other, to cosmic rays with a wave length of approximately one-trillionth of a millimeter. Because the series of radiations involved are continuous, division into groups is somewhat arbitrary. Therefore, for the purposes of this discussion, the ultraviolet radiation band is considered to include wave length of 10 to 400 millimicrons, the visible band to consist of wave lengths of 400 to 780 millimicrons and the infrared radiation band includes wave lengths of 0.78 to 6 microns.

III Biological Effects of Electro-Magnetic Energy:

Radiant energy exerts a biological effect upon animal tissues only in so far as it is absorbed by them. The process of absorption may be considered to consist of two forms: a) the energy of the radiation may be dissipated in the resistance offered by the tissue to its passage, or b) the radiation is absorbed into an appropriate part of the molecular system of the organism. In the second mechanism, radiation is directly absorbed in an inverse relationship to its wave length. Thus the proportion of energy absorbed from ultraviolet light is greater than that from infrared radiations. Radiant energy absorbed in this manner results in an increased rate of molecular movement and, if sufficient in quantity, can alter the nature of the tissue by producing an abiotic (photo-chemical or photo-electric) lesion or a thermal lesion.

IV Abiotic Lesions:

The ultraviolet band of the energy spectrum produces a photo-chemical reaction in animal tissues. The substances particularly involved are the proteins and the effect is essentially a photo-chemical denaturation. The typical reaction appears only after a latent period of generally six to eight hours. The cellular manifestations are most often an inhibition of mitosis, a nuclear fragmentation, and an eosinophilic reaction in the nucleus and cytoplasm of the cell.

Because the reaction is dependent on the absorption of energy, a critical threshold of wave length and of intensity of radiation is necessary to excite it. In practice the degree of reaction varies directly with the time of exposure, inversely as the square of the distance of the source of light and directly as the cosine of the angle of incidence.

Most biological research and clinical data related to ultraviolet radiation has been concerned with the wave length band extending from the lower border of visibility (approximately 400 millimicrons) to the earth-bound limitations of transparency of air (approximately 180 millimicrons). It has been found that the erythemal effect is produced by the wave band from 180 to 315 millimicrons with peak action in the region of 240 and 297 millimicrons. Tanning effect is produced by the wave band from 315 to 400 millimicrons.

Although the body of the astronaut is protected by clothing or shielding, the areas of potentially greatest relative exposure to ultraviolet radiation in space are the eyes and the skin of the face.

V <u>Visible Light Disturbances and Lesions</u>:

Because of a lack of dispersion medium above the earth's atmosphere, reflection of light on the haze and cloud cover of the earth results in a so-called "reversed light distribution." Bright light from below the subject is not shielded by the eyelids and thus produces a veiling glare whereas attempts to read instruments against such a bright background results in a dazzling glare effect. Both types of glare reduce effective visual acuity.

Except for clinical cases of photo-allergy, the pathological effects of visible light radiation on the human skin has been essentially unexplored. However, in relation to a damaging effect upon the structures of the eye, it is generally accepted that such effect is largely unrelated either quantitatively or qualitatively to any particular portion of the visible light wave lengths band but depends more simply on the concentration of energy incident in this region of the eye. There is presently no firm evidence that visible light causes pathological lesions in the eye except where it is absorbed by the pigmented structures and is of sufficient intensity so that its conversion to heat is great enough to produce a thermal lesion. Outside of the earth's atmospheric cover, visible light emanating from the sun is sufficiently intense to constitute a source of potentially damaging radiation to the eye.

VI <u>Infrared Thermal Lesions</u>:

Although radiation of any wave length on being absorbed suffers degradation into heat to some extent, particularly when it encounters pigmented tissue, pathological thermal effects are most readily produced by the infrared band of the spectrum. Such radiational burns may be classified as: a) flash burns which result from the absorption of a large amount of radiant energy in a short period of time and b) a burn which involves a smaller concentration of energy acting over a considerable time period.

In regard to the skin, the wave length band from 0.8 to 1.5 micron can penetrate to a depth of 3 cm if sufficient energy is envolved; whereas, penetration of radiation with a wave length above 6 micron is virtually nil.

For the eye, infrared radiation of 0.8 micron wave length results in 78% of the incident energy reaching the retina. At 1.5 micron, 20% of incident energy reaches the lens and only 3% reaches the retina. At 3 micron and above, essentially all of the incident energy is absorbed by the cornea.. The band of greatest biological damage is from 0.8 to 1.2 microns.

Outside of the protective cover of the earth's atmosphere, the potentially damaging effect of the solar infrared radiation, particularly to the face and the eyes, is a matter of concern which is yet to be resolved.

Edward J. McLaughlin, Ph.D.

Code MMD - Space Medicine

SIMULATION

I. WORKING DEFINITION - THREE APPROACHES:

A. Convenience

B. Performance

C. Control

II. BACKGROUND

A. Early Simulators

B. Integrated Simulators

III. SIMULATION THEORY

A. Approach

B. Model

C. Program

IV. CLASSES OF SIMULATORS

A. Flight

B. Ground

1. Fixed Base

2. Moving Base

V. UTILIZATION OF SIMULATION DATA

A. Design Studies

1. Vehicle

2. Human

B. Systems Evaluation

C. Operational Procedures

D. Human Capacities

E. Training

F. Prediction

VI. SIMULATION METHODOLOGY - DEVELOPMENT SEQUENCE

A. Purpose

B. Task Analysis

C. Method

D. Equipment

E. Training

F. Subjects

G. Duration

H. Data

I. Results

VII. SUMMARY AND CONCLUSIONS

THE ROLE OF THE VESTIBULAR ORGANS IN THE EXPLORATION OF SPACE

I. Vestibular Mechanisms

A. Peripheral Organs

B. Central Nervous System Connections

C. Normal Functions

D. Functional Disturbances

1. The gravitoinertial force environment.

2. Illusions.

3. Neuromuscular disturbances.

4. Motion sickness.

II. Weightlessness and Subgravity States

III. Rotating Environments

IV. Summary

Under natural living conditions the most important cues for the perceived direction of space are furnished by the visual and gravitoinertial force environments. The best concordance between the two is manifested with man upright and its achievement represents one of the most dramatic manifestations of man's adaptation to his outer environment. Thus, in the course of his primitive sense experiences, the visual world underwent a reversal to conform with the gravitational upright and the central nervous system integrative mechanisms, continuously ensuring spatial orientation, constitute an elegant example of homeostasis.

It is necessary to keep in mind the evolutionary manner in which orientational homeostasis was acquired properly to appreciate how and why it is disturbed when man extends his natural abilities by artificial means. In adapting to these new force environments man at once reflects his habituation to specific natural terrestrial conditions, and the plasticity which characterizes his central nervous system. The conditions of aerospace flight have presented the greatest orientational problems for the following reasons; 1) man is operating in three dimensional space; 2) he may be exposed to a variety of force environments differing in magnitude and patterning of forces; 3) the transitions are usually abrupt, leaving little time for adaptation; 4) the forces may have injurious effects, and 5) the awareness of a possible abort poses a hazard ~~(1-3)~~.

Functional disorders may be a consequence of exposure to unusual force environment, including mental confusion, disorientation, illusory phenomena, motion sickness, and neuromuscular disturbances, including ataxia. Man's ability to cope with these disorders is determined by many factors which fall into different categories including 1) inherited characteristics, 2) the acquired functional central nervous system integrative patterning, 3) the ability to intellectualize the orientation task and deal with symbolic information, 4) the mental and physical demands of the operational task, other than orientation, and 5) the specific characteristics of the unusual force environment.

In approaching this problem from the operational standpoint the objectives are accuracy in predicting man's responses in gravitoinertial force environments to be encountered, definition of tolerance limits in terms of comfort, functional disorder and pathological change and validation of countermeasures. This represents an enormous undertaking due in no small part to the difficulty or impossibility of stimulating different force environments in the laboratory and, even when possible, the difficulty in providing small controlled incremental changes in strength of stimulus. Some of the investigations will have to be conducted under flight conditions despite the constraints due to cost and the many other disadvantages recognized as belonging to field laboratories.

In delimiting the subject matter for purposes of this report, attention will be focussed on some of the problems involved in spatial orientation which have occupied many investigations in our laboratory over a long period. The first part will be in the nature of a review, followed by a discussion centering mainly on disturbances which may be experiences in weightlessness and in rotating orbiting spacecraft.

POTENTIAL TOXIC HAZARDS IN SPACE FLIGHT

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The toxic effects of radiant energy, including the effects of ionizing radiation, microwave, ultraviolet, visible and infra-red light are being discussed by others. For this reason, this discussion will limit itself to the toxic effects of material substances, expecred to be encountered, in space travel. The subjects to be discussed are outlined below. It is assumed that we are dealing with space flights of six months or longer duration.

I. The Atmosphere of the Space Ships:

A. Particulate Matter (Solid)

1. Mechanical Effects:

These effects include skin and eye irritation, irritation to the intestinal and pulmonary tracts. They include irritation from material such as cotton, wool, animal hair, certain synthetic fibers and particles of proteinase nature including bacterial debris. They also include particles from food and excreta. In a weightless environment any of these particles may become atmosphere born. If particular importance are particles produced by wear due to friction. Chronic irritation, by the clothes worn by the astronaut is also a potential hazard. Decomposition of plastics and fragmentation must also be considered.

2. Allergic Response: In long range flight, allergy can develop to any of a host of substances included in (1) mentioned above. Chemical allergy is common in the chemical industry and the constant handling of certain materials can also result in allergy. Mercury is a particular offender and allergy to mercury is common.

B. Gaseous Composition:

1. Oxygen: The range of oxygen partial pressures tolerated by man, for extended periods of time, is rather narrow. Long-range experiments indicate toxic symptoms even at PO_2 levels as low as 174 mm of mercury as compared to 150 mm, at sea level, normally. Toxic symptoms appear at levels 110 mm of mercury typical to chronic hypoxia, for short periods of time, less than a few days, levels of the order of 400 mm of mercury have been tolerated. Symptoms of high oxygen pressures include substernal distress, syncope, pulmonary irritation, convulsions,

general malaire and fatigue. Enzyme inhibition results in deterioration of the overall metabolic process.

2. Ozone: Ozone is produced whenever oxygen is irradiated by ionizing radiation including ultraviolet light and low potential discharge. Thus ozone produced in space travel becomes a potential significant hazard. Ozone in air, at levels higher than 0.1 ppm, becomes significant in long range flight. The toxic effects of ozone simulate that of high oxygen concentration levels. Some of the toxic effects of ionizing radiation are due to ozone formation.

3. Carbon Dioxide: High concentrations of carbon dioxide result in acidosis and the attendant sequellae. Early symptoms of carbon dioxide intoxication are headache, drowsiness and decreased efficiency.

4. The Inert Gases:. The presence or absence of the inert gases particularly, nitrogen and their effect on the well being of the individual in long range experiments is controversial. One obvious effect of the absence of any inert gas is the fact that if the individual holds his breath for a period of time (e.g., 2-3 minutes), there is danger of lung collapse since a certain volume of gas is needed to keep the alveoli distended. Nitrogen, helium, neon and mixtures of these components have been suggested and tested.

5. Carbon Monoxide: The major danger of carbon monoxide intoxication is decreased efficiency of the individual, since high levels are not anticipated. Above 20% of hemoglobin saturation with carbon monoxide there is danger of death. At levels below 4%, hemoglobin saturation the levels can be tolerated. Such levels are often reached by heavy smokers. Carbon monoxide occurs in small amounts in normal exhaled air. It can also be produced in the space capsule by ionizing radiation or high temperatures acting on any organic materials such as plastics, oils, foods, etc.

6. Other Gases to be Considered:

a. Hydrogen sulfide and oxides of sulfur are a distinct probability of atmosphere contamination during space travel. Materials on the spacecraft such as rubber contain a relatively high percentage of sulfur. Degradation of food and from flatus ones obtain the sulfur containing gases. For H_2's the upper limit of tolerance is 20 pp.m. Toxicity at low concentrations is mainly due to combination with hemoglobin and the cytochromes.

b. Fluorine and Compounds of Fluorine: Because of the use of Teflon and related plastics, in numerous components of the space capsule, one must consider the results of their degradation. Teflon softens at 250°C and above that temperature degradation products appear. Ionizing radiation also degrades teflon at low temperatures. Thus, the danger of fluorine contamination of the atmosphere is a real one. Freons are also fluorine compounds and must be considered as potential toxic agents.

Fluorine in the atmosphere is toxic above the 0.1 ppm level.

c. Gases from Flatus: The volume of flatus varies from 500 (± 50%) milliliters per 24 hours in the normal adult. The lower volume is associated with a milk diet and the higher volume with a legume diet. The composition varies and generally consists of: - CO_2 - 8 - 34%; methane - 0-56%; hydrogen 1-4%; and nitrogen 10-64%. Other components such as H_2's, skatole and metabolism intermediates exist in small and variable concentrations. The higher percentage of combustible gases which may accumulate in a confined space represents a fine hazard, but not necessarily a toxic hazard. The precummulation of even small amounts of such intermediates as cadoverine or putrescine from bacterial decay in the intestine does represent a potential toxic hazard.

d. Other Gases: Chlorine is a toxic above the 1 ppm level. Generation by electrolysis from sodium chloride can possibly occur and must be considered. Decomposition of chlorine containing organic compounds such as in certain plastics (e.g., tygon, Kelef, etc.) are a distinct possibility.

Cyanide formed from nitrogen and carbon by ionizing radiation needs to be considered. Human tolerance is up to approximately 10 ppm in air. However, these observations are made for short periods and long range effects will probably simulate carbon monoxide poisoning. Cyanide inhibits the cytochrome oxidase system.

Metalic compounds such as of zinc (15 ppm toxic level), and copper (15 ppm toxic level) must also be taken into account. Beryllium, used in numerous components of the aircraft is of such high toxicity that the minimum acceptable concentration of this material should be below the level of detectability. Mercury and other heavy elements should not be present above the 1 ppm. level in the atmosphere. Although these heavy elements can be tolerated at higher levels for short periods of time, their effect is cumulative and this must be considered in long range flight.

e. Aerosols: Aerosols comprise fine suspensions of liquids, such as water or oils, which serve to act as solvents for chemicals, such as N_3, acids, alkalis, alcohols and other substances. Since particles readily suspend in the weightless state it becomes apparent that aerosols are formed more readily in space flight than under the influence of gravity.

Much of the "smog" in contaminated areas on earth may be classified as aerosols of irritating chemicals derived from factory or automobile exhausts. Any regent or liquid medicinal carried on board is capable of forming an aerosol when the container is opened. The fine suspension of water serves as a solvent, in addition, for the decomposition products of organic materials, such as plastics, on board. It can serve also to increase the hazard of toxic substance in the atmosphere by dissolving and thus concentrating them. Toxic effects from single eye irritation to systemic intoxication must be considered. Allergic manifestations are also distinct probabilities.

Fluorine in the atmosphere is toxic above the 0.1 ppm level.

c. Gases from Flatus: The volume of flatus varies from 500 (± 50%) milliliters per 24 hours in the normal adult. The lower volume is associated with a milk diet and the higher volume with a legume diet. The composition varies and generally consists of: - CO_2 - 8 - 34%; methane - 0-56%; hydrogen 1-4%; and nitrogen 10-64%. Other components such as H_2's, skatole and metabolism intermediates exist in small and variable concentrations. The higher percentage of combustible gases which may accumulate in a confined space represents a fine hazard, but not necessarily a toxic hazard. The precummulation of even small amounts of such intermediates as cadoverine or putrescine from bacterial decay in the intestine does represent a potential toxic hazard.

d. Other Gases: Chlorine is a toxic above the 1 ppm level. Generation by electrolysis from sodium chloride can possibly occur and must be considered. Decomposition of chlorine containing organic compounds such as in certain plastics (e.g., tygon, Kelef, etc.) are a distinct possibility.

Cyanide formed from nitrogen and carbon by ionizing radiation needs to be considered. Human tolerance is up to approximately 10 ppm in air. However, these observations are made for short periods and long range effects will probably simulate carbon monoxide poisoning. Cyanide inhibits the cytochrome oxidase system.

Metalic compounds such as of zinc (15 ppm toxic level), and copper (15 ppm toxic level) must also be taken into account. Beryllium, used in numerous components of the aircraft is of such high toxicity that the minimum acceptable concentration of this material should be below the level of detectability. Mercury and other heavy elements should not be present above the 1 ppm. level in the atmosphere. Although these heavy elements can be tolerated at higher levels for short periods of time, their effect is cumulative and this must be considered in long range flight.

e. Aerosols: Aerosols comprise fine suspensions of liquids, such as water or oils, which serve to act as solvents for chemicals, such as N_3, acids, alkalis, alcohols and other substances. Since particles readily suspend in the weightless state it becomes apparent that aerosols are formed more readily in space flight than under the influence of gravity.

Much of the "smog" in contaminated areas on earth may be classified as aerosols of irritating chemicals derived from factory or automobile exhausts. Any regent or liquid medicinal carried on board is capable of forming an aerosol when the container is opened. The fine suspension of water serves as a solvent, in addition, for the decomposition products of organic materials, such as plastics, on board. It can serve also to increase the hazard of toxic substance in the atmosphere by dissolving and thus concentrating them. Toxic effects from single eye irritation to systemic intoxication must be considered. Allergic manifestations are also distinct probabilities.

II. Drinking Water:

1. Particulate Matter; Mechanical effects are the major probelm which may develop. Spicules of fiber glass from degradation of the water tanks, if used, or plastic or metal particles would all serve as mechanical irritants to the intestine tract.

2. Soluble Contaminants: Any of the elements, considered toxic may contaminate the water supply. Those include mercury, thalluim, bismuth, cadmium, beryllium, arsenic, antemony, silver, copper, lead, fluorine, zinc, and others depending upon the metals carried on the spacecraft the composition of the water tanks, filters and purification equipment. Bacterial contaminants must also be considered. If a recycling process includes ion exchange, then one must consider the efficiency of the ion exchange system in removing these and other contaminants. Generally, a level of 0.1 ppm. of these elements should not be exceeded. For elements like sodium, chlorine, calcium and magnesuim, these should be kept to a minimum although concentrations as high as 100 ppm, can be tolerated even for magnesium for long periods of time. Concentrations of other soluble contaminants such as sulfur compounds (H_2s, 502) can serve as a hazard if present in excess of 10 ppm.

III. Food:

1. Organic Substances: Since the food intake will be largely of dehydrated natural foods, the hazard exists of the intake of toxic amounts of insecticides from fruits, and vegetables. Certain foods such as chicken and meat products are produced under the stimulating effect of certain hormone preparations. In dehydrated form, it is possible to consume larger amounts of a particular chemical than would be consumed of the hydrated product. Thus, such a hazard exists in long range flights.

2. Inorganic Susbstances: Ingestition of the elements listed would produce toxic symptoms in excess of the levels indicated. In mg/24 hrs. the maximum acceptable limit for certain elements is as follows: antemony 0.5, arsenic 0.6, lead, 2.5, mercury 1.0, cadmium,0.5, beryllium 0.1, cyanide 1.0, fluorine 3.0, thallium 0.5. Any of these elements will produce acute symptoms at relatively low dosage. For example, if 10 mg of cadmium is ingested at any one time toxic symptoms are observed. Some of these elements like thallium or lead will affect the central nervous system. Mercury is particularly injurious to the kidneys. Atemony and arsenic will interfere with normal metabolism by inhibiting normal oxidative phosphorylation, in addition to the gastritus observed when a large dose is taken. Fluorine inhibits glycolysis and lipose activity. In general, these elements inhibit metabolism and even in small amounts will result in a decrease in the number of erythrocytes resulting from an aplastic anemia.

3. Radioactive Elements: If experiments are carried onboard, using radioactive substances the hazard exists in ingesting them contamination

with the hands or surfaces of the capsule. The toxic effect of most of these elements, depending upon their half life, is essentially the same as receiving a continuous dose of irradiation externally. The toxicity will vary with the type of emission, activity and half life of the isotope.

IN-FLIGHT MEDICAL EXPERIMENTS

S. P. Vinograd, M.D.

I. GENERAL PRINCIPLES

A. Incremental approach is method of NASA Manned Space Flight to Determine feasibility of prolonged manned flight.

B. Two purposes of in-flight medical information:

1. Medical safety in-flight (mission at hand)

2. Determine effects of space flight (future missions). Primary purpose of in-flight medical experiments.

C. Experiments must be:

1. Valid

2. Reliable

3. Technically and Operationally feasible:

(a) Technical (engineering) constraints

Examples:

(1) Volume

(2) Weight

(3) Power

(4) TM Requirements

(5) On-Board recording requirements

(6) Long Lead Time

(b) Operational Constraints:

Examples:

(1) Time

(2) Non-Interference with Astro freedom of motion

(3) Non-Interference with other Mission Objectives

(4) Ease of Performance

(5) Ground Support Requirements

D. Medical Problems Requiring Experiments:

1. Stress Factors

(a) Prolonged Weightlessness and Combinations of others with it are only ones that cannot duplicate terrestrially.

(b) List of Stress Factors of Prolonged Flight (Barring Launch)

(1) Weightlessness

(2) Ionizing Radiation

(3) Confinement

(4) Social Restriction

(5) Monotony

(6) Threat of Danger

(7) Artificial Atmosphere

(8) Toxic Substances

(9) Particulate Contamination of Atmosphere ("Floating" Particles)

(10) Micro-organisms

(11) Change in Circadian Rhythms

(12) Magnetic Fields

(13) UV Light

(14) IR Exposure

(15) Noise

(c) All except weightlessness and combined effects can be investigated on ground - once measured.

2. Stress Effects on Man:

(a) Most important (present status)

(1) Cardiovascular Deterioration
(2) Bone Demineralization
(3) Muscle Atrophy
(4) Dehydration

} Phenomena of Disuse

(b) Other important effects possible:

(1) Hematologic
(2) Respiratory
(3) Vestibular
(4) Metabolic
(5) Peristaltic
(6) Ciliary
(7) Alertness
(8) Performance

(c) Disuse phenomena a potential problem on return to G environment primarily

E. In-flight medical experiments objectives:

1. Operational purposes:

(a) Determine human effects of prolonged space flight
(b) Mechanisms of Effects
(c) Means of predicting on-set and severity
(d) Means of prevention and/or remedy

2. Scientific purposes:

F. Method - Comparison of In-Flight with Baseline Data

1. Sources of Baseline Data

(a) Astronaut Selection, Medical Surveillance, and Training Procedures

(b) Ground Based Studies (Non-Astronaut Subjects)

(1) Bed Rest Studies

(2) Studies Validating Methods and Hardware

(3) Stress Studies (Subjects Instrumented During Stressful Activity)

2. Purposes of Baseline Data

(a) Control for Comparison of In-Flight Data

(1) To determine validity of observed changes

(2) To distinguis space flight factor as cause of observed change

(b) Validity of Measurements and Methods Planned for used in flight

(c) Establish normal range of responses to stress

II. <u>MERCURY PROGRAM</u>

A. Medical Measurements - Project Mercury

1. Safety Medical Monitoring

(a) Temperature

(b) Respiration

(c) ECG

(d) Blood Pressure

2. Medical Experiments

   (a) Xylose Absorption

   (b) Calibrated Exercise

   (c) Tilt Table - Flack Test

   (d) Urinary Calcium Output

   (e) Hormone Assays, Steroids, Adrenalin, Catechol Amines

   (f) Radiation Dosimetry

B. Medical Findings - Project Mercury

1. Cardiac Arrhythmias (Physiological)(Critical Periods)

   (a) Ectopic Beats

   (b) Tachycardia

2. Transitory Circulatory Change (weightlessness not proven cause)

   (a) MA-8, mottling of skin and venous distension of ankles

   (b) MA-9, near syncope, reduced tilt table tolerance

3. Dehydration

4. Norepinephrine Reduction (needs confirmation)

5. Reversal of Neutrophile-Lymphocyte Ratio Post-Flight MA-9, cause unknown, probably not significant

6. Negative Findings: Calcium Excretion, Xylose Absorption, Calibrated Exercise.

III. GEMINI PROGRAM

A. Safety Medical Monitoring same as Mercury; Equipment Improved

B. In-Flight Medical Experiments

1. M-1 Venous Cuffs; Preventive Measure

2. M-2 Tilt Table and Fluid Compartments (now operational procedure)

3. M-3 Calibrated Exercise

4. M-4 Phono-Electrocardiography

5. M-5 Hormone Assays

6. M-6 X-ray Densitometry

7. M-7 Calcium and other Electrolyte Balance

8. M-8 In-flight Sleep Analysis (EEG)

9. M-9 Otolith Function

C. Processing of Proposed In-Flight Medical Experiments in Manned Space Flight

1. Space Medicine Division
   (a). NIH Study Sections
   (b). Medical Advisory Council (Scientific Evaluation)

2. ECB

3. MSC, Houston (compatability evaluation)

4. MSFEB

IV. ORL STUDIES - SPAMAG

A. Method - Format

1. Three Phases

a. Support of Crew

b. Medical Experiments

c. ORL Design and Operations Recommendations

2. Final Product Including Recommendations for:

a. Prerequisite Space Flight Experiments

b. Prerequisite Ground Based Experiments

c. Prerequisite R&D

B. Importance of SPAMAG Study

1. Assist Design of ORL

2. Assist Formulation of Over-All Medical Experiments Program.

V. APOLLO PROGRAM

A. Three categories of Medical Experiments:

1. Define Environment, Intra- and Extravehicular, and Lunar (i.e., Man Made and Natural)

2. Determine Human Response

3. Test Evaluative Techniques Considered for Future Programs

B. Presently Planned Apollo In-Flight Medical Experiments

1. SA 204 - First Manned Apollo

2. SA 205 - Second Manned Apollo

C. Lunar Surface Medical Experiments - Present View

VI. APOLLO APPLICATIONS PROGRAM

A. General

B. Medical-Behavioral experiments; dual approach

1. R&D Program

2. Proposed experiments - Scientific community

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Code MM/Space Medicine

GROUND BASED STUDIES

The ground based studies are part of the space medicine program. Within this frame they have their own specific function and this is indicated in Table I.

TABLE I

GROUND BASED STUDIES

PURPOSE:

1. To study the effect of the space environment (earth simulation) on the astronaut.
2. To determine monitoring requirements and needs of protecting the astronaut.
3. To develop monitoring methods and protective devices.
4. To evaluate monitoring methods and protective devices.
5. To provide baseline data for evaluation of in-flight observations in the fields of anthropometry, physiology, and psychology.
6. To prepare the astronaut for spaceflight by exposing him to simulated space stress and familiarizing him with the mission's tasks and problems.
7. To supplement, extend, and verify in-flight observations.
8. To check out complete systems or subsystems (space suits, life support system).

If it is one of the major goals of the ground based experiments to supplement and extend in-flight information, we need criteria for selection of experiments and of suitable experimental approaches, and for interpretation and evaluation of results. This is the purpose of Table II.

TABLE II
COMPARISON OF GROUND BASED STUDIES WITH IN-FLIGHT EXPERIMENTS

ADVANTAGES:

No limitation of weight volume and power.

Chance of using large number of subjects, animals or plants (statistical significance).

Use of bulky equipment may increase sensitivity and reliability of measurements.

Possibility of increasing the variety of measurements and the frequency of data collection.

Availability of experts in many fields.

Possibility of using delicate procedures like intra-arterial measurements in man and surgery in animals.

Ease of scheduling.

Low cost.

No hazard to subject.

DISADVANTAGES:

Simulated instead of true space environment.

Lack of motivation.

Absence of hazard factor.

Difficulty of getting adequate data on astronauts or equivalent.

These two tables indicate what can be done and what cannot be done by means of ground based experiments. In addition we have to identify the problems that have to be solved. For this we use a matrix system plotting 58 environmental factors against 142 physiological and psychological functions. The 8236 intersections are then rated as to:

1. Critical for Apollo Mission.
2. Not critical for Apollo but possibly for future manned space flight.
3. Notcritical.
4. Unknown.

The utilization of this matrix approach is indicated in Table III.

TABLE III
IDENTIFICATION OF PROBLEM AREAS   STORAGE AND RETRIEVAL OF INFORMATION

Use of matrix approach by plotting the space-environmental parameters against the physiological and psychological functions.

a. Systematic approach assures that all possible problems will be considered.

b. Matrix provides a framework for collection and integration of existing information.

c. Storage of information for easy retrieval of information on individual effects or large fields.[1]

d. Identification of loopholes of information requiring further research.

e. Identification of problem areas.

f. Utilization of rating of intersections as a means of scheduling ground based studies according to mission requirements.[2]

g. Establishing a framework suitable for integrated presentation of many types of medical problems (normal ranges, sports physiology, industrial hygiene).

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1. (U.V. radiation and visual acuity)(environmental temperature and work performance)
2. (1 = Apollo 2 = Apollo Applications 3 = Lunar Shelter 4 = Mars Mission)

In manned space flight we are not only interested to find the tolerance limits under various environmental stresses, but we would like to know also when the performance of the astronaut will be significantly affected. Therefore, we are trying now to use a three dimensional matrix with mission phases and mission tasks as the third dimension. Dr. McFarland will discuss this work in greater detail.

A MODEL FOR THE SOCIAL SYSTEM FOR THE MULTIMAN EXTENDED DURATION SPACE SHIP *

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ABSTRACT

The conditions of isolation, confinement, and other stresses to which extended duration space crews will be exposed are unprecedented and many of the problems are not yet understood. Hypotheses directed toward principles to optimize crew organization and adaptation must be generated from present knowledge. Extrapolations might be attempted from various literature sources of human experience in extreme situations. However, the appropriateness of such generalization depends on the system similarity of the various situational contexts to that of the spaceship. A model social system for such microsocieties was constructed and system profiles of [illegible] well known system patterns were compared with that postulated for the extended duration spaceship. Greatest similarity was found for submarines, expedition parties, naval ships and bomber crews, and least for shipwrecks and disasters, industrial work groups, and prison groups.

INTRODUCTION

This report is part of a research program undertaken in anticipation of a need for behavioral science principles related to crew adaptability in the microsociety of extended duration space missions. Current analyses by space scientists at Boeing (1965), Douglas (1965) and General Dynamics (1965) of the timetable for manned flights to Venus and [illegible] estimate the earliest flyby of Mars between [illegible] 1977 and landing between 1982 and 1986. It is apparent that the conditions of confinement, isolation, and stress to which these crews will be exposed, during flights of one to three years duration, are unprecedented and that the problems involved are as yet not clearly understood. The lead time is not great and these problems must receive immediate attention to provide adequate opportunity for the research and development that will be required.

The present study is an attempt to understand and formulate the group behavior problems applicable to the extended duration space mission. It is concerned with group organization, structure, and interpersonal interaction of crew members in the environmental circumstances of a typical mission. The approach is to attempt to formulate a set of principles of social structure and group behavior as hypotheses for further research, using present knowledge as a point of departure. To maximize the application of present knowledge, it has been planned to supplement reviews of relevant literature with consultation with selected social scientists and experienced personnel in related situations.

Preliminary Exploration

One of the first steps in this study involved correspondence with a carefully selected panel of over 200 distinguished social scientists chosen on the basis of expertise in some aspect of the overall problem. They were sent a summary of the project objectives, approach, and procedures, and were asked to suggest significant problem areas, relevant literature, and ideas that might, in their judgment, pay off. This correspondence elictied overwhelming approval of the undertaking, without exception, from the entire panel, and a wide range of sugtions in response to the questions raised.

After reviewing and summarizing the suggestions, however, it became apparent that some definite criteria were needed to judge the relevance of data based on various situations, ranging from laboratory experiments to hazardous field observations, to the problems of the extended duration space ship. Such criteria in effect imply a conceptual model of the social system of the space ship microsociety.

Model definition was implicit in the discussion of constraints expected in the space ship situation that was presented in the summary memorandum referred to above. Among the probable features of this situation, the following were mentioned:

1. A formal organization with prescribed responsibility patterns for the entire crew;
2. Crew composition characterized by an elite corps of highly selected, trained, and educated volunteer specialists, all extremely ego-involved in the program and the mission;
3. Low organizational autonomy as a result of the NASA organizational and operational system and the affiliation of crew members with military and civilian career services;
4. Low formally prescribed status distance among crew members; and
5. High task demand and mutual dependence, under high levels of isolation, confinement, limitation of mobility and privacy, and environmental threat.

These constraints are believed to be correct, but

[1]Prepared as a report of NASA Grant No. NGR 44-009-008.

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although they point out several important characteristics of the space ship social system, they fall short of specifying the model. Further specification is attempted in this paper.

The Literatures on Isolation and Stress

An obligation of scientists approaching the present problem is to review critically available records and literatures on human experience in stressful, isolated, and confined situations in order to extrapolate significant observations, at least as hypotheses, to the situation of the extended-duration space ship. However, the literature in this broad category is vast and varies widely in relevance. Among the potential sources of information that have been suggested by consultants or staff members are field studies, participant accounts, and historical documents of incidents concerning naval ships, submarines, aircrews, prison populations, mental hospital populations, personnel at remote-duty radar sites and work parties, industrial work groups, athletic teams, exploration parties, personnel in air-raid shelters, shipwrecks, disaster situations, POW camps, and a variety of related situations that have received attention because they emphasized some unusual aspect of crisis, hazard, confinement, isolation, small-group process under stress, or the like. The problem of generalization of observations from such diverse situations is a major one which has received little systematic consideration by social scientists, who have apparently been more interested in particular aspects of behavior selected for study than in the contextual and systems aspects of the situations in which the behavior occurred.

The importance of this issue may be illustrated by an example. Consider for instance the difference between the effects of prison confinement of convicted criminals, of hospital confinement of mental patients, of confinement during depth bombing of a trapped submarine crew, and of confinement of a space crew in a capsule on a 500-day mission. The obvious differences, in intellectual and social level of the different groups, their motivation and identification with the situation, the conditions of confinement, the nature and acuteness of the stresses endured, the group solidarity, their training and preparation for the experience, and the payoff to individuals and group for successful endurance of the confinement, require little comment. In our opinion, variations among other relevant variables, such as those enumerated, may be of greater magnitude than that of the common, but by no means identical, variable, confinement.

Unfortunately, such is the nature of the literature available as background for the study of this new social situation in which isolation and confinement appear to be prominent conditions. However, these must be considered not only as particular aspects of a complex, multidimensional social system, but also in relation to other significant dimensions of the system. Despite the attention they have received, it appears that recognition of these variables as primary foci of the problem would be oversimplification.

DIMENSIONS OF THE MODEL

A distinction must be made between the broad dimensions of different types of social situations in which men have faced extreme environmental hazard and the modes of interaction exemplified in their behavior. In the former category, which is the focus of the present analysis, are such factors as group size, membership composition, organization, types of goals, sites of activity, equipment, skills, authority, and the like. The latter includes interpersonal behavior, leadership style, factors promoting or interfering with member motivation, and other principally behavioral aspects of group functioning. For purposes of clarity in communication we shall designate the first category by the term system structure of the microsociety, and the second, behavior patterns. In some cases, group behavior patterns may be highly standardized and appear as dimensions of structure.

In a perceptive report on the American Mount Everest Expedition, Emerson (1964) identified a number of aspects of the system structure of the Expedition as a means of facilitating the generalization of his results to a related class of group undertakings. Particular attention was directed in this report to three structural factors: (a) group size, (b) pursuit of group goals for which success or failure can be empirically defined, and (c) probability of success uncertain. Other factors, such as membership preselection and composition, sites of activity, equipment, skills, and authority involved were implicit in the identification of the Expedition. Such description of the setting in which certain behavior patterns were observed places these behaviors in a context of social structure in which the relevance of important constraints imposed by the system or particular system requirements can be evaluated. Generalization across contexts would be greatest when system characteristics are most similar. As similarity decreases, it is necessary to evaluate the effects of the variations observed.

The aim of this discussion is to propose a standard set of system structure characteristics that could be applied generally as a means of ordering various microsocieties according to their similarity to each other. This preliminary effort does not consider the weight or relative importance of particular characteristics to various systems or the variations among these over time or in different system states (confrontation with different problems). Some inferences on these issues are logically apparent and some information is available in the literature. However, the studies are scattered and do not fit into a uniform taxonomy. It is possible that the present attempt may have heuristic effects on needed studies of this type.

The system description involves seven categories that have general relevance. These are:

I. Objectives and goals
II. Philosophy and value systems
III. Personnel composition
IV. Organization
V. Technology
VI. Physical environment
VII. Temporal characteristics

Each of these categories involves important factors which can be ordered to some extent on continua conducive to comparative analysis.

Objectives and Goals

Several aspects of the objectives and goals of social organizations are more properly treated under category 4, organization. These relate to the degree of formal structure and involve consideration of whether they are officially specified and published or implied, whether they are mandatory or voluntary, and the nature of the authority under which they exist. In this section, the aspects of concern are the following:

Polarization. This reflects the extent to which an organization is goal oriented with respect to one or more major goals of importance to its sponsors and members. The space organization is highly polarized in both programs and projects, with clearly defined, announced goals.

Remoteness. This aspect refers to the time required between initiation of an activity and goal attainment. As the space program progresses, remoteness of overall goals is decreased, but duration of individual missions tends to increase, making their particular goals more remote.

Success Criteria. The criteria of success in goal attainment may vary from confusion and ambiguity, in the case of certain types of organizational goals, to clearly defined, measurable events or dimensions. Space mission goals have generally involved specific, measurable criteria, but some ambiguity may be pointed out in the assignment of credit. It has appeared, at least in the public press, that a greater share of credit is due to the planners and directors whose training and guidance was followed so skillfully by the astronauts in flight.

Success Uncertainty. An important consideration in any group enterprise involves the amount of uncertainty of mission success, both objectively and as perceived by the participants, and the objective and perceived consequences of failure. Despite the phenomenally successful record of American manned space missions to date, they may all be objectively characterized as involving high risk. The superb planning, provision of "backup" systems, testing, training, and overall preparation for successive missions has undoubtedly reduced subjective risk and increased confidence in the Mercury and Gemini programs. Nevertheless, new programs, such as Apollo, MOL, and Mars, bring new problems of unknown and known hazards to be faced and both objective and subjective uncertainty may be expected to fluctuate as new programs and missions within programs are activated.

Philosophy and Value Systems

The aspect of organizational philosophy of most general interest in the present context involves the values accepted with respect to the relative importance attributed to alternative goals and alternative means, costs, and risks related to the attainment of the preferred goals. With the exception of formal religious organizations, the governing value systems are rarely available in documentary form, but must be inferred from a variety of sources, such as the record of critical decisions made, key appointments, speeches and directives (as well as selected correspondence) by key officials, and the like. Such a study of NASA and related official values with respect to the space program would be valuable in the context of the present study. In its absence, the following speculations are tentatively proposed:

First, the operations of the American space program appear to continue the tradition of American military aviation with respect to command structure, mission emphasis, respect for individual lives, and cost-risk decisions.

Second, the American government has until now given the space program a very high priority and has placed virtually all of its facilities at the disposal of the space agencies for effective support.

Third, the astronaut value systems appear to reflect those of American military airmen, in character, motivation toward mission, family, and personal goals, professional attitudes and identifications, and of the traditions of American culture with respect to religious, moral, political, and social philosophy.

Personnel Composition

To the extend that the intellectual, motivational, personality, educational, professional, and moral characteristics of its members affect the functioning of an organization, both by the constraints implied by interaction of these with other factors, the limitations or specifications of the organization with respect to such characteristics constitute an important dimension.

More specifically, this category may be examined with respect to the upper and lower limits of intellect, education, training, experience, specified personality and moral characteristics, motivation of members to participate, dedication to mission, physical requirements, required skills, age range, sex, marital and parental status, religious background, and the like. This inventory might properly include the entire range of individual differences and demographic characteristics. However, in the present context, it is believed that most of the relevant factors have been enumerated. The well-known bases of astronaut selection have, at least thus far, proved successful, although it is not possible to examine many of the critieria critically. To date, the astronaut group has been drawn, first from a select group of military test pilots with extensive jet experience, and more recently from a more heterogeneous group of men with this or other relevant scientific training. In all cases, intellectual, motivational, emotional maturity, moral, educational, and physical standards have been exceptionally high.

Organization

It is necessary to examine organizational structure in terms of the degree of formal structure involved, organizational complexity and formal provision for authority, decision-making and direction (command). These considerations involve centralization of authority, sanctions permitted, provision for succession, chain of command, and the power and role structure. Other factors include autonomy, control of member behavior by the organizational authorities, degree of participation of members in organizational activities, and degree of stratification of ranks or echelons.

The question of authority brings in formal documents, such as constitution, laws, directives, and the like, which may specify objectives and goals, as well as the limits of authority assigned to various offices and roles.

Although the organizational characteristics of the Mercuty and Gemini programs and space crews can be fairly well described, certain changes may be expected in extended-duration missions as a result of their duration and isolation, concerning which decisions must be made, to which it is hoped the present study may contribute. The organizational patterns of the Mercury and Gemini programs, with respect to overall structure as well as crew organization resemble closely those of military aviation, with much of the command responsibility held by ground command. However, in the Mars mission and other extended-duration efforts, there are grounds for expecting the transfer of much authority to the spaceship commander, and with this, problems of assuring integrity of command in the isolated space ship become acute. Another factor, which probably belongs in this category, is the size of the organization, in terms of the number of participants required to perform the central tasks.

Technology

It is almost meaningless to discuss organizational behavior without taking account of the nature, complexity, characteristic operations, and traditions implied by the technology involved. The technology not only makes distinctions, such as between jet aviation and the earlier piston-propeller era, which involve differences in speeds, altitudes, schedules, and pay-load, but also between personnel types, traditions, training, and other significant factors associated with the respective technological fields. The technology of the space programs is new, although it follows the aerospace tradition. Among the peculiar aspects are the overwhelming significance of intensive training in anticipated emergencies as a means of insuring reliability of performance, the high level of training, experience, and skill required of crew members, the glamor associated with astronaut status (at least until the present), and the high risk associated with the very masculine (in the United States) astronaut role. The space technology has created new jobs, new vocabulary and technical jargon, and is currently regarded as one of the frontiers of human advancement. The type and extent of training and preconditioning provided participants are related to this section.

Physical Environment

Among the significant characteristics of various social systems are the distinctive features of their task environments, which have implications for the level of risk involved and the nature and magnitude of stresses encountered. The space environments are principally two, the space medium, which is unfriendly and hazardous to man, and the space ship and equipment which protect him and provide a supportive environment that enables him to endure in space. In extended duration missions, with the enforced isolation and confinement of groups of men from 8 to 12 in number for periods up to 500 days or longer, the protective capsule itself may be a major source of social stress, compounded by the period of time during which crew members must share the unnaturally confined quarters as work, living, recreational, and quasi-personal space. Here, again, is an unprecedented experience for man, with only fragmentary sources from which to extrapolate estimates of needs and reactions.

Several additional aspects of the physical environment, which are also related to the technology, involve the distinctions between a maneuvering operation and a static environment, between extended exposure to embedded, but not intrusive stresses and occasional, insidious exposure to highly threatening conditions, and between organizations that plan and prepare means of coping with the hazards expected and those that are caught unprepared. It can be stated that the space ship is a maneuvering group, exposed to embedded, but not intrusive stresses over long periods, whose preparations for coping are exceptionally thorough and, until now, effective.

Temporal Characteristics

So far as is known, the Mars mission and others of its general class involve continuous exposure to stress for human groups of an unprecedented temporal magnitude. Further, the capsule environment fits the description of a <u>total environment</u> (Goffman, 1957), in which enforced assocation is continuous and without the respite of discontinuity afforded man in his demographic characteristics. However, in the present context, it is believed that most of the relevant factors have been enumerated. The well-known bases of astronaut selection have, at least thus far, proved successful, although it is not possible to examine many of the critieria critically. To date, the astronaut group has been drawn, first from a select group of military test pilots with extensive jet experience, and more recently from a more heterogeneous group of men with this or other relevant scientific training. In all cases, intellectual, motivational, emotional maturity, moral, educational, and physical standards have been exceptionally high.

Organization

It is necessary to examine organizational structure in terms of the degree of formal structure involved, organizational complexity and formal provision for authority, decision-making and direction (command). These considerations involve centralization of authority, sanctions permitted, provision for succession, chain of command, and the power and role structure. Other factors include autonomy, control of member behavior by the organizational authorities, degree of participation of members in organizational activities, and degree of stratification of ranks or echelons.

The question of authority brings in formal documents, such as constitution, laws, directives, and the like, which may specify objectives and goals, as well as the limits of authority assigned to various offices and roles.

Although the organizational characteristics of the Mercuty and Gemini programs and space crews can be fairly well described, certain changes may be expected in extended-duration missions as a result of their duration and isolation, concerning which decisions must be made, to which it is hoped the present study may contribute. The organizational patterns of the Mercury and Gemini programs, with respect to overall structure as well as crew organization resemble closely those of military aviation, with much of the command responsibility held by ground command. However, in the Mars mission and other extended-duration efforts, there are grounds for expecting the transfer of much authority to the spaceship commander, and with this, problems of assuring integrity of command in the isolated space ship become acute. Another factor, which probably belongs in this category, is the size of the organization, in terms of the number of participants required to perform the central tasks.

Technology

It is almost meaningless to discuss organizational behavior without taking account of the nature, complexity, characteristic operations, and traditions implied by the technology involved. The technology not only makes distinctions, such as between jet aviation and the earlier piston-propeller era, which involve differences in speeds, altitudes, schedules, and pay-load, but also between personnel types, traditions, training, and other significant factors associated with the respective technological fields. The technology of the space programs is new, although it follows the aerospace tradition. Among the peculiar aspects are the overwhelming significance of intensive training in anticipated emergencies as a means of insuring reliability of performance, the high level of training, experience, and skill required of crew members, the glamor associated with astronaut status (at least until the present), and the high risk associated with the very masculine (in the United States) astronaut role. The space technology has created new jobs, new vocabulary and technical jargon, and is currently regarded as one of the frontiers of human advancement. The type and extent of training and preconditioning provided participants are related to this section.

Physical Environment

Among the significant characteristics of various social systems are the distinctive features of their task environments, which have implications for the level of risk involved and the nature and magnitude of stresses encountered. The space environments are principally two, the space medium, which is unfriendly and hazardous to man, and the space ship and equipment which protect him and provide a supportive environment that enables him to endure in space. In extended duration missions, with the enforced isolation and confinement of groups of men from 8 to 12 in number for periods up to 500 days or longer, the protective capsule itself may be a major source of social stress, compounded by the period of time during which crew members must share the unnaturally confined quarters as work, living, recreational, and quasi-personal space. Here, again, is an unprecedented experience for man, with only fragmentary sources from which to extrapolate estimates of needs and reactions.

Several additional aspects of the physical environment, which are also related to the technology, involve the distinctions between a maneuvering operation and a static environment, between extended exposure to embedded, but not intrusive stresses and occasional, insidious exposure to highly threatening conditions, and between organizations that plan and prepare means of coping with the hazards expected and those that are caught unprepared. It can be stated that the space ship is a maneuvering group, exposed to embedded, but not intrusive stresses over long periods, whose preparations for coping are exceptionally thorough and, until now, effective.

Temporal Characteristics

So far as is known, the Mars mission and others of its general class involve continuous exposure to stress for human groups of an unprecedented temporal magnitude. Further, the capsule environment fits the description of a total environment (Goffman, 1957), in which enforced assocation is continuous and without the respite of discontinuity afforded man in his accustomed habitat, in which he enjoys discontinuities of a tension-relieving quality when he moves from home to work to lunch, and so forth, in his daily life. An effect of the total environment, which may be mitigated to some extent by scheduling and by the provision of opportunities for privacy and solitude, is the magnification of interpersonal stresses generated by the enforced close contacts.

COMPARISON OF TWELVE SOCIAL SYSTEM PROFILES

On the basis of descriptive information on their generic characteristics in the literature, an attempt has been made by the writer to compare fifty-six reputed system characteristics of the extended-duration space ship with those of eleven other reference systems, each of which involves isolation, confinement, and/or stress to a high degree, and for which there is substantial information in the literature. These are:

1. Exploration parties and expeditions
2. Submarines
3. Naval ships
4. Bomber crews
5. Remote duty organizations (e.g. radar sites)
6. Professional athletic teams
7. Industrial work groups
8. Shipwrecks and disaster situations
9. Prisoner of war groups
10. Prison society
11. Mental hospital wards

The fifty-six system characteristics are subsets of the seven major categories described in the preceding section and are listed in the margin of Table 1. Taken as a whole, they constitute a preliminary effort to develop a system profile of significant aspects of a miniature social system. The entries in Table 1 represent comparison ratings of similarity to the condition of the extended duration space ship on each factor for each of the eleven comparison systems selected. Thus each column in Table 1 is presented as a system profile.

The entries in Table 1 are on a three-point scale: 2 (highly similar to the extended-duration space ship situation), 1 (moderately similar), and 0 (dissimilar or unrelated). These were inserted according to the judgment of the author on the systems compared. A maximum similarity score, for the 56 items, would be 112; scores could range from 112 to 0.

The data in Table 1 rank the eleven comparison systems on similarity to the extended duration space ship as follows:

Systems	Similarity Rank	Similarity Score
2. Submarines	1	79
1. Exploration parties	2	68
3. Naval ships	3	61
4. Bomber crews	4	60
5. Remote duty stations	5	59
9. POW situations	6	39
6. Professional athletic teams	7	37
11. Mental hospital wards	8	23
10. Prison society	9	20
7. Industrial work groups	10	16
8. Shipwrecks and disasters	11	11

Table 2 is interesting in that it indicates areas of similarity and dissimilarity among the eleven comparison systems with the space ship system by major category of comparison. Submarines are most similar overall, but match the space ship situation more closely in respect to goals, value systems, and organization, than on the other factors. POW situations, mental hospital wards, and prison groups are low in profile similarity, but are nevertheless high with respect to similarity of physical environment and temporal characteristics. In terms of overall closeness of fit, submarines, exploration parties, and bomber crews are most similar to the social system of the extended-duration space ship, while industrial work groups and shipwreck and disaster situations are most dissimilar. Nevertheless, it is of interest that the latter situations have been so frequently cited as significant literatures source for the present problem, without concern for the appropriateness of such generalization.

DISCUSSION

The foregoing analysis represents a preliminary attempt to compare the social system of the extended-duration space ship with several other types of social system that have been suggested as background sources for extrapolation of observations and generalization of principles. Although based on subjective judgment and on an unweighted and preliminary set of factors, the results demonstrate widespread differences among the twelve selected social systems compared, thus raising questions that invite serious concern about the utility to studies of the extended duration space ship problem of some of the most frequently suggested sources, as well as greater interest in others.

As a result of the favorable position of exploration parties, submarines, and naval ships (which would come out even more favorably if confined to the sailing ship era), several profitable historical studies of these literatures have been undertaken within our research group. The results of the present analysis also enhance the importance of certain contemporary studies, such as those of Emerson (1965) and Lester (1965) on the Mount Everest Expedition, of Weybrew (1963) and others in the submarine service, and of Gunderson and Nelson (1963) in the Antartic. Until adequate evaluation is made of the influences of variations in major system characteristics on behavior of groups and individuals in these groups, extreme caution is indicated in making generalizations from experimental and field observational results.

Table [illegible] Comparison of Social System Profiles of Eleven System Patterns with that of the Extended Duration Space Ship. Comparison Systems are identified as follows: 1. Exploration Parties and Expeditions, 2. Submarines, 3. Naval Ship[illegible]mber Crews, 5. Remote Duty Stations, 6. Professional Athletic Teams, 7. Industrial Work Groups, 8. Shipwrecks and Disaster Situations, 9. Prisoner of War Situations, 10. Prison Society, 11. Mental Hospital Wards. Ratings indicate degree of simi[illegible]rity to the Extended Duration Space Ship social system on a three-point scale: 2 (highly similar), 1 (moderately similar), 0 (dissimilar or unrelated).

System Characteristics	Comparison System 1	2	3	4	5	6	7	8	9	10	11
I. Objectives and Goals											
1. Formally Prescribed	1	2	2	2	2	2	2	0	1	1	1
2. Mandatory	1	2	2	2	2	1	1	0	1	1	1
3. Formal Authority	1	2	2	2	2	1	1	0	1	1	1
4. Polarization	2	1	1	2	1	2	1	0	0	0	0
5. Remoteness of Goals	1	2	2	0	2	1	1	0	2	0	0
6. Success Criteria	2	2	1	2	0	2	1	0	2	1	1
7. Success Uncertainty	2	2	2	2	1	2	1	2	2	0	0
II. Value Systems											
8. Obedience to Command	1	2	2	2	2	1	1	0	1	0	0
9. Mission Emphasis	1	2	2	2	2	1	1	0	0	0	0
10. Respect for Indiv. Lives	2	2	2	2	2	0	1	0	1	0	1
11. High National Priority	0	1	1	1	1	0	0	0	0	0	0
12. Military Trad. in Pers. Attits.	0	2	2	1	1	0	0	0	2	0	0
13. Accept. of Amer. Way of Life	0	2	2	1	1	0	0	0	0	0	0
III. Personnel Composition											
14. Intellectual	1	1	0	0	0	0	0	0	0	0	0
15. Educational Level	1	1	0	0	0	0	0	0	0	0	0
16. Extent of Relevant Training	1	1	1	0	1	1	1	0	1	0	0
17. Extent of Relevant Experience	2	1	1	0	0	1	1	0	0	1	0
18. Personality Selectivity	1	1	0	1	0	0	0	0	0	0	0
19. Moral Selectivity	1	1	0	1	1	0	0	0	0	0	0
20. Physical Selectivity	1	1	1	1	1	1	0	0	1	0	0
21. Possession of Requisite Skills	2	1	1	1	1	2	1	0	0	0	0
22. Motivation to Participate	2	1	0	0	0	1	0	0	0	0	0
23. Sex of Participants	2	2	2	2	2	2	0	0	2	0	0
24. Age Range	1	1	0	0	0	2	0	0	0	0	0
25. Presence of Non-Crew Pers.	2	1	0	0	0	0	0	0	0	0	0
26. Rank distribution (all "officers")	1	0	0	0	0	0	0	0	0	0	0
IV. Organization											
27. Formal Structure	1	2	2	2	2	1	1	0	1	0	0
28. Prescribed Roles	2	2	2	2	2	1	1	0	1	0	0
29. Command Structure	1	2	2	2	2	1	0	0	1	0	0
30. Centralized Authority	1	2	2	2	2	1	0	0	0	0	0
31. Chain of Command with Provision for Succession	1	2	2	2	2	0	0	0	1	0	0
32. Extensive Back-up Organization	1	2	2	2	2	0	0	0	1	0	0
33. Low Autonomy re Goals	1	2	2	2	2	0	1	0	0	0	0
34. Group Size (8-12)	0	0	0	0	0	0	0	0	0	0	0
35. Prescribed Discipline	1	2	2	2	2	1	0	0	1	2	1
36. Low Prescribed Social Distance Among Crew	2	0	0	0	2	0	0	0	0	0	0
37. Congruency of Rank and Status	2	2	1	1	1	0	0	0	0	0	0

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Living Conditions and Standards in Multiman Spacecraft

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I. Frame of Reference

A. Dependence of "Living Conditions and Standards" on all other aspects of the space mission.

B. Objectives.
   Mitigation of Stress
   Skill Maintenance
   Habitability
   Group Effectiveness

C. Salient Considerations.
   Multifactor Situations
   Mission Characteristics, including duration, size of group (crew), prior experience, national interest and support, group psychology problems

D. Sources of Information.
   Historical
   Laboratory Studies
   Field Experience

E. Research and Development Perspective.
   Dynamic, Emergent Nature of the Problem
   Relations Among Criteria; Selection of Criterion
   Problems of Extrapolation and Generalization
   Interdisciplinary Cooperation
   Definition of Research Problems, Optimal Design Characteristics

II. Conditions Related to Effective Performance

A. Characteristics of Individual Participants (Individual Differences).
   Health, Fitness, Aptitude, Training, Adaptation, Conditioning, Prior Experience, Motivation, Defenses Against Threat, Relations to Other Participants, Role, Relations to Task and Mission

B. Characteristics of Tasks.
   Task Components: difficulty, load, homogeneity, autonomy, transferability, redundancy, risk, reward
   Task Organization: relations to other tasks and to Mission

C. Characteristics of Environs (Micro- and Macro-environment).
Physical: Temperatures, Atmospheric Components, Noise, Vibration, Acceleration, Radiation, Zero-g
Social-Environmental (aspects of task and location) Isolation, Confinement, Task Load, Sleep-Rest, Privacy, Group Interactions, Mission Accomplishment (success-failure)
Psychophysiological: Fatigue, Diurnal and Other Cycles (Work-Rest organization), Nutrition, Adaptation, Acclimatization
Social: Formal Structure, Role Relationships and Concomitants, Responsibility Patterns, Interaction Patterns, Discipline, Mutual Support, Resistance to Disorganization, Cooperation, Conflict, Cliques, etc.

III. Tolerance Limits to Stress and Factors Deleterious to Reliable Performance
A. Limitations of the Concept of Tolerance Limits.
B. Lack of Relationship between Physiological and Performance End Points.
C. Special Problems of Group Stress.

IV. Approaches to Optimization of Individual and Group Performance
A. Cumulative vs. Alternative Measures.
B. "Making up the Difference."
C. Discussion and Illustration of Major Measures.
Personnel Selection
Physiological Adaptation
Realistic Training, Conditioning, and Accustomization
Nutrition
Psychopharmacology
Individual Protective and Supportive Equipment
Environmental Engineering
Human Factors Engineering
Task Systems Engineering
Psychophysiological Monitoring
Organizational Management
Leadership and Group Direction

V. Management and Leadership Problems in Multiman Spacecraft
A. Formal Organization Requirements.
B. Role Definition and Relationships.
C. Command, Discipline, Conformity.
D. Problem and Conflict Resolution.

E. Superior-Subordinate, Interpersonal Relationships.
F. Crew Training, Crew Integrity, Crew Identification.
G. Communications Problems Requiring Special Consideration.

VI. Trading-Off Problems, Priorities, Compromises

VII. Conclusions and Recommendations for Follow-up

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Harvard School of Public Health

Engineering Aspects of Space Medicine

Psychological Factors with Special Reference to Human Performance in Space Flight

I. The Relative Advantages of Men and Machines

A. A brief analysis of the superiority of men or of machines, depending upon the mission, or objectives to be accomplished.

B. The advantages of manned spacecraft.

1. Sensors and computers alone do not tell where to go, and if failures occur, man can take over.

2. Examples from the Mercury flights.

3. Man's ability to reason, use judgment, to make decisions, and to analyze and report.

C. The limitations of the human operator.

1. The impact of environmental factors, such as prolonged weightlessness, radiation, extremes of temperatures, fatigue, and loneliness.

2. The cost and excessive precautions which must be used for human subjects on dangerous missions.

D. Since the decision has been made to send men into space, solutions must be reached to achieve success in a wide range of missions.

1. The engineer should be informed of human capabilities and limitations in the design and operation of all types of equipment in the early stages of each project.

II. Sensori-motor Functions and Skills

A. The role of psychophysical methods in determining design requirements.

1. The relative human sensitivity for various sensory categories.

2. Three kinds of sensory measures, i.e., discrimination, category, and magnitude scales.

3. Threshold studies in relation to long exposures to adverse environments.

4. Combination of multiple variables in the environment.

a. Use of nomograms

B. The application of data from psychophysical measurements of selected sensory functions.

1. Differential light sensitivity in relation to seeing at sea level and at altitude.

2. The combined effects of altitude and selected toxic agents, such as carbon monoxide.

3. Examples from the fields of a) ventilation, temperature, and humidity, and b) noise and vibration.

C. Measurement of skill in sensori-motor performance.

1. Reaction times in the fields of vision and distance travelled in a) low altitude high speed flight, and b) at increasingly higher altitudes and speeds.

2. The effects of accelerative stress on sensori-motor skill and performance.

3. Studies of the effective field of view during visual fixation on displays of various sizes and shapes.

III. The Measurement of Complex Mental Functions and Abilities

A. The importance of understanding higher mental functions involved in the interpretation of data, information processing, and decision making during space flight.

B. The influence of adverse environmental factors and stress on cognitive abilities.

1. The effects of variation in altitude, temperature, and vibration, singly and in combination.

2. Workloads and channel capacity, including vehicle environment in relation to safety and efficiency.

C. Examples of objective measurements in the field of visual perception and interpretation.

1. Eye movement studies in relation to field of view, pattern recognition, and interpretation of the visual scene, including the phenomenon of "looking without seeing."

2. The recognition of patterns in relation to complex stellar and lunar formations.

D. The effects of confinement and isolation on higher mental abilities.

IV. The Implications of the Above Findings for the Design and Operation of High-Performance Aircraft and Space Vehicles.

ENGINEERING ASPECTS OF SPACE MEDICINE

OUTLINE OF

MAN-MACHINE SIMULATION

By

Milton A. Grodsky, Ph.D.

I. INTRODUCTION

A. What is man-machine integration? - The development of a system in which the capabilities of both the man and the machine are coupled appropriately so that the maximum performance of the overall system is obtainable.

B. In the development of a man-machine system, one must differentiate between inherent capability and ability to perform in certain environments.

C. Major variables under consideration in man-machine systems.

1. Habitability variables.

2. System or mission variables.

3. Task variables.

D. Importance of man-machine integration to the system.

1. Cost

2. System effectiveness.

3. Mission success.

4. Crew safety.

5. Overall system reliability.

II. SYSTEM INTEGRATION TECHNIQUES

A. Analytical Approach

1. Useful in an ill-defined area.

2. Use of mathematical or quasi-mathematical techniques to determine generalized factors.

3. Useful in early design.

4. As valid as the assumptions made.

B. Laboratory Approach

1. Experimental demonstration of man-machine performance capability.

2. Systematic approach when system problem is sufficiently defined.

3. Artificial in the sense that laboratory performance may differ from flight performance.

C. Simulation Approach

1. Test of concepts and a realistic approach for the collection of data on man-machine problems.

2. Provides a mode of investigation at a similar level to actual flight. Realism of actual flight can be simulated in most areas.

3. Types of simulations.

   a. Part-task.

   b. Integrated mission.

4. Provides training and selection data and can be used as a precursor to actual trainers.

D. Measurement Systems

1. The development of measurement schemes which are unique to man-machine problems.

2. The development of useful conceptual models which are fruitful in the conceptualization of man-machine system problems.

III. SYSTEM INTEGRATION PHASES

A. Conceptual design.

B. Phase I design.

C. Hardware design.

D. Factory test.

E. In-flight evaluation.

F. Personnel training.

The discussion will center on the type of system integration technique suitable for each of the design phases and the particular problems associated with each of these design phases.

IV. EXAMPLES OF PROBLEM AREAS & TECHNIQUES UTILIZED FOR THEIR SOLUTION

A. Pilot Performance Level During Flight

1. Importance of the problem.

   a. Man's role in the system.

   b. Support equipment for man.

   c. System reliability.

   d. Mission success.

2. Measurement of pilot performance. - Use of an integrated mission simulation technique which allows for the collection of a large amount of data on a variety of measures.

3. Results of studies performed.

   a. Capability studies.

   b. Laboratory studies.

   c. Simulation studies.

B. Weightlessness Effects

1. Determination of possible effects and the validity of the available data.

2. Engineering and systems solution to these possible effects.

   a. Artificial gravity.

   b. Exercise.

   c. Drugs.

3. Variables which will determine the engineering approach to be implemented.

   a. Cost and weight.

   b. Physiological protection and performance.

   c. Valid data prior to design.

V. CONCLUDING REMARKS

A. The future of man-machine integration is dependent upon the:

1. Increased complexity of the machine systems.

2. More system automation.

B. Areas such as intelligent machines and automata will eventually become a serious problem area in space flight. Will require inputs from a discipline which can design and put into being the intellectual and decision-making capabilities of man and the strength, endurance, and general tolerance of the machine into a working system.

Telemetry Modulation Techniques - a description of modulation techniques currently employed.

- Pulse Amplitude Modulation (PAM) - a description of a modulation format which varies the amplitude of each pulse in a pulse train in correspondence with the values of measured parameters.

- Pulse Duration Modulation (PDM) - a description of a modulation format which varies the time duration of each pulse in a pulse train in correspondence with the values of measured parameters.

- Pulse Position Modulation (PPM) - a description of a modulation format which varies the interval between subsequent pulses in a pulse train in correspondence with the values of measured parameters.

- Pulse Code Modulation (PCM) - a description of a modulation format in which the value of a measured parameter is converted to an encoded series of binary digits corresponding to the analog value of the date sample. A discussion of analog to digital conversion and digital handling techniques as well as a description of a typical PCM format will be included.

Transmission Techniques

Wire Transmission: The manner in which telemetry data is transmitted over long distances by use of "wide band data", "high speed data" and "low speed data" techniques will be presented. Long distance transmission of aeromedical data by special facilities will also be discussed.

R.F. Telemetry Links: A description of the UHF telemetry link used in Project Mercury and the UHF link planned for Project Gemini will be presented. The "Unified S. Band" RF link planned for use on Project Apollo flights will be covered.

Demultiplexing Arrangements - A description of the various arrangements used to separate composite telemetry into independent signal channels will be provided. Included will be a description of a typical FM/FM station, a PAM decommutator as well as a discussion of a "hardwire" vs. a stored program PCM ground station.

Display Techniques - A general description of conventional analog display devices for telemetered information will be presented. Project Mercury display methods will be discussed as will the recently implemented Gemini remote site display console group. Generation and display of computer processed telemetry information at the Manned Spaceflight Control Center will also be included. Typical aero-medical display formats will be presented.

Data Storage and Recording

Delayed Transmission Techniques - spacecraft recording of telemetry data for delayed transmittal to ground stations or post mission analysis will be discussed.

Ground Station Recording Devices - a comprehensive survey will be made of magnetic tape and oscillographic recording devices currently in use. Included will be a discussion of pre-detection and post detection recording arrangements as well as Visicorder, events recorder and strip chart records which can be employed for near real-time analysis of telemetered data.

NASA MEDICAL DATA ANALYSIS PROGRAM

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OUTLINE

1. Three Main Objectives

   a. Safety of Astronauts
      (1) While Mission is in Progress
   b. Scientific Products
      (1) Derivable from Total OMSF/NASA Program
   c. Standardization of Medical Data
      (d) For Computer Inputs and Analysis

2. First Objective - SAFETY - Involves

   a. Acquisition and Utilization of Data by Physicians
      (1) In Real-time(almost Instantaneous)(Displays)
      (2) While Mission is in Progress
   b. Readily Intrepretable Form
      (1) Both In-Flight and Ground-Based Medical Data
      (2) All Pertinent Medical Data about the TOTAL Individual and Environmental Conditions

3. Second Objective - Scientific Products

   a. Also Involves Acquisition and Utilization of Data
      (1) Near Real-Time Desirable
      (2) Real-Time Displays not Manditory
   b. Data Applicable to Longer Range Goals
      (1) Advances in Medical Science and Technology
      (2) Increasing the Safety of Space Crews
      (3) Prerequisites for More Extensive Flights
      (4) Development and Design of Spacecraft Equipment
      (5) Improved Criteria for the Selection of Future Space Crews

4. Third Objective - Standardization of Data for Computer Utilization

a. Involves Preparing All Types of NASA Medical Data on Magnetic Tape
   (1) In Interchangeable Form for Inputs to Computers
   (2) For Immediate Retrieval, Analysis and Application

5. Actions Necessary to Satisfy Objectives

   a. Determine Types of Data to be Standardized
      (1) In-Flight
         (a) Physiological
         (b) Environmental
         (c) Activity
      (2) Astronaut Clinical
      (3) Centrifuge
      (4) Baseline, etc.
   b. Develop Standard Format
      (1) Place Emphasis on Safety-Type of Data First
         (a) In-Flight Highly Important
   c. Prepare all Data in Standard Form for Computers
      (1) Assure Interchangeability of Types
         (a) For Purposes of Comparison and Prediction
      (2) Store on Magnetic Tape
         (a) For Computer Inputs Retrieval and Analysis
   d. Develop and Implement Computer Programs and Systems
      (1) For Analysis and Presentation (Display)
   e. Evolve and Coordinate ALL with Users (MSC)
      (1) Medical Research and Operations
      (2) Crew Systems Division
      (3) Appropriate Data and Computer Sections

6. Reasons for Preparing Data in Standard Form for Computer Inputs

   a. Interchangeability of Various Types
      (1) For Analytic Purposes
   b. Quick Retrieval and Analysis
      (1) Can't begin to Analyze Data Stored in Cabinets
   c. Broad Applicability
      (1) Applicable to one Type of Data
      (2) Applicable to all in Standard Form
   d. Selection of Best Methods of Various Diciplines
      (1) Sets and Sub-sets, Fourier Analysis, Factor Analysis, Rate of Change Analyses, etc.
      (2) Physicians, Engineers, Psychologists, Mathematicians, etc.
   e. Pay for Computer Program and System Once-Use Repeatedly
      (1) In Service Costs once only
      (2) Contractural Costs once only

7. Example concerning Principle of Interchangebility

   a. Various Types of Data in Standard Form
      (1) Pre- and Post-Flight Laboratory, Clinical, Simulation, Baseline, etc.
   b. Development of Computer to Analyze one Type
      (1) Best of All Diciplines
      (2) Applicable to all Types and all Missions
   c. Contract for Testing Hypothesis, Analyzing, Interpreting, and Reporting Results

8. Current Status-Progress Towards Integrated System at MSC

   (a) In Flight
      (1) Computer Program Already Developed for Time-Line Presentation of Data
         (a) Considering Total Individual
      (2) Clinical History in Process
         (a) System Compatible with MSC Computers
      (3) Laboratory Data in Process
         (a) Pre- and Post-Mission Blood Chemistries, Urines, Calcium etc.
      (4) Centrifuge in Process
         (a) Employ same Format and Computer Programs as In-Flight Data
      (5) EKG Pattern Analysis
         (a) Real time Analysis of EKG Patterns
         (b) Ready for Apollo (Nov/Dec)
      (6) Baseline
         (a) Comparisons
      (7) EEG Pattern Analysis
         (a) Objective Analysis-Computers
         (b) Consensus
      (8) Experiments
         (a) Computer Program Analysis
         (b) Real time for 5 Medical Experiments
      (9) Voice
         (a) Digitize with Computer
         (b) Relate to Medical Data
      (10) Contourograph
         (a) Stacking EKG
         (b) Comparison of Contours

9. Usual Ground Rules for each Contract

   a. Put all Appropriate Data on Tape in Standard Form
      (1) For each Type of Data
      (2) Provide NASA with all Tapes
   b. Be able to Select and Print-Out
      (1) Provide NASA with Various Listings

(2) Applicable to Immediate and Long Range Objectives of NASA

c. Make each System Open-Ended
   (1) Accept more Astronauts
   (2) Accept more Parameters
d. Be able to Question Computers
   (1) Key Safety Questions
   (2) Long Range Applicability
   (3) Furnish NASA with Computer Programs for Analyses Employed
e. Make System Compatible with MSC Computers
   (1) Must Develop a Usable System
   (2) Correct Machine Language
f. Use AMA International Coding
   (1) All Medical Terms
   (2) Convert Data on-hand if Required
g. Describe What was Done
   (1) Why, How, Results
   (2) Suitable for NASA Publication
h. Prepare and Administer Instructional Program
   (1) Short Course
   (2) Train NASA Personnel to Implement Program
i. No Press Release on Medical Data
   (1) Confidential Nature of Data
   (2) Unprofessional Interpretations could Result in Much Trouble, Misunderstandings, etc.

10. MSC Medical Data Program for Fiscal Year 67

a. In Service Analysis of Medical Data
   (1) Mercury
   (2) Gemini
   (3) Apollo
   (4) Basis for being Knowledgeable
b. Prepare Contractural Requirements
   (1) Work Statements based on Needs
   (2) Additional Computer Utilization
c. Evaluate Unsolicited Proposals
d. Initiate and Monitor Contracts
e. Implement Systems as they Become Operational

11. Summary

D. H. Stoddard, M.D.
Director, Occupational Me

OCCUPATIONAL MEDICAL SUPPORT OF NASA

Like many of you, we feel very strongly that occupational medicine is a much broader discipline than that normally understood by the medical profession. Indeed, we subscribe to the thesis that occupational medicine is a concrete, specific, coordination activity involving at least three scientific disciplines: The science of sociology, the science of engineering, and the science of clinical medicine. We include physiology and bio-electronics under the section of clinical medicine.

Since relative good, overall surveillance of a controlled population is readily available in the occupational environment, it provides us with an unusually good opportunity to study disease and its manifestations. It should be made clear at the outset that the majority of our time in occupational medicine is spent in evaluating disease whose etiology is not found in the occupational environment. The extent of this opportunity to study disease in the occupational environment was expressed very accurately by Pell. He suggested using the captive population of industry, since epidemiological research can be undertaken with a degree of completeness and accuracy, that would, perhaps, be impossible to duplicate in the ordinary population survey.

Like all of you, we appreciate the value of quality data. A tremendous effort is being made within our organization at this time to obtain better quality and more comprehensive data so that we have more factual data available to use in problem analysis. Furthermore, we feel strongly that more rapid handling of this data is necessary so that medical appraisals are more timely. As a result of this conviction, we are beginning to computerize as much of our relevant data as possible.

In the summary of this introduction, we might suggest that our strength in occupational medicine comes not from our unique training in the discipline of medicine, but rather because of our unique position in relationship to a given population, in which we can coordinate the skills of the social scientist, the engineer and the clinical medical experts in appraising the mechanism and significance of health in the working population. Furthermore, since the manifestation of disease which we encounter in industry, has its origin outside the occupational environment so frequently, we had better not limit our medical approach to a patient's problem to the work environment only.

ANALYSIS OF SPACE FLIGHT DATA

John C. Townsend, Ph.D.
Professor and Director, Experimental Psychology Laboratories
The Catholic University of America

The immediate concern of analysts of data on space flight personnel is with the GEMINI series and the planned experiments of the Orbital Research Laboratory. As the flights are now planned there will be a minimum of two and a maximum of approximately ten astronaut subjects participating in these flights. From the statistical point of view this means that although there will be thousands of measurements taken during each flight the analyses will be, in terms of subjects, conducted on very small samples. One might well ask the question "How can data be gathered on such a small number of subjects and still yield information that is reliable and generalizable enough to permit, perhaps, life and death decisions to be made affecting future astronatus?"

As a beginning point, it is wise to ask what kinds of questions will be asked of the data, and just what kinds of data will be available for analysis. In answer to the first question we can say that securing information concerning the validity and, concurrently, the reliability of the measures themselves will be paramount. It will be useless to perform elaborate analyses and draw decisive conclusions on data that are in themselves invalid. As to the second question concerning the kinds of data available, we know that the samples will be small, the variability large, and the data often reducible only to categorical rubrics wherein the quantification is in terms of frequency of occurrence of a particular behaviorism.

To the statistician this means that small sample statistics performed on non-parametric data may form the major part of his analysis. To analyze such data the latest techniques of this area of statistics will be applied. However, where sufficient numbers of data points are retrievable, and the pertinent assumptions are met then the more conventional parametric statistical tests will be applied.

Regardless of the particular statistics chosen for treating the data, the statisticians will be interested in at least the following types of analyses: the determination of the reliability of the measurements taken; the determination of base line data; the significance of relationships between variables; the significance of differences between various conditions; the interaction of variables which produce effects not attributable to any one variable acting alone; the practicality of certain statistical differences; the problem of absolute vs relative measurements of performance in evaluating performance; the use of several variables combined in their most efficient means to predict a future condition; and, the interpretation of trends as indicative of developing adverse effects.

Each of the above statistical problems and probable solutions will be discussed in the context of the data expected from space.

FUNDAMENTALS OF SPACE MEDICINE

"Human Standards"

by

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George Washington University
Washington, D.C.
October 25, 1966

Human Standards

I. Introduction

A. Definition of terms. Human Standards in space medicine obviously can be developed along various lines. In this lecture an introductory statement will be made in regard to the psychological and medical aspects of the problem. Emphasis will be placed, however, on those aspects of human standards relating to the tolerance of airmen and astronauts as well as their capability to carry out difficult and prolonged mission.

B. Standards Relating to Psychological Performance. In the selection of astronauts, it will be necessary to have minimum standards in regard to the following variables:

1. Mental Performance. The mental ability of potential candidates must be measured to insure the presence of the necessary skills. A college degree and additional graduate study will usually, but not always, assure minimum standards in this area.

2. Psychomotor and Related Skills. By means of a previous test analysis, it will be necessary to determine what skills are required. Appropriate tests can then be devised to predict the required skills. Simulation can be of great assistance here.

3. Personality and Emotional Adjustments. The objective measurements and tests in these fields are less reliable and it may be necessary to develop new ones in establishing minimum standards. An appraisal of the potential Astronaut's ability to work with others in isolation on prolonged missions must be considered.

4. Research Related to New Concepts in Developing Minimum Standards. Many of the mere traditional approaches will have to be reconsidered in this new field of selection and minimum standards for Astronauts.

C. Medical Aspects. The questions relating to medical fitness in the development of minimum standards is currently being studied in great detail and will be discussed by other speakers in this course. Only a few points will be emphasized here based on the wide experience of flight surgeons in the air transport and military services.

1. Diagnostic Techniques in Relation to Future Physical Fitness. At the present time a great deal of thought is being given to the best techniques for predicting fitness and health during middle age, i.e. 40 years of age. Minimum standards will have to be developed in various fields of stress testing, such as a) exercise tolerance, b) simulated loss of cabin pressure, and c) selected tests of adrenal function and central nervous system integrity.

2. Computer Techniques for Medical Data. At the present time the experience of the FAA is very revealing in the development of human standards for private, commercial, and air transport pilots. More than 450,000 medical examination records have been placed on punch cards for the first time. It is now possible to study the data from individual tests in regard to the distribution and variability of the findings, and their relevance to operational procedures including accidents. Similar techniques might be applied to advantage in the study of Astronauts.

3. Studies of Physical Examination Records and Accidents. In the past no objective proof has been produced to show the possible relationship between physical defects or "standards" in regard to operational efficiency and accidents. A brief report will be presented of studies by Harper and Dougherty, as yet unpublished which suggest a new approach of considerable significance. Similar investigations should be made of the Astronaut population in regard to developing human standards in various psychophysical and medical areas.

II. Human Standards in Relation to Tolerance

It is necessary to attempt to measure the thresholds and tolerance limits under any given stress to be experienced by the Astronauts. Furthermore, each stress is critically dependent upon the exact environmental configurations at the time of the exposure. Thus, standards may vary and those devised under one specific set of conditions cannot be extrapolated to another.

A. Injury Thresholds to Impact. Several examples will be presented from the experimental literature of the dangers involved in applying the findings from experiment to another under different conditions. Graphs will be presented from the experiments of Eiband, Hirsch, and Kornhauser to demonstrate this point.

III. Human Standard in Relation to Capability

It is equally important to develop standards in regard to capability for carrying out the varied tasks of space flight under different conditions of stress. In recent years the techniques of measurement have been greatly improved so that studies can now be made of an Astronaut's capabilities in regard to the above variables. These tests include not only the psychological aspects of performance but also impairment in physiological changes and work output, including the overt activity of the integrated organism during operational procedures.

IV. Techniques of Measurement

Techniques have now been developed in sensory and perceptual research which may be of use in developing human standards of Astronauts in space flight. Primary features of such tests include a high degree of sensitivity, independence of the results from conscious effort, and stability of function when the stresses are applied.

A. Measures of Speed and Accuracy Combined. With the development of information theory a way of combining measures of speed and accuracy into a single "rate-of-information-transmission" measure is available. In this way it is possible to determine the magnitude of task-induced stress required to produce an environmentally interacting effect.

B. Tests that Detect and Scale Increased Effort. Two avenues of research offer tests of increased effort. One of these is concerned with spare capacity and of peripheral attention. The deterioration of performance on a primary task with increased load at a secondary task is a good example of this area of testing. The effects of fatigue can be measured in terms of the steepening gradient of these spare capacity measures. The other area of research relates to physiological measure of arousal, tenseness and so forth. A number of techniques for measuring not only muscular tenseness, but also central nervous system acitivy, and even specific components of neural reaction to signals have been developed.

V. Experimental Results Relating to Studies of Tolerance and Capability in Developing Human Standards for Space Flight.

The major part of this presentation will be devoted to reviewing the experimental literature in selected fields such as noise and vibration, temperature, hypoxia, carbon monoxide, and circadian rhythms in the development of human standards for space flight for Astronauts.

A. Effects of Noise and Vibration on Human Performance. There is strong evidence of interaction between the environmental stresses of noise and vibration and task difficulty in determining performance decrement. Examples will be given to show how the proper selection and combination of tests will give rise to positive findings in areas that have previously resulted in negative findings.

B. Effects of Temperature. In this field it has been possible to show how reactions times or errors in computation are not present until conditions become extreme. The newer approaches, however, where a selected grouping of tests have been used, have given positive results under more moderate environmental conditions. In one of our studies an apparatus has been developed with positive feedback so that the greater the success of responses, the greater becomes the rate of the stimulus programming. While performing this test, the subject is also required to monitor six signal lights, three on each side of his visual periphery. Thus, such a combination of tests can be used to study the effects on performance of temperature, hypoxia, sleep loss and other stresses.

C. Hypoxia and Carbon Monoxide. In these areas it is necessary to study the effects of both acute and prolonged exposures. A series of experiments will be reviewed in which the author has demonstrated the effects of altitudes as low as 4,000 feet. Other studies of sensory and mental functions will show the effects on a wide range of tasks of altitudes up to 20,000 feet.

The studies of carbon monoxide have included a combination of sensory and physiological tests, such as the blood gases, in minor, acute and prolonged exposures. In these studies nomograms have been developed so that one can follow a series of variables in a simple chart.

D. Circadian Rhythms. There is great interest in studies of tolerance and capability in regard to the effects of Circadian rhythm on human subjects. It is interesting to note that some of these newer techniques have been able to relate the subjective feelings to physiological measurements. A better understanding of this field will be of great importance in developing human standards for performance on long flights.

VI. Summary and Conclusions

In this lecture it has been pointed out that a completely new approach must be developed for appraising the performance and capability of Astronauts. The first step involves an adequate understanding of the physical stimuli which will be experienced during space missions. The next step is to try to simulate these tasks in the laboratory, and the final phase involves the integration of these findings into the development of human standards. Systems analysis, nomograms, and mathematical models are only as good as the data which are used to compile them. One can conclude that much remains to be done before satisfactory answers can be found to some of the questions raised above.

Guest Lecture for George Washington University short course, "Fundamentals of Space Medicine", 18 - 28 October 1966

DOD ORGANIZATION

by

Brigadier General John M. Talbot, USAF, MC*

Good morning, gentlemen. After many years of absence, it is stimulating to be back in a great university environment to spend a short time with you. My task is to inform you about the organization for space medicine within the Department of Defense. By way of introduction, several points should be clearly understood. First, although my remarks will concern mostly the organizations for research, development, test, and evaluation, the Department of Defense has some operational responsibilities in space medicine which are distinct from the research and development effort. Thus in the Minuteman program of the Air Force, for example, you will find a supporting service called the Aerospace Medicine Program, which is conducted by flight surgeons, bioenvironmental engineers, and other specialists in military preventive medicine. A more familiar operational space medicine program to this audience might be the medical flight monitoring and medical recovery forces which are deployed from Army, Navy, and Air Force for each of the NASA manned space flights. In a typical Gemini flight, as many as 60 officers and enlisted specialists of the medical services are placed on temporary duty away from their home stations to man the medical flight monitoring teams and medical recovery forces.

The second point. It should be of special interest to non-military scientists and engineers that the research and development programs of the

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armed services in the broad field of the life sciences must be mission oriented. That is, their products must clearly support some mission element of the national defense. However, because of official agreements between the NASA and the DOD, various biomedical research laboratories of the Air Force and Navy conduct space medical experiments and tests in direct support of NASA manned space programs. The third point concerns terminology. Our course is in space medicine. You should recognize at least two other words which are in common use in the armed services, which mean approximately the same thing as space medicine: in the Air Force, bioastronautics and aerospace medicine; in the Navy, aerospace medicine.

FIRST VUGRAPH

In the remaining time, I shall describe the organizations within the Department of Defense whose missions include responsibilities for space medicine. In addition, I mean to give examples of some of the resources of these organizations which are noteworthy in terms of space medicine. There is no particular need to take notes since most of the material to be covered is in the handouts.

SECOND VUGRAPH

The Secretary of Defense has a research and development chief known as the Director of Defense Research and Engineering. Within this directorate, under the Assistant Director for Research and Technology is the Chief of the Biological and Medical Sciences Division. This is a one man office, currently manned by a research medical officer of the Army. He is responsible for review and cognizance of all Department of Defense research and development programs in the medical, biological, behavioral, and social sciences. There are three research and development management offices in the Headquarters of the United States Air Force. These are the Chief of the Science Division in the office of the Deputy Chief of Staff for Research and Development; the office of the Special Assistant to the Surgeon General for Medical Research (which I am currently privileged to head); and the Assistant for Bioastronautics in the Manned Orbiting Laboratory Program Office within the Office of the Secretary of the Air Force. Both the Chief of the Science Division and I have two or three officers assigned who are specialists in aerospace medicine or one of its allied sciences. The MOL Assistant for Bioastronautics is a one man office. All of these are program management offices at the policy making level. In addition, and reporting directly to the Chief of Staff of the Air Force, we have the Aeromed/Biosciences Panel of the Scientific Advisory Board. This is a handful of outstandingly competent civilian scientists who advise on aerospace medical matters.

At the next organizational level, I show the Surgeon of the Defense Atomic Support Agency. This is a jointly staffed agency, whose chief reports directly to the Secretary of Defense. The medical office of this agency manages important research programs in the medical aspects of nuclear energy. In addition, note the Assistant for Bioastronautics to the DOD Manager for Manned Space Flight Support Operations. This bioastronautics specialist is currently Colonel Frese, who is stationed at Patrick Air Force Base, Florida. He is responsible for planning and directing the program which uses Army, Navy, and Air Force medical personnel for the support of NASA manned space flights. In the Air Force Systems Command Headquarters at Andrews Air Force Base, D. C., is the Office of the Deputy Chief of Staff for Bioastronautics and Medicine. This deputate, and in particular, its Director of Bioastronautics, is responsible for the management of all the life sciences laboratories, test units, and support units of the Systems Command. The airbase and combat organizational staffs of all the Air Force's operational commands are involved in medical support of manned space flights. These commands include SAC, TAC, ADC, USAFE, and PACAF.

Here at the subordinate command level, we list the Headquarters of the Aerospace Medical Division, the Research and Technology Division, the Air Force Flight Test Center at Edwards Air Force Base, California, and the Air Force Eastern Test Range, with Headquarters at Patrick Air Force Base, Florida. Each of these subordinate command organizations has a role to play in the space medicine program; however, by far the most significant in this column is the Aerospace Medical Division. As may be seen in the last overlay, this division has assigned to it the three principal space medical research laboratories of the Air Force: namely, the School of Aerospace Medicine at Brooks AFB, Texas, the Aerospace Medical Research Laboratories at Wright-Patterson AFB, Ohio, and the Aeromedical Research Laboratory at Holloman AFB, New Mexico. Also listed because of its significant research program in the effects of simulated weightlessness and physical fitness, is the Air Force's largest hospital, the Wilford Hall Hospital at Lackland AFB, Texas. But, to go back to the Defense Atomic Support Agency for a moment, note in this column, the Armed Forces Radiobiology Research Institute. It is located on the grounds of the National Naval Medical Center at Bethesda, Maryland. It has advanced facilities for investigation of the biological and behavioral effects of ionizing and other penetrating radiations; consequently, we expect that the scientific information generated at this institute will be of importance in terms of evaluating space radiation hazards.

Next, as a part of the Research and Technology Division, we note the Biophysics Branch of the Air Force Weapons Laboratory, located at Kirtland AFB, New Mexico. This branch is important in the space medicine program because of its capabilities for measuring space radiations by rocket probes and satellites, and for flight test in orbit of advanced designs of radiation dosimeters.

At the Air Force Flight Test Center and organizationally a part of the USAF hospital there, we have the Directorate of Bioastronautics. This directorate gives specialized aerospace medical support to advanced developmental projects such as the X-15 program and to the Aerospace Research Test Pilot School. It is exceptionally well qualified in life support and physiological telemetering. The Director of Bioastronautics at Headquarters Eastern Test Range, Patrick AFB, Florida is one and the same as the Assistant for Bioastronautics noted above in connection with the DOD Manager for Manned Space Flight Support. In his role as Director of Bioastronautics, AFETR, he is responsible for planning medical support of recovery operations for DOD manned space flight programs and for developing improved methods and equipment for in-flight monitoring of astronauts and for automatic processing of flight medical data.

THIRD VUGRAPH

The Department of the Navy organization for space medicine appears slightly more complex than that of the Air Force, as you will see; however, if one remembers one or two key offices at the departmental level, he can readily obtain accurate information about the whats and wheres of space medicine in the Navy. These are the Office of the Director of Research in the Bureau of

Medicine and Surgery in Washington, and the office of the Assistant for Medical and Allied Sciences in the Office of the Chief of Naval Research, likewise in Washington. Two other important research management offices within the Navy headquarters are these: The Assistant for Medical and Allied Sciences in the Office of the Deputy Chief of Naval Operations (Development) and, by the same title, in the Office of the Chief of Naval Materiel. It should be clear that these offices are concerned with the entire gamut of medical, biological, behavioral, and social sciences research and development in the Navy; that is, that space medical R&D is but a portion of the whole program. The bottom entry in this column is,again, the Bureau of Medicine and Surgery which corresponds with the Office of the Surgeon General in the Air Force and Army. It is placed in this position to show a supervisory relationship with certain subordinate activities and laboratories, as will be shown in the overlays. In this column we see the key major commands or equivalent activities through which management control and direction are funneled to the laboratories. First the Naval Air Systems Command and the Naval Ships Systems Command, both in Washington. Then the Naval Air Training Command at Pensacola, Florida. In addition, the Naval operational commands, certain shore establishments, and Naval hospitals enter the picture in terms of medical support for manned space flights. To return to the Chief of Naval Research, we see here the two directorates in the Office of Naval Research whose programs include items of interest to space medicine: The Directorate of Biological Sciences, and the Directorate of Behavioral and Social Sciences.

At the subordinate command level, the Navy has several agencies which are concerned with management control and communications for the space medical program. The Naval Air Engineering Center in Philadelphia; the Patuxent River Test Center, which corresponds to the Air Force Flight Test Center at Edwards AFB, California; and the Naval Air Development Center at Johnsville, Pennsylvania. Shown below are two medical organizations which are likewise in the management/communications chain between Washington and the laboratories: the National Naval Medical Center at Bethesda, and the Aerospace Medical Center at Pensacola.

At the laboratory level we see this rather imposing list of organizations whose programs contain elements of research and development of interest to space medicine. The Aerospace Crew Equipment Laboratory at Philadelphia roughly corresponds to the Air Force's Aerospace Medical Research Laboratories at Dayton; the Aeromedical Test Unit at Patuxent River is similar in mission to the Bioastronautics Directorate at Edwards AFB. At Johnsville, Pennsylvania there is the Aerospace Medical Research Department. This was formerly known as the Aeromedical Acceleration Laboratory because it was built around the famous "Johnsville" centrifuge. The Naval Radiological Defense Laboratory at Hunters Point in San Francisco is, of course, concerned with investigations of the biological effects of ionizing radiation. The Research Department of the US Naval Submarine Medical Center at New London is the former Naval Medical Research Laboratory at that location. Its studies in the biomedical and psychological aspects of submarine habitability and underwater physiology generate information of great interest to the space medicine program. The Naval Medical Research Institute and the Toxicological Unit at the National Naval Medical Center have considerable potential for investigating space medical problems. Probably the best known and single most important Naval laboratory for space medical research is the Naval Aerospace Medical Research Institute at Pensacola. It was, until recently, known as the Naval School of Aviation Medicine; its research program has been under the direction of the most able Captain Ashton Graybiel since the days of World War II. Finally, we should note that the personnel for medical support of NASA manned space flights are drawn largely from the Naval operational commands, shore establishments, and Naval hospitals.

I have not included a slide for Army biomedical research laboratories because the basic mission of the Army has not justified research and development in the space medical field. Nevertheless, it should be recognized that within the Army's extensive R&D resources are certain highly specialized scientific capabilities which from time to time are engaged in supporting space medical R&D. For instance, the Army's environmental physiology laboratory at Natick, Massachusetts is helping the Air Force in the development of improved space foods. In addition, the Army Medical Service contributes its share to the support of the NASA manned space flight program by providing doctors from its hospitals and aviation medicine activities to participate in the recovery operations and in-flight monitoring.

We have had a glimpse of the names of the main R&D laboratories of the Air Force and Navy, which contribute to the space medicine program; similarly, the research management and supervisory offices at various levels of responsibility. It seems appropriate at this point to mention a few of the scientific and technical capabilities of these laboratories. I'll not devote much time to this because this information is outlined in the handouts, which I'll tell you about in a few minutes.

FOURTH and FIFTH VUGRAPHS

(Cite examples of noteworthy scientific capabilities and test devices pertinent to space medical research as noted in Vugraphs 4 and 5.)

As I near the conclusion of this briefing, it appears useful to say a word about where to go in the Air Force and Navy to present research and development proposals. First, it should be realized that each of the laboratories, institutes, test units, and life sciences research management offices listed in the preceding material has a continuing interest in and responsibility for cooperating with the civilian scientific community in research and development matters of mutual concern. In other words, if an individual scientist with a university, industry, or private group has a research proposal which he feels would be appropriate for support by the military, he could expect and receive an interested audience at these activities. If he wishes to submit a written proposal for consideration for contractual support, he should send it to the following: in the Air Force, to Headquarters of the Aerospace Medical Division (AFSC), Brooks AFB, Texas 78235; if the proposal is for a rather basic study, he should send it to the Director of Life Sciences, Air Force Office of Scientific Research, Washington, D. C. 22209. In the Navy, written proposals should be submitted to one of the following offices, depending on their content: Dr. Roger Reid, Chief of the Biological Sciences Division, Code 440, or Dr. Richard Trumbull, Chief of the Behavioral Sciences Division, Code 450, Office of Naval Research, Washington, D. C. 20360.

I have some handout material for you which I'd like to explain. First, there are copies of the Vugraphs and the text of my remarks; then a map indicating the locations of all the Air Force aerospace medical research and development activities as well as three or four special scientific support laboratories. I've included a booklet entitled "Aerospace Medical Division Fact Sheet". And a descriptive packet on R&D under the cognizance of the Navy Bureau of Medicine and Surgery. Also, a booklet about the Office of Naval Research Contract Research Program. Finally, there is the Department of Defense booklet titled "Facilities for Research and Development in the Medical Sciences", to which we have added a change sheet which updates the names of some of the laboratories which have changed since the publication date of the booklet.

I have presented a summary of the DOD organization for space medicine research, development, and operational support. Probably the long list of headquarters and intermediate command level offices involved in the management and communications aspects of this program seems somewhat bewildering at first acquaintance. Don't feel upset. Some of us have been with it for years and we still find it difficult to stay abreast of all the organizational changes which seem to be a part of the normal anatomy and physiology of this vital and dynamic endeavor.

TELEMETRY AND STORAGE OF INFORMATION

Introduction - a brief discussion of the definitions, history and application of telemetry. A simplified "block diagram" discussion of the elements of an aerospace telemetry system will be included.

Acquisition of Data - a discussion of principles of transducer operation as applied to telemetry.

- Engineering Sensors - a description of the types of sensors employed in the collection of engineering data.

- Aeromed Sensors - a description of the types of sensor in current use for collection of biomedical information.

Multiplexing Techniques - considerations of the effective utilization of communications facilities and bandwidth. General considerations of bandwidths required for data transmission will be included.

- Frequency Division Multiplexing - a description of the technique for frequency sharing a communication channel for simultaneous use by independent information sources. An explanation of frequency modulation and of IRIG standards is included.

- Time Division Multiplexing - the principle of time-sharing multiplexer techniques based on the sampling of continuous data by the commutating of signal sources. A description of mechanical and solid state commutators with a discussion of commutation, sub-commutation and super-commutation will be provided.

Table 1. Continued

System Characteristics	Comparison System 1	2	3	4	5	6	7	8	9	10	11
V. Technology											
38. High Technologic Complexity	1	2	1	1	1	0	0	0	0	0	0
39. Relation to Aviation Tradition	0	1	1	1	2	0	0	0	0	0	0
40. Use of Simulators and Other Technical Training Devices	0	1	1	1	1	0	0	0	0	0	0
41. Extensive Preparation for Missions	2	1	1	1	0	1	0	0	0	0	0
42. Use of Technical Language in Execution	2	2	1	1	1	1	0	0	0	0	0
43. Physical Preconditioning	1	1	1	1	0	1	0	0	0	0	0
44. Scientific Principles Involved	1	1	1	1	1	0	0	0	0	0	0
VI. Physical Environment											
45. Required Physiol. Protection and Life Support	1	2	0	0	0	0	0	0	0	0	0
46. Extreme Remoteness from Base	1	1	1	1	1	0	0	1	2	1	1
47. Presence of Unknown Environmental Hazards	2	1	1	1	0	0	0	2	2	0	1
48. Extreme Confinement in Capsule	0	1	0	0	1	0	0	0	2	2	2
49. High Endurance Demands	2	1	0	0	0	1	0	2	2	0	0
50. Reduced Communication	1	1	1	1	1	0	0	2	2	2	2
51. Social Isolation	1	1	1	1	1	0	0	2	2	2	2
52. Maneuvering Situation	2	1	1	1	0	1	0	0	0	0	0
53. Embedded Environmental Stresses	2	2	1	1	1	0	0	0	2	0	1
VII. Temporal Characteristics											
54. Long Duration of Exposure	1	1	1	1	1	0	0	0	2	2	2
55. Total Environmental Situation	2	2	0	0	2	0	0	0	2	2	2
56. Remoteness of Goals	1	1	1	1	1	1	0	0	2	2	2

Table 2. Analysis of System Similarties by Descriptive Category. The numbers 2,1, and 0 are used here to indicate similarity on the following basis: 2, for matching over 70 per cent of items in the category (Table 1); 1, for matching 31 to 70 per cent; and 0, for matching less than 30 per cent.

Comparison Systems	System Description Category: Objectives and Goals	Value Systems	Pers. Comp.	Organiz.	Technol.	Phys. Envir.	Temporal Chars.
2. Submarines	2	2	1	2	1	1	1
1. Explorat. Parties	2	1	1	1	1	1	1
3. Naval Ships	2	2	0	2	1	1	0
4. Bomber Crews	2	2	1	2	1	1	0
5. Remote Duty Stas.	2	2	0	2	1	0	1
9. POW Situations	1	1	0	0	0	2	2
6. Prof. Athl. Teams	2	0	1	0	0	0	0
11. Ment. Hosp. Wards	0	0	0	0	0	1	2
10. Prison Society	0	0	0	0	0	1	2
7. Industr. Work Grs.	1	0	0	0	0	0	0
8. Shipwrecks and Disasters	0	0	0	0	0	1	0