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ABSTRACT

This curriculum guide is prepared for the Aerospace Education III series publication entitled "Human Requirements of Flight." It provides specific guidelines for teachers using the textbook. The guidelines for each chapter are organized according to objectives (traditional and behavioral), suggested outline, orientation, suggested key points, suggestions for teaching, instructional aids, projects, and further reading. Brief explanations regarding major concepts are included. Page references corresponding to the textbook are given where appropriate. (PS)

AE-III-7304 APRIL 1974

AE-III

INSTRUCTIONAL UNIT IV

HUMAN REQUIREMENTS OF FLIGHT

PREPARED UNDER
THE DIRECTION OF

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AEROSPACE EDUCATION CURRICULUM DIRECTORS

INSTRUCTIONAL UNIT IV

HUMAN REQUIREMENTS OF FLIGHT

INSTRUCTIONAL UNIT OBJECTIVES - When this book is completed each student should:

a. Know the major stresses placed on the human body in flight.

b. Know the principal milestones in the development of aerospace medicine and human engineering.

c. Know how the primary life-support systems protect aircrews and passengers during flight.

d. Know the additional stresses man faced because of flight in space.

e. Know the main biomedical findings made and expected on American manned spaceflights.

f. Be familiar with leading predictions about future human requirements of flight.

INSTRUCTIONAL UNIT IV CHAPTERS:

CHAPTER I - PHYSIOLOGY OF FLIGHT

This chapter summarizes the basic principles of the physiology of flight. It describes the nature of the different layers of the atmosphere, and it explains how the respiratory and circulatory systems are affected by reduced pressure. It describes the causes and symptoms of hypoxia, trapped gases, and decompression sickness, and discusses the effects of rapid decompression. It also explains how the eyes function during flight and how the flier's body is affected by disorientation and motion sickness, increased G-forces, noise and vibration, excessive heat and cold, noxious gases and vapors, and self-imposed stresses.

1. OBJECTIVES:

   a. Traditional - Each student should:

      (1) Know how the body is affected by flight in each physiological zone of flight environment.

      (2) Know how the human body is affected by reduced pressure.

      (3) Be familiar with the causes and symptoms of hypoxia, trapped gases, and decompression sickness.

      (4) Know why good health and vision are required of all pilots.

      (5) Be familiar with at least three other stresses of flight.

   b. Behavioral - Each student should be able to:

      (1) List the physiological zones and describe how the human body is affected by flight within each zone.

      (2) Tell how the circulatory and respiratory systems are affected by a decrease in the amount of oxygen in the atmosphere.

      (3) Outline how gases are trapped in the body at high altitudes, and tell where these gases are most likely to be trapped.

      (4) Describe decompression sickness and tell how it is related to the nitrogen content of the atmosphere and the body.

      (5) State why good health and vision are important to a pilot.

      (6) Name at least three other stresses of flight and tell how the human body is affected by each.

2. SUGGESTED OUTLINE:

a. Nature of the atmosphere

(1) Content: approximately 78 percent nitrogen, 21 percent oxygen, and 1 percent other gases

(2) Layers of the atmosphere: troposphere, stratosphere, ionosphere, and exosphere

(3) Physiological divisions (zones): physiological zone, physiological-deficient zone, partial space-equivalent zone, and total space-equivalent zone

(4) Physical laws of gases

(a) Boyle's law: The volume of a gas is inversely proportional to its pressure if the temperature remains constant.

(b) Dalton's law: The total pressure of a mixture of gases is equal to the sum of the partial pressure of each gas in that mixture.

(c) Henry's law: The amount of gas in a solution varies directly with the partial pressure that this gas exerts on the solution.

b. Respiration and circulation

(1) Larger meaning of respiration: all the steps entailed in taking oxygen into the body, carrying oxygen to the cells to support oxidation of food, and removing carbon dioxide from the body

(2) Close relation of respiration and circulation

(3) Respiratory system: lungs, bronchial tubes, windpipe, mouth, and nose

(4) Circulatory system: heart and blood vessels

(a) Four cavities of the heart: two atria and two ventricles

(b) Exchange of oxygen and carbon dioxide within the body

(5) Respiratory process: inhalation and exhalation

c. Effects of reduced pressure at altitude

(1) Hypoxia and hyperventilation; time of useful consciousness

(2) Trapped gases

(a) Cause: no escape route for body gases; acts IAW Boyle's law

(b) Effects: ear block, sinus block, tooth pain, gases trapped in stomach and intestines

(3) Decompression sickness

(a) Cause: escape of gases normally held in solution in the body; acts IAW Henry's law

(b) Kinds of decompression sickness: bends, chokes, skin and nervous system

(c) Treatment in special compression chamber

d. Rapid decompression

(1) Explosion and rapid loss of pressure; decreased temperature

(2) Effects on body: hypoxia; boiling of blood at 63,000 feet or above

e. Principles and problems of vision

(1) Importance of good vision to pilot

(2) Action of cones and rods in vision; dark adaptation

(3) Factors affecting visibility of object during flight: angular size, amount of illumination, contrast, length of time visible, and condition of atmosphere

f. Spatial disorientation and motion sickness

(1) Sensory equipment for orientation during flight: vision, balance organs in inner ear, and muscle sense of balance

(2) Balance organs in inner ear: semicircular canals and otolith organs

g. Acceleration and deceleration: increased G-forces

(1) Negative and positive G-forces

(2) Means of coping with increased G-forces: training to cope with them, changing position in vehicle, and using a G-suit

h. Noise and vibration

(1) Headaches and fatigue from noise

(2) High noise levels and permanent effects on hearing

(3) Need to minimize vibrations

i. Heat and cold during flight

(1) Heat became a problem with advances in flight (aerodynamic heating)

(2) Capability of body to adjust to only relatively small changes in temperature; frostbite

j. Noxious gases and vapors

(1) Carbon monoxide

(2) Carbon dioxide

k. Self-imposed stresses

(1) Alcohol

(2) Tobacco

(3) Drugs

(4) Neglect

3. ORIENTATION:

a. This is the only unit in the course that concentrates on the study of flight physiology and human engineering, and it is the only unit that combines the study of aviation and spaceflight. Coming as it does near the end of AE-III, this unit gives the students an opportunity to combine and relate what they have learned about aviation and spaceflight and apply this knowledge to problems of human engineering. Students are also challenged to recall what they have learned in other courses about human physiology and apply this knowledge to problems of flight. Because of the unique nature of the subject matter, this unit presents a real challenge to both instructor and students and it can be a fruitful source of motivation.

b. Although the students will have some background for this unit, the subject matter itself is new and technical in nature. It will therefore have to be carefully related to what is already known. Chapter I, which is the introduction to the unit, will require thorough preparation and time and patience for the presentation.

c. Besides being an introduction to the unit, Chapter I also includes a summary of the main principles of flight physiology. These principles must be mastered before proceeding with the remaining chapters. The other chapters are in a sense an application of these principles.

4. SUGGESTED KEY POINTS:

a. To make flight in high-performance aircraft and spacecraft possible, man had to learn how to surround himself with a stable, earthlike environment during flight. The body cells must be maintained in a stable condition to sustain life during flight.

b. The nature of the atmosphere changes with increasing altitude.

**V-9023D pp 53-55 (1) The most important change is the progressive decrease in oxygen pressure with increasing altitude; oxygen is the one element of the atmosphere required to sustain human life.

**V-9047 pp 14-25 (2) Decrease in total pressure of atmosphere at altitude also affects the body.

**V-9156 pp 2-10, 506-507 (3) Temperature changes with altitude were important during the early history of flight.

**AFP 161-16 Chap 1 (4) Changes of the atmosphere with altitude are described according to the physical divisions of the atmosphere (troposphere, stratosphere, ionosphere, and exosphere) and the physiological divisions (the physiological zone, the physiological-deficient zone, the partial space-equivalent zone, and the total space-equivalent zone). Aircraft fly as far up as the stratosphere and the partial space-equivalent zone. Only spacecraft travel above this level.

c. The human body is filled with fluids and gases that are affected by decreases and increases in atmospheric pressure as the altitude varies. The gases in the body act according to the physical laws of gases (Boyle's law, Dalton's law, and Henry's law).

**AFP 161-16 Chap 2 d. The stresses of flight and the conditions of flight affect every part of the human body in some way, but they affect the respiratory and circulatory systems most directly.

**V-9156 pp 507-509 (1) The respiratory and circulatory systems are closely tied in with each other. Respiration in its larger sense includes carrying oxygen to the cells to support oxidation of food, and removing carbon dioxide from the body.

(2) The respiratory system consists of the air passages of the mouth and nose, the windpipe, the bronchial tubes, and the lungs. Inhalation and exhalation are directly affected by

changes in atmospheric pressure. The mechanical processes of inhalation and exhalation had to be understood before man's oxygen supply could be controlled during flight.

(3) The circulatory system, including the heart as pump and the blood vessels, exchanges oxygen and carbon dioxide within the body. The breathing rate is controlled by the amount of carbon dioxide in the bloodstream.

**V-9023L pp 45-49

e. The body is affected by decreased atmospheric pressure at altitude in three principal ways: through hypoxia and hyperventilation; through trapped gases; and through decompression sickness.

**V-9156 pp 509-511

**AFP 161-16 22-30

(1) Hypoxia, a deficiency of oxygen in the body cells, is the most common and pronounced effect of high altitude. The onset of hypoxia is sudden, and it may quickly become serious. Symptoms vary with each person. Each pilot learns to recognize his own personal symptoms of hypoxia and guard against it. Lack of oxygen may lead to hyperventilation, or overbreathing. Symptoms of this condition are similar to those of hypoxia.

**V-9156 pp 511-512

**AFP 161-16 Chap 5

(2) With sudden ascents and descents during flight, gases may become trapped in different parts of the body. Gases are most commonly trapped in the middle ear and the sinuses. They may also be trapped in the teeth and in the stomach and intestines. Trapped gases cause severe pain.

**V-9156 pp 512-513

**AFP 161-16 Chap 4

(3) Decompression sickness is caused by gases that evolve, or come out of solution, at altitude. Since nitrogen is the most abundant gas in the atmosphere, it is the one that most often evolves. The most common form of decompression sickness is the bends, which can cause excruciating pain in the joints. Decompression sickness may also occur as the chokes pain in the chest, or it may affect the skin or nervous system. The Air Force has special compression chambers for treating decompression sickness. In these chambers the evolved gases are subjected to pressure to force them back into solution in body fluids. To prevent decompression sickness, pilots and astronauts undergo denitrogenation before flight to high altitudes.

**AFP 161-16 Chap 6-7

f. If a pressurized cabin is punctured at altitude, it may undergo rapid decompression. There is an explosion and flying debris, and the victims in the cabin may be exposed to sudden cold temperatures, windblast, and the hazards of reduced atmospheric pressure, such as hypoxia. At 63,000 feet and above, the blood boils. Fortunately, pressurized cabins are built well, and rapid decompression is a rarity. A military aircraft may be depressurized suddenly under gunfire, but special measures are taken to protect these aircraft against rapid decompression.

g. A pilot needs good vision even when he flies on instruments. Not only must a pilot have good eyes, but he must also learn how to use visual cues accurately, as there are fewer visual references seen from the air than on the ground.

**V-9156 pp 514-516, 517-518

(1) Pilots should learn about the functioning of the cones and rods in vision. The cones are associated with day vision and the rods with night vision. A pilot learns how to attain dark adaptation and maintain it for night flying.

** AFP 161-16 Chap 9

**V-9023L pp 77-81

(2) A pilot learns how to increase the visibility of objects seen during flight and he should guard against all forms of visual illusions.

h. Learning to maintain a sense of balance and orientation after rotation or rapid movement is one of the first things a prospective pilot must do. A pilot depends primarily on vision to keep oriented during flight. Other senses for maintaining orientation are the muscle sense and the balance organs in the inner ear.

**V-9156 pp 519-521

**V-9023L p 71

(1) The muscle sense of balance is used when a pilot flies "by the seat of the pants."

** AFP 161-16 Chap 11

(2) Balance organs in the inner ear are the semicircular canals and the otolith ("ear dust") organs.

(3) A pilot who flies on instruments must learn to trust his instruments and disregard the signals sent to his brain by his senses. During visual flight, a pilot relies on his senses for maintaining balance and orientation.

i. Pilots and astronauts who maneuver are subjected to increased G-forces during flight. These forces are caused by pronounced or extended acceleration and deceleration. G-forces may be either positive or negative. Pilots of aircraft cope with G-forces through training and through use of a G-suit. Astronauts, in addition, have their position changed in the flight vehicle, enabling them to take the G-forces across their body (transversely) rather than from head to foot.

**AFP 161-16 Chap 12

j. Other stresses that affect pilots, aircrews, and passengers during flight are noise and vibration, excessive heat and cold, noxious gases and vapors, and self-imposed stresses.

**V-9156 pp 516-517

(1) Noise and vibration cause headaches and fatigue. Both the frequency and the intensity of the noise must be considered. Pilots and astronauts who are subjected to excessive noise from jet and rocket engines must be protected to prevent permanent impairment of hearing. Excessive vibration could cause the organs of the body to rupture. Vibrations in aircraft and launch vehicles have been partially dampened to prevent such injuries.

**AFP 161-16 Chap 13

(2) During early flights to high altitudes, fliers had to be protected against the severe cold. Today, in high-performance aircraft and spacecraft, heat rather than cold is a problem. Aircraft and spacecraft traveling through the atmosphere at high speeds are subjected to aerodynamic heating. The heat generated by the human body, and electrical equipment in an enclosed environment, must be considered also.

** AFP 161-16
Chap 8

(3) Poisonous gases and vapors become a real hazard in enclosed space cabins. If the air in such cabins is not purified, it would soon become poisoned with carbon dioxide from breathing. All space cabins must have some means for removing carbon dioxide. Another gas that presents a hazard in flight is carbon monoxide, the odorless gas that causes victims to die when automobile engines are left running in enclosed spaces. In space cabins, instruments are used to detect the presence of harmful gases and vapors.

**AFP 161-16
Chap 15

(4) A pilot cannot afford to impose additional stresses on himself by using alcohol, tobacco, or drugs during flight or shortly before flight time. Even when taken in small amounts at altitude, these items have more pronounced effects on the body than at sea level. At altitude, where there is reduced oxygen pressure, self-imposed stresses from using alcohol, tobacco, and drugs may seriously interfere with the intake of oxygen into the body and its distribution to the cells. A pilot must keep mentally and physically fit at all times so that he can make decisions and act quickly when subjected to flight stresses.

5. SUGGESTIONS FOR TEACHING:

a. Suggested time: 4-6-8 (Interpretation: It is recommended that you allow two weeks for teaching this chapter. If you teach two hours per week, use four hours; if three hours per week, six hours; and if four hours per week, eight hours.) The suggested time is just that--a recommendation. If, for example, your students are well prepared in both the study of flight and physiology, you may wish to cover this chapter in a week's time or less and go on to more interesting aspects of application in succeeding chapters. If, on the other hand, your students are not well prepared and the time allowed for the unit has had to be shortened, you may wish to build your teaching for the entire unit around this basic chapter, bringing in material from later chapters to meet the minimum objectives set for the unit, such as information on protective equipment and on the additional stresses encountered in spaceflight. You could use the flight experiences of members of the class or their family and information on the Skylab spaceflights for motivation.

b. Since the entire unit, and especially this chapter, rests upon a foundation of fundamental knowledge of human physiology, it would be well to consult with members of the school's biology department while planning this unit. Because of research required for spaceflight, the study of biology and medicine has been revolutionized. Textbooks on biology have been rewritten. It would be well to capitalize on the renewed interest in the study of biology and medicine to motivate students to learn during this unit. You might also arrange for some cooperative projects with members of the biology department.

c. This entire unit, but especially this first chapter, might be used as a basis for teaching students appreciation of ideals and right attitudes toward living. Just as a pilot cannot permit self-imposed stresses to handicap him when meeting the stresses of flight and reacting quickly to difficult situations and incidents, the student cannot allow self-imposed stresses to handicap him when coping with the stresses and strains of everyday living. Just as the captain of a ship is instilled with ideals of service to his crew and passengers, the pilot of a modern aircraft is imbued with similar ideals of service to his crew and passengers. The ideals of professional service might be further interpreted in terms of ideals the students hope to attain some day in their chosen careers.

d. Text Corrections:

(1) Page 31 - Figure 17, left figure, change distance from heart to brain from "130cm" to "30cm"

(2) Page 47 - Temperatures are marked in error. Surface temperature should be 59°. Change: "59°" to "16.2°"
"16.2°" to "-12.3°"
"12.3°" to "-47.8°"
"47.8°" to "-69.7°"
"69.7°" to "-69.7°"

(3) Page 62 - para 2, line 9, change "official" to "officials"

(4) Page 159 - Figure 83, line 3, change "ara" to "area"

6. INSTRUCTIONAL AIDS:

a. Films:

(1) USAF Films

AFMR 627. Wonders of Weightlessness. 7 min, B&W, 1964.

FTA 249A. Ear Defense for Jet Mechanics - Sound and Noise. 11 min, B&W, 1957.

FTA 249B. Ear Defense for Jet Mechanics - Effects of Jet Engine Noise. 10 min, B&W, 1957.

TF 1-4964. G-Facts. 28 min, Color, 1954.

TF 1-8194. G-Forces. 30 min, Color, 1962.

TF 1-5038A. Oxygen - Inflight Requirements. 23 min, Color, 1956.

TF 1-5372. Problems in Aircraft Decompression. 17 min, Color, 1960.

TF 1-8174. Huff and Puff. 7 min, Color, 1957.

TF 1-8187. Respiration and Circulation. 26 min, Color, 1961.

TF 1-8193. Meet Mr Noise. 26 min, Color, 1962.

TF 1-8195. Hypoxia. 22 min, Color, 1963.

TF 5689. Pilot Vertigo - Sensory Illusions In Flight. 25 min, Color, 1965.

TF 5718. Vision In Military Aviation - Sense of Sight. 24 min, Color, 1962.

TF 6048. Vision In Military Aviation - Inflight Recognition and Closure. 20 min, Color, 1963.

TF 6050. Perception of Orientation, The. 37 min, Color, 1963.

TF 6482. Self-Imposed Physiological Stresses - Keep The Odds In Your Favor. 15 min, Color, 1972.

TF 8225. Decompression Sickness In Flight. 18 min, Color, 1966.

TF 8233. Plasma Bubbles and Decompression Sickness, 8 min, Color, 1969.

TF 1-4021. Physiology of High Altitude Flying. 12 min, Color, 1948.

TF 1-4889. Mechanisms of Breathing. 11 min, B&W, 1953.

TF 8227 h. The Human Body - The Respiratory Systems. 14 min, Color, 1961.

TF 1-4921. Crew Safety in Cabin Pressure Flight. 25 min, B&W, 1953.

(2) US Navy Films

MN 3446. The ABC of G. 19 min, Color, 1944.

MN 5311. Physiology of High Altitude Flying. 15 min, Color, 1948.

MN 6915A. High Altitude, High Speed, Flight Problems - Physiological Effects. 23 min, Color, 1952.

MN 9480B. Vision In Military Aviation - Illusions. 32 min, Color, 1963.

(3) FAA Films

FA-05-70. Eagle Eyed Pilot. 14 min, Color, 1970.

FA-618. Charlie. 22 min, Color, 1967.

FA-01-70. Medical Facts for Pilots. 25 min, Color, 1970.

FA-606. Rx for Flight. 20 min, Color, 1968.

FA-704. Stable and Safe. 20 min, Color, 1959.

FA-209. One Eye on the Instruments.

b. Transparencies

V-1034. Regions of the Atmosphere

V-1035. Divisions of Space

V-1036. G-Forces and Weightlessness

7. PROJECTS:

   a. The NASA published curriculum resource, EP-50, Space Resources for Teachers: Biology, contains many activities that have a direct relationship to subjects covered in this chapter. Pages 75-78 outline an experiment on vibration stress. Its purpose is to examine human performance under simulated conditions of lift-off or re-entry vibration. All of the materials required for the experiment should be available in your school. Pages 117-120 explain some simple demonstrations of sensory and perceptual problems. Pages 126-129 explain how the spatial disorientation problems of vertigo and nystagmus can be demonstrated using a common swivel chair.

   b. See textbook, pages 40-41.

8. FURTHER READING:

   a. See textbook, page 41.

   b. There is a 1972 edition of the Federal Aviation Administration publication "Physiological Training" available. The Physiological Operations and Training Section of the Civil Aeromedical Institute is available at all times to assist you in problems concerning Aviation Physiology. Inquiries should be addressed to:

      Chief, Physiological Operations and Training Section
      Civil Aeromedical Institute
      FAA Aeromedical Center
      P. O. Box 25082
      Oklahoma City, Oklahoma 73125
      Phone: (405) 686-4237 or 686-4881

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK AND/OR INSTRUCTOR'S GUIDE AND TEACHING TECHNIQUES MOST EFFECTIVE FOR THIS CHAPTER. TO BE COMPILED AT END OF TEXT AND SENT TO JRC

HUMAN REQUIREMENTS OF FLIGHT

CHAPTER II - AEROSPACE MEDICINE AND HUMAN ENGINEERING

This chapter explains how specialists in the fields of aerospace medicine and human engineering combined their knowledge and skills to enable man to progress in flight through the atmosphere to the fringe of space. The chapter relates how early balloonists and physiologists studied the lower atmosphere and how aerospace medicine and human engineering began. Next, it explains the services performed by flight surgeons and human engineers. Finally, the chapter tells how test pilots and balloonists helped to make flight safe in high-performance aircraft and how they and animal astronauts prepared the way for spaceflight.

1. OBJECTIVES:

   a. Traditional - Each student should:

      (1) Know how early balloonists and physiologists prepared the way for aircraft.

      (2) Know the role and kinds of services that a flight surgeon performs for fliers.

      (3) Know the role of human engineers in designing aircraft and protective equipment.

      (4) Know the kind of research done with aircraft, balloons, and animal astronauts to prepare man for spaceflight.

   b. Behavioral - Each student should be able to:

      (1) Describe how early balloonists and physiologists prepared the way for aircraft flight.

      (2) Discuss the role of the flight surgeon, and tell three services he performs for fliers.

      (3) Describe the role of the human engineer in advancing flight in high-performance aircraft.

      (4) Give example of how test pilots, balloonists, and animal astronauts prepared the way for spaceflight.

2. SUGGESTED OUTLINE:

   a. More stresses with greater performance

   b. Beginnings of aerospace medicine

      (1) Balloonists and early studies of the atmosphere

(a) Flights of balloonists and encounter with lowered oxygen pressure: Montgolfier brothers; Dr John Jeffries and Blanchard; Coxwell and Glaisher; Sivel, Croce-Spinelli, and Tissandier

(b) Paul Bert (1833-86), Father of Aviation Medicine: French physiologist; some 700 experiments with atmospheric pressure; first low-pressure (altitude) chamber

(2) Military schools of aviation medicine

(a) General Theodore Lyster, Father of Aviation Medicine in America, founder (1918) of research laboratory at Hazelhurst Field, New York (predecessor organization of Air Force School of Aerospace Medicine)

(b) Naval School of Aviation Medicine at the Naval Air Station at Pensacola, Florida (1939)

(3) Founding of medical and biological departments in aircraft companies and of the predecessor organization of the Aerospace Medical Association

c. Care of fliers

(1) Flight surgeon in military services

(a) Role developed as research in aviation medicine progressed

(b) Services performed: acting as physician and personal counseler to fliers, giving medical examinations for fitness to fly, investigations of aircraft accidents, and advice and recommendations to prevent accidents

(2) Role of civilian doctors in performing similar services for civil pilots.

d. Matching man and machine: work of the human engineer

(1) Designing aircraft that take pilot skills into account

(2) Attempting to minimize flight stresses

(3) Designing efficient controls

(4) Standardizing the arrangement of flight instruments and engine instruments

(5) Developing servomechanisms

(6) Designing and constructing protective equipment

e. Research on the fringe of space: importance in helping meet increased stresses in high-performance aircraft and in preparing the way for spaceflight

(1) Work of test pilots in research aircraft

(a) X-1: Captain (now Brig General) Charles Yeager's first supersonic flight

(b) X-2 and attempts to overcome the heat barrier.

(c) X-15: Major Robert White, first pilot to win astronaut wings; flights to increase aircraft performance; flights for collecting physiological data for spaceflight; use of the full-pressure suit by pilot

(2) Later balloonists: gradual advance to ceiling for balloons and winged aircraft

(a) Auguste Piccard and the pressurized balloon gondola

(b) Flight of Captains Anderson and Stevens (72,395 feet)

(c) Major David G. Simons and Man High (102,000 feet); sealed gondola

(d) Captain Joseph W. Kittinger, Jr., and the three Excelsior flights (102,800 feet); open gondola and pressure suit; tests of escape equipment and parachute descents

(3) Animal astronauts: development of space capsules and ability to survive in space

(a) Animals used: first, mice and other small animals; later, American use of chimpanzees and larger monkeys and Soviet use of dogs

(b) Tests of resistance to G-forces during rocket launch and descent

(c) Tests of ability to survive in space

(d) Advance test for first Mercury astronaut to go into space (Shepard) and first to orbit (Glenn) made by Ham and Enos, respectively

3. ORIENTATION:

a. This chapter can be tied in with information acquired in AE-I or AE-II about the history of flight. It can also be related to what has already been learned in AE-I and AE-III about manned spaceflight, as it describes the kind of biomedical research that helped to make spaceflight possible. The chapter is to serve only as an introduction to manned spaceflight, however. The subject itself is taken up in two later chapters.

b. This chapter should give the students additional insight into the principles of flight physiology outlined in Chapter I. It should help the students understand how this knowledge was acquired gradually over the centuries and only then through diligent effort in the laboratory and through courageous exploration of the upper atmosphere. It should add human interest to the story of man's efforts to counter the stresses of flight.

c. This chapter is also closely connected with Chapter III and should serve as an introduction to it. This chapter outlines progress in research for meeting the human requirements of flight. Chapter III describes the practical results of this research and study in terms of protective equipment for aircraft flight and means for training pilots.

4. SUGGESTED KEY POINTS:

a. Long before the first aircraft flight, man acquired knowledge about the upper atmosphere and his reaction to flight within it, just as he acquired advance knowledge about the physiology of spaceflight before the first spacecraft was orbited.

(1) Meeting the human requirements of early aircraft flight was relatively simple because of the advance studies made and the relatively low performance aircraft used.

(2) Problems of flight stresses became acute with the development of high-performance aircraft, and further research was needed.

(3) Human requirements of flight were met by combining the knowledge about flight physiology with knowledge about flight engineering to produce practical results in terms of protective equipment for flight. As the fields of aerospace medicine and human engineering were developed, specialists in these two fields combined their efforts and worked closely with pilots to make progress possible.

b. Aerospace medicine had its beginning with the flights of the early balloonists and with early studies of the upper atmosphere. As early as the late 1700s, balloonists tried to find out something about flight physiology. The American doctor John Jeffries made a pioneer balloon flight in 1785. In the 1800s, balloon flights, like those of Coxwell and Glaisher, advanced to higher altitudes and encountered greatly reduced oxygen

***V-9023L
pp 25-40

pressure and severe cold. Paralleling the exploration of balloonists was the work of French physiologist, Paul Bert (1833-86), who conducted experiments with varying atmospheric pressures to learn more about how man could protect himself during flight to higher altitudes. Paul Bert made the first altitude chamber and became known as the Father of Aviation Medicine.

c. Interest in flight physiology increased with the flight of the first aircraft (1903). The military services had a special interest in promoting aviation medicine. The ability of a pilot to achieve victory in battle often depends upon overcoming flight stresses.

(1) During World War I, General Theodore Lyster founded the first laboratory for research in aviation medicine at Hazelhurst Field, New York (1918). This laboratory was the forerunner of the present Air Force School of Aerospace Medicine, now located at Brooks Air Force Base, Texas. Among the pioneers in aviation medicine was General Harry G. Armstrong, who wrote the first textbook on the subject, and Dr Hubertus Strughold, who began the study of space medicine.

(2) The Navy also conducted research at the School of Aviation Medicine at Pensacola, Florida (established in 1939).

(3) Aviation medicine (finally aerospace medicine) was supported by the establishment of human engineering departments in aircraft companies and by the founding of professional societies.

d. Aerospace medicine focuses attention on the care of fliers

(1) In the military services, special doctors known as flight surgeons act as personal counselors and physicians to fliers, make examinations to determine fitness for flying, investigate aircraft accidents, and make recommendations for promoting flying safety.

(2) Aviation flight examiners and other civilian doctors perform similar services for civil pilots.

e. Human engineers match man with the flight machine and the systems in it in many ways.

**V-9023L pp 128-134

(1) They modify aircraft designs to lessen flight stresses.

***V-9156 pp 108-121

(2) They design more efficient controls.

(3) They position controls and instruments to take pilot skills into consideration; they attempt to standardize the arrangement of flight and engine instruments (basic-T).

(4) They develop servomechanisms.

(5) They design and develop protective equipment for flight.

f. Before astronauts orbited in space, US scientists and engineers conducted research on the fringe of space. Research aircraft, balloons, and animals launched in space capsules were used for this research.

(1) Test pilots flying special jet- and rocket-powered aircraft (X-series) penetrated the upper atmosphere to cross the sound barrier (X-1), to attempt to overcome the heat barrier (X-2), and to take aircraft to new limits of altitude and speed (X-15). The X-15 was later used to collect physiological data for spaceflight.

(2) Balloonists continued exploration of the upper atmosphere until they reached the flight ceiling.

(a) After Auguste Piccard developed the pressurized gondola, Captains Anderson and Stevens penetrated the atmosphere to 72,395 feet and survived (1935).

(b) On Man High, Major David G. Simons penetrated to 102,000 feet in a closed gondola.

(c) On three Excelsior flights, Captain Joseph W. Kittinger, Jr., in an open gondola and protected only by a pressure suit and oxygen bottle, tested flight escape and the use of a parachute. He reached an altitude of 102,800 feet.

**V-9044 pp 86-89

(3) After World War II, medical researchers began to send animals aloft on sounding rockets. The first space capsules were constructed to make it possible to recover these animals alive.

(a) US space capsules first contained small animals like mice and small monkeys. Later, US scientists used chimpanzees and larger monkeys, and the animals were trained. The intent was to approach as nearly as possible the conditions for manned spaceflight.

(b) The Soviets orbited the first animal, the dog Laika, which survived in orbit for about seven days.

(c) To test equipment for the first spaceflights, the US used animal astronauts. Ham preceded Astronaut Alan Shepard, the first US astronaut to go into space on a suborbital flight. Enos preceded Astronaut John Glenn, the first US astronaut to orbit in space.

5. SUGGESTIONS FOR TEACHING:

a. Suggested time: 2-3-4

b. Since this chapter is closely connected with Chapter III, you may feel that you can save time by combining the contents of the two chapters and teaching them together. You may wish, for example, to cover the contents of this chapter briefly and emphasize the practical results of research rather than the research itself. A decision to combine the chapters would rest upon the kind of preparation that your students have, their interests, and the objectives you hope to achieve in teaching. By teaching this chapter separately, it should be possible to give the students a better insight into biomedical research and a better foundation for understanding manned spaceflight.

c. Since this chapter covers a wide sweep of time, you will want to focus attention on achievements that will give students the best foundation for what you intend to emphasize during the rest of the unit. If, for example, you intend to emphasize escape equipment, point up Kittinger's flights as tests of escape equipment. If you plan to emphasize manned spaceflight as the highest achievement in countering the stresses of flight, focus attention on work with animal astronauts. To motivate the students, build up some human interest in achievements that are significant for your purposes.

6. INSTRUCTIONAL AIDS:

a. Films

(1) USAF Films

SFP 316. Animals In Rocket Flight. 14 min, B&W, 1953.

SFP 1314. Pioneers of the Vertical Frontier - ARL. 24 min, Color, 1967.

SFP 1011. X-15 Man Into Space. 8 min, Color, 1959.

SFP 1074. X-15. 27 min, Color, 1961.

TF 1-5371. Man In Flight. 18 min, Color, 1960.

(2) FAA Films

FA-801. All It Takes Is Once. 25 min, Color, 1969.

(3) NASA Films

HQ 79. Research Project X-15. 27 min, Color, 1966.

(4) Navy Films

MN-10930. Wings for the Doctor - A Story of the Naval Flight Surgeon. 28 min, Color, 1971.

7. PROJECTS:

See textbook, page 63.

8. FURTHER READING:

See textbook, pages 63-64.

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK AND/OR INSTRUCTOR'S GUIDE
AND TEACHING TECHNIQUES MOST EFFECTIVE FOR THIS CHAPTER.
TO BE COMPILED AT END OF TEXT AND SENT TO JRC

HUMAN REQUIREMENTS OF FLIGHT

CHAPTER III - PROTECTIVE EQUIPMENT AND PILOT TRAINING

This chapter describes the protective equipment and the pilot training that make flight possible in modern high-performance aircraft. It explains how oxygen masks, pressure suits, and G-suits are used to protect pilots and aircrews; how the pressurized cabin operates and how aircrews and passengers are protected against rapid decompression; and how military pilots and aircrews use ejection-seat systems and parachutes to escape from aircraft. Next, the chapter surveys military and civil pilot training programs and describes the different kinds of flight simulators used in training.

1. OBJECTIVES:

a. Traditional - Each student should:

(1) Know how aircrews are protected by oxygen masks, pressure suits, and G-suits.

(2) Know the major differences between pressurized and non-pressurized oxygen systems.

(3) Know the major differences between the conventional pressurized cabin and the space cabin.

(4) Know how parachutes and ejection-seat systems are used for escape.

(5) Be familiar with the major facets of military and civilian pilot training.

(6) Be familiar with the use of the altitude chamber and other flight simulators for training pilots.

b. Behavioral - Each student should be able to:

(1) Discuss how aircrews are protected by oxygen equipment, pressure suits, and G-suits.

(2) List the major differences between pressurized and non-pressurized oxygen systems.

(3) Outline the principal differences between a space cabin and a conventional pressurized cabin.

(4) State the differences between a simple bailout and escape with an ejection-seat system.

(5) Recall the major facets of military and civilian pilot training.

(6) Describe the altitude chamber and name two other kinds of flight simulators.

2. SUGGESTED OUTLINE:

a. Importance of breakthroughs in meeting human needs in flight

b. Protective equipment: gradual development until pressurized cabin was possible; with pressurized cabin, use of oxygen masks and pressure suits as backup

(1) Protective clothing and accessories

(a) Oxygen systems (oxygen masks plus tanks and accessories): continuous-flow, demand, and pressure-demand

(b) Pressure suits: Wiley Post's suit and principle of layering; partial-pressure suit and full-pressure suit; parts of partial-pressure suit--suit itself (bladder and capstans), helmet, and gloves

(c) G-suit: use by military pilots; protection against positive G-forces (protection against negative G-forces provided by other means); many kinds of G-suits; may be part of pressure suit

(2) Pressurized cabins

(a) Pressure differential with surrounding atmosphere

(b) Maintaining purified atmosphere within cabin

(c) Conventional pressurized cabin vs space cabin: space cabin completely sealed; used above 50,000 feet

(d) Hazards of rapid decompression: explosion, windblast, cold, hypoxia, decompression sickness, and other hazards of low atmospheric pressure (review from Chapter I)

(3) Escape equipment

(a) Parachute for bailout (unassisted escape): parts of parachute--parachute pack, harness, risers, suspension lines, and canopy; use of parachute

(b) Ejection equipment (assisted escape): need for means of ejection to escape from aircraft traveling at high altitudes and great speed; effect of high G-forces, windblast, cold, etc.; operation of the ejection-seat system and use of parachute; emergency oxygen cylinder; prevention of tumbling during free fall; integrated flight capsules (F-111)

c. Training programs for pilots and navigators; need for transition training for pilots.

   (1) Military programs: Air Force Undergraduate Pilot Training (UPT); Navy program - special training for flight from carriers in addition to normal flight training

   (2) Civil program: flight instructor and basic pilot training; training provided by airlines

d. Flight simulators: developed by military; wide use today in training pilots and navigators; many kinds for training pilots; broad meaning of simulator

   (1) Stress devices: low-altitude chamber, human centrifuge, Coriolis chair ("biaxial stimulator"), and others

   (2) Mockups giving the feel of flight: Link trainer; sophisticated trainers resembling aircraft cockpit used in military and civil training programs

3. ORIENTATION:

a. This chapter presents the practical results of combining the specialized knowledge and skills developed in aerospace medicine (flight physiology) with those developed in human engineering. Chapter II pointed up the need for making this combination and Chapter I outlined the principles of flight physiology upon which this chapter is based. The students are not expected to master engineering principles, but they should have gained a good working knowledge of the principles of flight from previous work in the course.

b. This chapter is also an introduction to a study of the human requirements of manned spaceflight. The subject of manned spaceflight has already been covered in two previous units, but the emphasis has not been on human requirements. This chapter will prepare students for a more specialized study of manned spaceflight in the remaining chapters of the unit. As pointed out in Chapter I, there is no sharp dividing line between the atmosphere and space as far as the human body is concerned. Pilots in high-performance aircraft were flying under partial space-equivalent conditions some time before man orbited in the first spacecraft. The astronaut's space suit (full-pressure suit) developed from the pilot's full-pressure suit. The pressurized cabin in the spacecraft represents a refinement of the space cabin used in high-performance aircraft.

4. SUGGESTED KEY POINTS:

a. In the advancement of flight, breakthroughs in knowledge about flight physiology and in the development of protective equipment have been just as important as engineering developments. Without proper protective equipment, flight in high-performance aircraft would not be possible.

b. In describing flight stresses, there are two large categories of persons to consider: passengers who travel in comfortable pressurized cabins and are subjected to only mild flight stresses; and military pilots and aircrews, who are often subjected to much greater flight stresses. Passengers in high-flying jet aircraft are provided with emergency oxygen masks, but they do not wear protective flight equipment, as military pilots and aircrews do. The pilot and aircrew in commercial transports are trained in the physiology of flight and in the means used to protect passengers and themselves in an emergency. Military pilots and aircrews are trained to wear and use protective equipment and to escape from aircraft disabled during flight. A civil pilot and aircrew stay with their aircraft in an emergency and attempt to bring the passengers safely to the ground.

c. To understand how flight stresses develop progressively with increased altitude and speed, it is necessary to consider how man gradually experienced greater flight stresses and how he countered them (done in Chapter II). Another way of extending one's understanding of flight stresses is to consider the greater flight stresses experienced by military pilots and aircrews and the means they use for countering them.

d. Developing protective equipment for flight was a gradual process. First, scientists and engineers developed oxygen masks and pressure suits, then the pressurized cabin. Once the pressurized cabin was developed, oxygen masks and pressurized suits were needed only as a backup.

*AFP 161-16 Chap 3

(1) Oxygen masks ~~are~~ connected to oxygen tanks and valves control the flow of oxygen to the mask. The whole arrangement is known as an oxygen system.

(a) There are three kinds of oxygen systems: continuous-flow, pressure, and pressure-demand.

***V-9023L
pp 40-45

(b) The pressure-demand system is needed to give life support above 35,000 feet and can function for this purpose to 45,000 feet. Because most modern military aircraft reach high flight altitudes, the pressure-demand system is gradually replacing other systems in these aircraft.

(c) An aircrewman making use of the pressure-demand oxygen system breathes in reverse. Reverse breathing must be controlled and can be dangerous. Oxygen systems are reserved for use in an emergency or for use for only short periods of time.

(2) Above 45,000 feet a pressure suit is needed as backup in an emergency or to support life if the cabin is not pressurized enough for the higher flight altitudes.

(a) Complex engineering was required to develop and perfect the pressure suit. The first pressure suits were developed and worn by Wiley Post. They were constructed on the principle of layering, a principle still used in modern pressure suits.

(b) There are two kinds of pressure suits: the full-pressure suit and the partial-pressure suit. The full-pressure suit incloses the body in one continuous envelope; the partial-pressure suit is pressurized in segments.

(c) The full-pressure suit gives greater protection but is more difficult to construct and must be fitted individually. Full-pressure suits are used by pilots flying to higher altitudes. They may eventually replace partial-pressure suits in the military services, but partial-pressure suits are still used extensively and give adequate protection, especially when used only for backup in an emergency.

(d) The partial-pressure suit consists of a large bladder which covers the torso and tubes (called capstans) which extend along the arms and legs. Besides the pressure suit itself, there are also the pressurized helmet and gloves. The entire body must be protected by pressurization when the suit is needed for life support. The pressure suit often includes a G-suit, which serves another purpose.

*AFP 161-16
Chap 12

(3) Countering negative G-forces and red-out, as research showed, presented a different problem from countering positive G-forces. With adequate supplemental oxygen supplied during flight, the negative G-forces do not

present the serious hazard they once did. Positive G-forces are countered by using a G-suit. Increased G-forces, caused by acceleration and deceleration, are a problem for pilots who maneuver (Chapter I).

**AFP 161-16 pp 187-190

(a) There are many kinds of G-suits in use, but the principle upon which they operate is essentially the same.

(b) The G-suit has bladders that can exert pressure against the body at key points. The bladders are connected to a compressed air system. When G-forces reach a positive 2, the bladders inflate automatically, exerting pressure against the blood vessels in the lower part of the body. The pressure helps to keep the blood flowing from the legs to the heart and head and prevents blackout.

**AFP 161-16 Chap 6 & 7

e. Development of a realiable pressurized cabin represents a high point in man's efforts to meet the human requirements of flight.

(1) Aircraft cabins are not maintained at sea level pressure, but at a level of 8,000 to 10,000 feet, well within the pressure level of the physiological zone of the atmosphere.

(2) The difference in pressure level between the atmosphere in the cabin and that on the outside is called the pressure differential. The larger the pressure differential, the stronger must be the walls of the cabin. Building cabins strong enough to support the pressure differential was one of the engineering problems that delayed the development of the pressurized cabin.

(3) There are two principal kinds of pressurized cabins: the conventional pressurized cabin, which can be used at lower flight altitudes, and the space cabin, which is required above 50,000 feet. In the conventional cabin, which is only partially sealed, fresh air is drawn in from the outside and compressed, and stale air is allowed to escape. The space cabin is completely sealed. Oxygen must be drawn from a supply stored within the craft and the cabin atmosphere must be purified from within.

*AFP 161-16 pp 235-236

(4) Purifying the cabin atmosphere presents a problem in the space cabin.

(5) All pressurized cabins are subject to decompression if punctured. If the opening is large, decompression is likely to be rapid. Rapid decompression subjects the occupants of the cabin to explosion, windblast, severe

cold, and the hazards of reduced atmospheric pressure. Cases of rapid decompression are rare, however, as pressurized cabins have proved to be reliable. A military aircraft that is subject to decompression from enemy gunfire is usually pressurized less to decrease the danger of rapid decompression. Supplemental oxygen may then be required at the higher flight altitudes.

*AFP 161-16 Chap 14 & 16

f. Military pilots and aircrews flying under hazardous conditions wear protective clothing and equipment and are trained in the use of escape equipment.

(1) To escape from slow, low-flying aircraft, a pilot simply bails out and uses his parachute.

(a) The parachute is the basic means of recovery in all kinds of flight; it is used with the ejection-seat system and in recovering astronauts.

(b) The parachute consists of the pack, harness, suspension lines, risers, and canopy.

(c) Using a parachute to make a safe recovery requires skill that must be developed through training. An aircrewman learns how to guide the parachute during descent, how to roll over to deflate the canopy upon landing, and how to keep from being dragged along the ground.

(2) A pilot or aircrewman who escapes from an aircraft traveling at high speed needs an ejection device to enable him to clear the aircraft structure. Such a device is part of the ejection-seat system.

(a) Much research on G-forces and the conditions of flight at the time of escape was required to develop and perfect the ejection-seat system. One of the pioneer researchers in the field of G-forces was Air Force Colonel John Paul Stapp (Ret).

(b) Ejection-seat systems are now highly reliable and afford a pilot greatly improved chances of escaping and recovering if triggered in time. Devices such as the "One for Zero" and "Zero-Zero" Systems are being added to increase the chances of survival.

(c) An ejection-seat system follows a sequence, part of which is automatically timed. The time of the opening of the parachute is crucial, as this determines the altitude at which the parachute descent begins.

This, in turn, affects the amount of shock upon opening and the oxygen content of the atmosphere. Since pilots in high-performance aircraft must often eject at very high altitudes, they must go into free fall before the parachute is opened. To support life until a safe altitude is reached, the escapee carries with him an emergency oxygen cylinder (oxygen bottle).

**V-9071 entire

g. Another key factor in meeting the human requirements of flight is the use of scientific programs for training pilots and aircrewmen. A pilot receives transitional training, or training to prepare him to change over from one kind of aircraft to another.

(1) Each of the services has its own programs for training pilots. The Air Force program for basic pilot training is known as Undergraduate Pilot Training (UPT). A Navy pilot learns how to fly and to make flights from carriers.

(2) Civil pilots must provide for their own basic training, which is given at local airports and in colleges, universities, and special schools. A flight instructor must be qualified by the FAA. Airlines give pilots training in the kind of aircraft they are to fly.

(3) Both military and civil pilot training programs make use of a wide range of flight simulators. Military pilots, who are normally subjected to greater flight stresses, make use of a wider range of flight simulators.

(a) Military pilots use two types of flight simulators: stress devices, such as the low-altitude chamber, the human centrifuge, and the Coriolis chair ("biaxial stimulator"); and devices giving the feel of flight, such as the Link trainer and devices resembling the cockpit of specific aircraft.

(b) Civil pilot training programs concentrate on the use of highly sophisticated simulators giving the feel of flight and resembling the cockpit of specific aircraft.

(c) As flight simulators have been developed, they have made pilot training safer, more efficient, and more economical.

5. SUGGESTIONS FOR TEACHING:

a. Suggested time: 3-5-6

b. If you plan to place emphasis on the practical aspects of aircraft flight, you may want to allow more time for this chapter.

You could do this by combining it with Chapter II or by cutting down on the time for teaching manned spaceflight or both.

c. Whatever aspect of meeting the human requirements of flight you intend to emphasize, it is advisable to keep in mind the students' interests and the objectives you hope to achieve by your teaching. Pilots and aircrewmen who receive training in the use of protective and escape equipment are highly motivated because they realize that their lives may some day depend on their using this equipment correctly. Your students will have little or no direct use of the equipment. What you are trying to do in this series of lessons is to show the students how the principles outlined in Chapter I are applied. Objectives pointing to distinguishing differences between equipment, such as differences between pressurized and non-pressurized oxygen systems and between the conventional pressurized cabin and the space cabin, are important only as they compel the students to examine the principle underlying the operation of this equipment, not to teach use of the equipment. Since the human body can adapt to flight within only very narrow limits, it is necessary instead to adapt the flight environment to the body. This is done to keep the body cells stable and to promote well being and maintain life during flight. In teaching this chapter, as in presenting other lessons in this unit, you are dwelling on some aspect of this basic theme for meeting the human requirements of flight.

d. Since this chapter focuses attention on equipment and devices, it would be a good plan to have some samples or pictures and diagrams to show the students. Visual aids should be especially useful in teaching this chapter. If you are near a UPT base, plan a field trip to the altitude chamber and personal equipment shop.

6. INSTRUCTIONAL AIDS:

a. Films

(1) USAF Films

TF 1-5038B. <u>Oxygen-Inflight Equipment</u>. 18 min, Color, 1956.

TF 1-8192. <u>Pressure Suits</u>. 24 min, Color, 1962.

TF 8205. <u>Oxygen Equipment</u>. 27 min, Color, 1964.

TF 1-4921. <u>Crew Safety In Pressure Cabin Flight</u>. 25 min, B&W, 1953.

TF 5720. <u>Better Break on Bailout-Parachute Four Line Cut</u>. 14 min, Color, 1966.

TF 5572. <u>Passport to Safety</u>. 22 min, Color, 1963.

TF 1-5375. <u>Survival Stresses</u>. 30 min, Color, 1961.

SFP 1235. <u>Stars In Their Eyes</u>. 15 min, Color, 1963.

SFP 1856. <u>Ejection Vectors</u>. 22 min, Color, 1969.

SFP 1169. <u>Space Pilot-Aerospace Research Pilot School</u>. 20 min, Color, 1963.

FTA 17. <u>Use of the "G" Suit</u>. 10 min, B&W, 1955.

(2) FAA Films

FA-209. <u>One Eye On the Instruments</u>. 16 min, Color, 1962.

FA-601. <u>Other Passenger, The</u>. 30 min, Color, 1965.

FA-805. <u>Restraint For Survival</u>. 8 min, Color, 1967.

(3) NASA Films

AD-3. <u>Rehearsal for the Moon</u>. 7:10 min, Color, 1969.

AD-4. <u>Astronaut Training</u>. 7:30 min, Color, 1969.

7. PROJECTS:

See textbook, pages 101-102.

8. FURTHER READING:

a. See textbook, page 102.

b. For a description of experience in an altitude chamber, see TSgt Tom Dwyer, "Up to Hypoxia," Airman (December 1973), pages 19-21.

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK AND/OR INSTRUCTOR'S GUIDE
AND TEACHING TECHNIQUES MOST EFFECTIVE FOR THIS CHAPTER.
TO BE COMPILED AT END OF TEXT AND SENT TO JRC

HUMAN REQUIREMENTS OF FLIGHT

CHAPTER IV - SURVIVING AND LIVING IN SPACE

This chapter explains how man has countered the stresses of spaceflight and how he has adjusted to "routine" living in space. The chapter first describes the stresses new to spaceflight (radiation, meteoroids, and weightlessness) and then the stresses of aircraft flight that become more severe in spaceflight (increased G-forces, heating, noise and vibration, and lack of atmosphere). Next, the chapter explains the operation of the spacecraft's cabin and the astronaut's space suit and tells how these are tied into the central environmental control system. Then, the chapter describes the management of life-support supplies and waste on board a spacecraft and tells how the astronaut adjusts to day-night cycles, how he is medically monitored, and how he adjusts to mental stresses. Finally, the chapter outlines other measures taken to insure the astronauts' safety at launch and during flight.

1. OBJECTIVES:

   a. Traditional - Each student should:

      (1) Know the three stresses new to spaceflight.

      (2) Know why stresses experienced in aircraft flight increase in spaceflight.

      (3) Know the basic items needed for life-support on a spacecraft.

      (4) Be familiar with the environmental control systems of spacecraft and astronaut space suits.

      (5) Be familiar with measures taken to monitor the astronauts' mental and physical condition and to insure their safety.

   b. Behavioral - Each student should be able to:

      (1) Describe the three stresses new to spaceflight.

      (2) Discuss why stresses of aircraft flight increase during spaceflight.

      (3) List the three basic items of life-support needed on a spacecraft, and tell how each was provided on the Apollo spacecraft.

      (4) Recognize the major components of an environmental control system.

(5) Recall how doctors monitor the astronauts' safety and well being from the ground:

(6) Identify two other measures taken to insure the astronauts' safety.

2. SUGGESTED OUTLINE:

a. Space environment: the partial space-equivalent zone and the total space-equivalent zone

(1) Greatly reduced atmospheric pressure; approaches zero

(2) Radiation in space: a radiation environment as contrasted with a gaseous environment (atmosphere)

(3) Total darkness and silence of space

(4) Presence of meteoroids

b. Stresses of spaceflight

(1) New stresses

(a) Radiation: nonionizing and ionizing radiation (charged particles); greater danger from ionizing (particle) radiation, especially solar-flare particles, radiation trapped in the Van Allen belts, and galactic cosmic rays; shielding of spacecraft and monitoring of radiation.

(b) Meteoroids and micrometeoroids; danger not as great as once believed; protection provided by meteorite bumper (double wall on spacecraft and extra layer in space suit); gradual erosion from micrometeoroids

(c) Weightlessness (zero gravity): potential danger on long-duration flights not clearly understood; means for countering; possible use of artificial gravity in the future

(2) Other flight stresses increased during spaceflight

(a) G-forces: greatly increased at launch and reentry; otherwise, no G-forces (weightlessness or zero gravity) shift in position of astronaut to decrease G-forces (recumbent position and transverse G-forces); use of different kinds of controls to cope with increased G-forces

(b) Heating: shape of spacecraft designed to decrease aerodynamic heating during launch and reentry; heat shield and ablation cooling to control aerodynamic heating at reentry

(c) Noise and vibration: caused by firing of powerful rocket engines in the launch vehicle; manrating the missiles used for launch vehicles

(d) Lack of atmospheric pressure: need for a reliable environmental control system for spacecraft

c. Environmental control system: space suit connected with system in spacecraft; suit taken off and shirt-sleeve environment enjoyed during greater part of flight; suit worn at hazardous times during flight.

(1) Space cabin: oxygen supplies carried on board; carbon dioxide removed and atmosphere purified through use of lithium-hydroxide canisters; heat removed from spacecraft and released into space by radiator; single-gas (pure oxygen) and mixed-gas atmospheres (oxygen diluted with nitrogen)

(2) Space suit: a pilot's full-pressure suit developed further; many kinds of space clothing; EVA suit, space undergarment (air-cooled and water-cooled); Apollo moon suit with Portable Life-Support System (PLSS), a more advanced EVA suit; use of umbilical to connect with oxygen supply inside spacecraft.

d. Life-support supplies: oxygen, water, and food; semiclosed life-support system

(1) Oxygen supplied by environmental control system described above

(2) Water: supply carried on board; water produced as by-product of fuel cells; conservation of water resources on board

(3) Special foods used for spaceflight because of weightless condition: paste foods, bite-sized foods, and freeze-dried foods; special packaging; freeze-dried foods preferred; foods used on Skylab more like foods served on aircraft

e. Waste management: eventual recycling of all wastes; at present only hygienic management and safe disposal

(1) Need to take medical samples of urine and feces; routine sampling on Skylab

(2) Release of urine into space

(3) Storage of solid wastes aboard spacecraft to prevent their orbiting and contaminating space environment

(4) Waste facilities on the Skylab Workshop: modified toilet facilities and waste tank under floor

f. Day-night cycle: alteration of day-night cycle in space; possible effect on the biological time clock; before their return to earth the astronauts are put on a normal work-sleep cycle corresponding with that of their home region, to make them physiologically fit to cope with reentry stresses.

g. Medical monitoring: sensors and the biomedical instrumentation belt; telemetering the biomedical data; sensors not implanted but kept on surface of skin to prevent infection; voice monitoring to determine emotional reactions of astronauts and their mental condition; medical kits

h. Space rescue: system still undeveloped; use of escape tower at launch (ejection seats on Gemini spacecraft); redundant systems during flight; emergency procedures; rescue module prepared for use during Skylab flights; agreement of Soviets and Americans to cooperate in space rescue.

3. ORIENTATION:

a. This chapter on surviving and living in space is related to previous work on manned spaceflight done during AE-I and AE-III. The emphasis here is on meeting the human requirements of spaceflight, not the engineering requirements. To begin this more specialized study, you need to relate it to the earlier studies of manned spaceflight.

b. The study of manned spaceflight is also related to the study of advanced flight in high-performance aircraft, especially research aircraft like the X-15, and to other research on the fringe of space. In spaceflight there are new stresses, but many of the stresses of spaceflight are simply increased stresses of aircraft flight. Even though the student may have no special prior interest in manned spaceflight, he may become interested because the biomedical problems involved represent an extension of those encountered in aircraft flight. Studying the increased stresses of spaceflight has enabled scientists and engineers to gain a better insight into the stresses of aviation and the means for countering them.

4. SUGGESTED KEY POINTS:

a. After some sixty years of powered aircraft flight, man rocketed himself into space to begin orbital flight. In spacecraft, most stresses of flight have increased, and there are new stresses as well. Spacecraft travel at much greater speeds and at much higher altitudes than aircraft.

b. Three stresses new to spaceflight are: a condition of weightlessness; the presence of meteoroids; and a radiation environment, certain elements of which are harmful to man.

***V-9023L pp 105-127

*V-9051 pp 140-161

*V-9105 pp 72-77

*V-9145 pp 76-90

*V-9156 pp 603-604, 608-611

*AFP 161-16 pp 239-241

(1) Certain primary electromagnetic radiations (such as glaring visible light rays, infrared rays, and ultraviolet rays) may be harmful to man, but he can usually be protected against this kind of radiation. Ionizing radiation (charged particles caused by an interaction with primary radiation) is potentially the most hazardous. Particle radiation especially harmful to man is of three kinds: solar-flare particles, charged particles trapped in the Van Allen belts, and galactic cosmic rays (rays from beyond the solar system). Fortunately, the solar wind, a fourth kind of particle radiation present in abundance in space, is not harmful to man. Up to the present time astronauts have not been harmed by radiation although they are believed to have been exposed to the different kinds of ionizing radiation. Some protection was provided by shielding within the spacecraft and by monitoring the emission of particle radiation from the sun.

(2) Because of the great speeds at which they travel, meteoroids could easily rupture a spacecraft and cause decompression upon impact. Even very small meteoroids, or micrometeoroids, cause erosion of the outside of a spacecraft. Studies have shown, however, that there is much less danger that a spacecraft will impact with a meteoroid than was once believed to exist. Spacecraft were nevertheless protected with meteorite bumpers (double walls) and EVA suits have an extra layer to give astronauts some protection from meteorites.

*V-9023B pp 115-116

**V-9023L pp 70-91

*V-9044 pp 184-185

(3) The condition of weightlessness (zero G) during prolonged spaceflight affects the functioning of all bodily organs and especially the heart-blood system, as the body is accustomed to functioning under the condition of 1 G on the earth. The effects of prolonged weightlessness on the body have been studied during the Skylab flights. During orbital flights astronauts follow a program of exercise to keep the muscles in tone and to stimulate

the flow of blood, thus countering the effects of weightlessness. So far, American astronauts have readjusted to earth gravity after their flights, and have returned to normal within a reasonable time.

c. Stresses of flight have tended to increase as man progressed from flight in aircraft to spaceflight.

*V-9023B pp 111-115, 139-168

***V-9023L pp 50-63

*V-9044 pp 180-181

(1) During spaceflight greater G-forces are experienced. G-forces increase only at launch and reentry, however. (During orbital flight the astronaut experiences weightlessness.) Increased G-forces at launch are caused by acceleration and deceleration of the rocket launch vehicle. At reentry the spacecraft impacts the atmosphere with great force, and further shock is experienced as the parachutes open. To protect the astronaut against higher G-forces, he is placed on his back at launch and reentry. This position allows him to take the G-forces across his body (transversely) rather than from head to foot as the aircraft pilot does, and the adverse effects of G-forces are decreased as a result. In addition, the controls in a spacecraft have been redesigned to make it possible for the astronaut to operate them when affected by higher G-forces.

(2) The spacecraft is designed to cut down aerodynamic heating at launch and reentry. Even so, the spacecraft reaches extremely high temperatures at reentry. The spacecraft would burn up if it were not protected by a heat shield and ablation cooling. Heat is removed from the interior of the spacecraft by the environmental control system.

(3) The powerful rocket engines of the launch vehicle cause a high level of noise and much vibration at launch. The astronauts are protected against noise and vibration by their position at the top of the stack and by the shielding provided by their spacecraft and their space suit and helmet. The missiles used to launch the first two spacecraft (Mercury and Gemini) were modified and tested (manrated) before being used for manned flights. Excessive vibration could rupture organs or tear loose the tissue holding them in place in the body.

(4) At orbital altitudes the pressure of the atmosphere approaches zero. All oxygen must be pressurized, and it must be obtained from supplies carried on board. The breathing atmosphere must be continuously purified by a reliable environmental control system.

**V-9023B pp 100-105
***V-9023L pp 93-104
***V-9156 pp 604-606

c. An astronaut is protected by an environmental control system. The pressurized space cabin and space suit are part of the system. During most of the flight the astronaut is protected only by the space cabin (he works in a "shirt-sleeve" environment, but he keeps his space suit close by as a backup). He wears the space suit at launch and reentry and during other hazardous parts of the flight.

(1) The pressurized breathing atmosphere of the space cabin is controlled through a complex environmental control system. Lithium-hydroxide canisters are used in the system to remove carbon dioxide from the atmosphere. The system circulates a coolant, which carries the excess heat to the radiator outside the spacecraft, which radiates the heat into space. Up to the end of the Apollo flights, a pure oxygen atmosphere was used for all American spacecraft. The Skylab used a mixed-gas atmosphere consisting of oxygen diluted with nitrogen.

*V-9023B pp 107-111
*V-9044 pp 140-141

(2) An astronaut is protected by his space suit, which was developed from the pilot's full-pressure suit. The inner layer of the space suit is the astronaut's space undergarment, which may be either air-cooled or water-cooled. Many variations of the space suit have developed as spaceflight progressed. A special EVA space suit is used to protect the astronaut when he goes outside the spacecraft to maneuver in space or on the moon. The Apollo moon suit was a highly developed EVA suit. It included a portable oxygen system. On the Gemini flights the astronaut's EVA suit was provided with oxygen by means of an umbilical connected with the oxygen supply inside the spacecraft.

**V-9023L pp 98-99
**V-9156 pp 606-607

d. The environmental control system is part of the larger life-support plan. Three basic items are needed for life support on board a spacecraft: oxygen, water, and food. If all three items could be recycled for reuse, once the spacecraft was supplied we would have a closed life-support system. If all items had to be stored and none could be reused, we would have an open system. At present we have a semi-closed system.

(1) Some water can be generated on board as a byproduct of the fuel cells, but a supply of water is stored on board in addition. Water must be carefully conserved during flight.

(2) On the three earliest series of spaceflights, specially prepared foods were used, and foods were put in special packages or containers. This was necessary because food and water particles that escape float about inside the spacecraft during the condition of weightlessness. Three

kinds of foods have been used for spaceflight: paste foods, bite-sized foods, and freeze-dried foods. The freeze-dried foods were preferred. On the later Apollo flights other items of food, such as sandwiches, were added, and the foods served on the Skylab flights were more like those served by the airlines, but special means had to be used to anchor the food trays and to keep the food and water particles from escaping into the spacecraft.

**V-9023L pp 99-101

**V-9156 pp 607-608

e. Special provisions must be made for waste management on spacecraft. Urine and feces samples are taken for biomedical study. The remaining urine is dumped and allowed to evaporate into space. Excess feces and other solid wastes are collected, deodorized, disinfected, and stored on board. Solid waste cannot be released into space, as it would orbit and contaminate the space environment.

**V-9023L pp 75-77

f. In space the time covered by day-night cycles are not the same as those on earth. During spaceflight in a low earth orbit, for example, the day-night cycle may last only 90 minutes. The question arises as to the effect the change in the day-night cycle may have on the astronaut's biological time clock. Insofar as possible, the astronauts keep to a sleep-work cycle that follows the night-day cycle of the region of the earth where they are living. This is the vicinity of Houston, Texas, where the Johnson Space Center is located. During the long Skylab visits, the astronauts' schedules were changed in space, but the astronauts were put back on their "home" schedule to put them in top physical condition for meeting stresses at reentry.

**V-9087 pp 128-140

***V-9023L pp 65-69

g. To keep the astronauts' doctors on the earth aware of their mental and physical condition during flight, the astronauts are monitored, and biomedical data is transmitted by telemetry. The data is collected by sensors on the skin, and the data is transmitted to equipment in the biomedical instrumentation belt. The astronaut's reaction to stress and his mental condition are judged by the tone of his voice. An astronaut makes use of a private voice circuit for consultations with his doctor.

h. No complete means of space rescue has as yet been devised. One special problem is the intense heating at reentry, at which time a spacecraft would burn up in the atmosphere if it were not protected by ablation cooling. A rescue module was fitted up during the Skylab flights, and the Americans and the Soviets have pledged to work together to develop means for rescuing astronauts or cosmonauts stranded in space. To insure the astronaut's safety, Americans use an escape tower or ejection seat at launch, emergency procedures are worked out in advance for use during flight, and one or more redundant (extra) systems are provided for use in case the main system malfunctions. All these means, together with medical monitoring, help to insure the astronaut's safety during flight.

5. SUGGESTIONS FOR TEACHING:

   a. Suggested time: 2-3-4

   b. If you want to either extend or shorten the total time allowed for teaching manned spaceflight, you might find it helpful to combine this chapter with the following one, which takes up the biomedical data obtained during the different series of flights. Keeping the two chapters separate enables you to show more clearly the increase in flight stresses as man progressed from aircraft flight to spaceflight. By discussing spaceflight stresses and survival in space separately from the actual flight data, it is possible to focus attention on theory and keep from becoming lost in details about the astronauts' experiences on specific flights.

   c. Whatever plan of presentation you follow, remember that the principles of meeting human requirements and surviving in space are basically the same as those for survival during flight in high-performance aircraft. Always emphasize the underlying principles. Otherwise the students may become involved in technical details and miss the point of the presentation. In spaceflight, just as during flight in the upper atmosphere, man has had to maintain an environment surrounding the body in which the cells and the life processes could remain stable. Because the stresses of spaceflight are greater than those of aircraft flight, man was forced to learn more about the nature of human biology and physiology to understand the stresses of spaceflight, and he had to further refine and develop the means for life support before spaceflight was possible. The cabin used in a spacecraft is a more complex system than that used in high-performance aircraft, and the astronaut's space suit is more highly developed and refined than the pilot's full-pressure suit. To survive in space for progressively longer periods of time and to act more freely in space, man has had to continue to develop more adequate means to counter the stresses of spaceflight.

6. INSTRUCTIONAL AIDS:

a. Films

(1) USAF Films

TF 6371. Space Rescue. 20 min, Color, 1971.

FR 1033. AFSC Annual Activities Report CY 69 - Bioastronautics and Medicine. 20 min, Color, 1969.

FR 354. Orbital Worker, The. 28 min, Color, 1958.

SFP 660. Widest Horizon, The. 28 min, Color, 1958.

SFP 263. V2 CH 8 Human Factors in Space Flight. 14 min, B&W, 1963.

SFP 1008. Space Feeding - Beyond the Gravisphere. 17 min, Color, 1960.

SFP 1120. Man and Space. 23 min, Color, 1963.

(2) NASA Films

AD-25. Living In Space. 8 min, Color, 1969.

AD-26. Space Suit. 5 min, Color, 1969.

HQ 131A. Living In Space - Part I - The Case For Regeneration. 12 min, Color, 1967.

HQ 131B. Living In Space - Part II - Regeneration Processes. 20 min, Color, 1967.

HQ 131C. Living In Space - Part III - A Technology for Spacecraft Design. 12 min, Color, 1967.

HQ 200. Apollo 13 - Houston We've Got a Problem. 28 min, Color, 1970.

b. Slides

V-0045 Bioastronautics

c. Transparencies

V-2004 Space Travel (Book of Transparencies) Transparency # 7 Space Suit

7. PROJECTS:

See textbook, pages 144-145.

8. FURTHER READING:

See textbook, pages 145-146.

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK AND/OR INSTRUCTOR'S GUIDE
AND TEACHING TECHNIQUES MOST EFFECTIVE FOR THIS CHAPTER.
TO BE COMPILED AT END OF TEXT AND SENT TO JRC

HUMAN REQUIREMENTS OF FLIGHT

CHAPTER V - THE MANNED SPACEFLIGHTS

This chapter outlines the biomedical findings made on the first three series of American manned spaceflights (Mercury, Gemini, and Apollo), and it explains how the Skylab visits should enable us to learn more about man's ability to live and work in space.

1. OBJECTIVES:

a. Traditional - Each student should:

(1) Know how the astronauts were gradually able to spend longer periods of time in space.

(2) Know the most significant achievements in meeting human requirements during each series of flights.

b. Behavioral - Each student should be able to:

(1) Describe the progress made in adjusting to orbital flight on the Mercury spacecraft.

(2) Outline the means the astronauts used to keep their bodies in condition during the 14-day Gemini flight.

(3) Tell how the astronauts obtained life support during EVA in space and on the moon.

(4) Discuss how routine living differed between Skylab and previous spaceflights, and state the new endurance record established during the Skylab visits.

(5) Identify at least one biomedical experiment conducted on the Skylab.

2. SUGGESTED OUTLINE:

a. First three series of flights

(1) Mercury flights

* V-9044 pp 92-97

(a) Ability of astronauts to survive launch and recovery; ability of body to perform normal life functions during weightlessness

(b) Demonstrated ability of astronauts to function as pilots

(c) Extended visibility in space

(d) Deconditioning of muscles and tendency of blood to pool in chest during orbital flight; tendency of blood to pool in legs and lower body at recovery; dizziness at recovery; staggering

(2) Gemini flights

(a) Routine for living in space better established; improvements in foods and in life-support equipment; workloads more realistic

(b) Experiment showing loss of calcium from bones during weightlessness; parallels to bed patients on earth; questions as to real effects of weightlessness; difficulties in simulating weightlessness on earth; many more experiments needed

(c) Endurance flight of 14 days; American record previous to Skylab flights; first flight in shirt-sleeve environment; previous experience in countering effects of weightlessness; program of exercises to counter weightlessness and keep body in condition

(d) EVA experiments: first difficulties in ventilating EVA suit; great amount of energy required for space work; difficulties in establishing leverage; need for handholds and footholds

(3) Apollo flights

(a) Further marked adjustment to routine living in space

(b) Exposure to cosmic rays; light flashes penetrating eyeballs; no apparent harmful effects; small dosages

(c) EVA on moon: great amounts of energy required; helpful effects of moon gravity although only one-sixth earth gravity; diet supplement (potassium); quarantine and its elimination

b. The Skylab: orbit around 270 miles; avoiding Van Allen belts and allowing enough altitude to prevent deorbiting and burn-up; temporary space station

(1) Living quarters and laboratory: space of a three-bedroom house; facilities for more nearly normal routine living

(a) Handholds and footholds for controlling motion in going through Skylab Workshop

(b) Wardroom with trays held in position and restraints to allow more nearly normal dining; knives and forks, used; standing position at table

(c) Modified toilet facilities

(d) Moistened terry cloths and shower for washing; problem of keeping water drops in shower

(e) Sleeping bags; vertical position while sleeping

(f) Breathing atmosphere: mixture of oxygen and nitrogen; American use for first time on Skylab; danger of breathing pure oxygen for extended periods

(g) EVA suit for Skylab; test of new backpack (Astronaut Maneuvering Unit)

(h) Equipment for conducting biomedical experiments: lower body negative-pressure chamber and bicycle ergometer; use of bicycle ergometer for conditioning exercises

c. Biomedical experiments: 16 life science experiments planned; 6 experiments concerning the effects of spaceflight as shown from measurements taken on ground before and after flights; 10 experiments concerning living in space; measuring effects of weightlessness on body

d. Skylab visits (flights)

(1) Skylab I: Conrad, Weitz, and Kerwin; launched on 25 May 1973

(a) Making essential repairs: deploying sun shade and cutting metal strip to allow solar panel to deploy; other repairs

(b) Successful adaptation to weightlessness

(c) Vigorous program of exercise on bicycle ergometer

(d) Loss of body weight and loss of about one inch of muscle on calf of leg

(e) Completion of about 80 percent of all tasks and about 90 percent of medical experiments in spite of time required for repairs to make Skylab habitable

(f) Successful recovery after 28 days in space; return to normal but some weakness; loss of red blood cells and blood plasma observed as on earlier spaceflights

(2) Skylab II: Bean, Lousma, and Garriott; launched on 28 July 1973

(a) Motion sickness of all three crew members during first week of flight; full recovery and adaptation to weightlessness afterwards

(b) Completion of work assigned and request for additional tasks; erection of new sun shade on top of first; other repairs; initial test of Astronaut Maneuvering Unit in Skylab

(c) Even more vigorous program of exercise than that of first crew

(d) Physical condition reported generally even better than that of first crew, but loss of body weight and loss of muscle on calf of leg, as experienced by first crew

(e) Recovery after 59 days in space; ability to stand erect after recovery; similar "space anemia" as with first crew but a more rapid return to normal

(3) Skylab III: Carr, Pogue, and Gibson; launched 9 November 1973

(a) Supplementary food (food bars) carried in Apollo command module to support a prolonged mission; food in Skylab sufficient for only 70 days of support

(b) Motion sickness and vomiting by one crew member (Pogue)

(c) Request for relaxation of rigid work schedule to allow time for rest and for adjustment to environment; request granted and human errors reduced

(d) One crew member (Carr) reported as holding body weight, but other two members undergoing usual loss of weight

(e) Even more vigorous program of exercise than that of second crew; treadmill added for exercising muscles of legs

(f) Physical condition of crew reported to be generally even better than that of second crew

(g) Observations of comet Kohoutek

(h) Difficulties with Skylab's gyros requiring curtailment of some experiments. The two gyros were successfully operating when flight was ended, however

(i) Recovery after more than 84 days in space; crew experienced slight dizziness but adapted to earth gravity again without any permanent ill effects

(4) From the first look at medical data, it seems that there is no reason why man cannot withstand much longer flights in space.

3. ORIENTATION:

a. This chapter is closely tied in with the previous chapter. If the students understand the basic problems of living in space, they can better appreciate the achievements of the astronauts in countering the stresses of spaceflight during the first three series of flights and on Skylab.

b. This chapter is directly related to the events that took place on the three Skylab visits even though these are not described in the textbook. When the textbook was typeset, the Skylab had just been orbited. At the time there was some doubt whether it could be made habitable because of the damage sustained at launch. Since that time the astronauts repaired the Skylab and made it habitable and maintained essential equipment for performing experiments. Three crews visited the Skylab, as noted. At the end of the Skylab flights the record of endurance in spaceflight was pushed up to 84 days, or six times that of the American record flight before Skylab. The principal events of interest from a biomedical standpoint are outlined here. You need to be on the alert for later information about the analyses of the biomedical data obtained from the experiments conducted on the Skylab and the conclusions drawn from these data.

4. SUGGESTED KEY POINTS:

a. During the Mercury flights, the astronauts demonstrated that man could survive in orbit for periods up to a day and a half and that he could act as a pilot of the spacecraft. Although medical data indicated that certain changes take place in the body during weightlessness, these changes did not appear to harm the body. The astronauts quickly recovered after their return to earth.

b. During the Gemini flights, the astronauts built up the endurance estimated to be required for the Apollo moon flights (14 days), and they gradually developed skill in performing EVA and space work. Again, medical data indicated that certain changes take place in the body during spaceflight. In spite of these changes, the Gemini astronauts were generally in much better condition than the Mercury astronauts when recovered because of the efforts made to counter the stresses of spaceflight. After a 14-day flight on the Gemini-7 spacecraft, the astronauts were recovered in excellent condition. An experiment conducted during the flight showed that the astronauts had lost calcium from their bones, much as bed patients do on the earth. The Gemini astronauts made the first step toward adjusting to routine living in space. They returned to normal soon after recovery.

c. During the Apollo flights, the astronauts made a further adjustment to living in space and on the moon. They suffered no harmful effects from exposure to radiation or to meteorite impacts on the moon. They were capable of performing useful work in collecting rock samples and in conducting scientific experiments. Upon recovery, the Apollo astronauts quickly returned to normal, and they brought back no organisms from the moon.

d. During the three Skylab visits the astronauts clearly demonstrated that man can adjust to routine living in space for prolonged periods (84 days) and that he can perform useful work in space. Extended EVAs were made during Skylab to repair the outside of the spacecraft or to operate the Apollo Telescope Mount and retrieve film from the telescope cameras. In spite of the difficulties with the Skylab, the experimental program was carried forward successfully and nearly completed, and new tasks were added. Since the medical experiments were least affected by the difficulties, data from these experiments promise to be the most complete.

(1) During Skylab I, the crew showed remarkable ingenuity in erecting the sun shade and making repairs, winning from NASA Administrator James Fletcher the title of "master tinkerers of space." Their success in making repairs is significant in view of the difficulties that the Gemini astronauts encountered when they first attempted space work. Success was made possible through previous experience, through careful coordination with experts on the ground, and through simulation and training for the tasks to be performed. The astronauts in the first Skylab crew readily adapted to the weightless environment. Although they suffered weight losses and some loss of muscle, as indicated by measurements of the calf of the leg, they reported a general feeling of well being, and they carried forward a full program of work. They easily adjusted to the routines of living in space. Upon recovery, after 28 days in space, the crew members adapted to earth gravity without problems. They walked somewhat unsteadily at first, and they reported some weakness later, but they soon returned to normal.

(2) The Skylab II astronauts suffered from motion sickness during the first week of their flight. This was the first time an entire crew had been affected. After a week of indisposition, the crew recovered and adapted fully to the weightless environment and the routines of living in space. They completed tasks assigned and asked for more work, and their physical condition was reported to be even better than that of the first crew. They experienced the same kind of weight losses and loss of muscle in the calf of the leg. They carried out an even more vigorous program of exercise on the bicycle ergometer, but this exerciser is intended to condition mainly the heart-blood system, not the muscles. Medical data indicated that after about 40 days in space the changes brought about during spaceflight had begun to level off. After 59 days in space, the second crew returned to normal even more readily than the first crew.

(3) The Skylab III crew took medication to prevent motion sickness, and only one member of the crew suffered from it. The crew requested a relaxation

of the rigid work schedule early in this longest flight to allow more time for recreation and adjustment to the environment in the hope of reducing work errors. Since many experiments had been crowded into this last flight, the schedule was adjusted and with good results. At the medical check made past mid-point of the flight, the crew was reported to be in even better physical condition than the second crew. A vigorous program of exercise was followed on the bicycle ergometer, and a treadmill was added to condition the leg muscles. One member of the crew even held to his preflight weight. When recovered after 84 days, 1 hour and 16 minutes in space, the Skylab III astronauts seemed to be in even better physical condition than the two previous crews. They did not show the loss of strength in leg and arm muscles experienced by the earlier crews. This could be attributed to the stepped-up exercise program. The astronauts immediately lost the 1 to 1 1/2 inches in height they had gained during weightlessness, as was expected. Although the astronauts experienced some dizziness after recovery, they ate a hearty meal. They had some difficulty in adjusting to earth gravity after this much longer stay in space. Pogue said that he felt as though he weighed a thousand tons, and it was even difficult to roll over in bed. Once-familiar sights and sounds on the earth seemed strange to the astronauts after their long stay in space.

(4) The performance of the three Skylab crews has demonstrated that man can live and work successfully in space for extended periods of time. The repair work done on the Skylab required remarkable skill and ingenuity. Before conclusions can be drawn about the biomedical results of Skylab, however, a detailed study must be made of the mass of data collected. Indications are that man does adapt to the weightless condition after longer periods in space. He does this in a way that causes some very large fluctuations at the beginning in some systems of the body, such as changes in the heart-blood system, the red blood cells, the muscles, and the calcium content of the bones. With time, these fluctuations tend to level off and the body begins to stabilize.

(5) NASA Administrator James C. Fletcher has said that Skylab has pointed the way to future manned missions in space. The new and more complex life support

systems on the Skylab functioned well. Dr Charles Berry said that from what we know now there is no medical reason why man cannot undertake a two-year flight to Mars. More biomedical data would, of course, have to be accumulated before such a flight was undertaken. At present, the only manned flight scheduled is for a rendezvous with the Soviet cosmonauts in earth orbit in 1975. With the cuts made in the NASA budget, the first test flights of the space shuttle will not take place until 1979, and the operational flights will start in the 1980s. Although there are no immediate plans for a US space station, the results of Skylab point to the fact that such a station would be both possible and useful.

5. SUGGESTIONS FOR TEACHING:

a. Suggested time: 2-3-4

b. If you wish to adjust the time allowed for this chapter, you may find it helpful to combine the contents with either that of the previous chapter or the following one or to consolidate all three chapters. The advantage in keeping this chapter separate is that you can examine biomedical experiments and relate them to flight experience.

c. As more information becomes available on the Skylab biomedical experiments and NASA publishes the results, more firm conclusions may be reached about the effects of weightlessness and the other spaceflight stresses on man. If this happens, you will be able to simplify your teaching of manned spaceflight and present facts more positively to the students. However, you might lose some of the motivation caused by the element of expectancy about what experimental data might reveal.

d. If data obtained from Skylab leads to significantly more positive knowledge about manned spaceflight, you may want to emphasize the Skylab flights and even build your study of the subject around Skylab. Findings from the earlier flights could then be brought in as examples of other findings. Even though the findings from Skylab should prove to be highly significant, you would not want your students to lose sight of the fact that man's adjustment to spaceflight has been gradual and that there is still much to learn.

6. INSTRUCTIONAL AIDS:

a. Films

(1) USAF Films

AFIF 145. Gemini 4. 10 min, Color, 1965.

(2) NASA Films

HQa 51. Freedom 7. 28 min, Color, 1961.

HQa 59. Friendship 7. 58 min, Color, 1962.

HQ 90. The John Glenn Story. 30 min, Color, 1963.

HQ 101. The Flight of Faith 7. 28 min, Color, 1963.

HQ 134. The Four Days of Gemini 4. 27 min, Color, 1965.

HQ 160. Legacy of Gemini. 27 min, Color, 1967.

HQ 191. Within this Decade: America In Space. 28 min, Color, 1969.

HQ 194. Eagle Has Landed: The Flight of Apollo 11. 28 min, Color, 1969.

HQ 211. Apollo 14: Mission To Fra Mauro. 28 min, Color, 1971.

HQ 216. Skylab. 27 min, Color, 1972.

HQ 217. Apollo 15: In the Mountains of the Moon. 28 min, Color, 1971.

HQ 219. A Man's Reach Should Exceed His Grasp. 23 min, Color, 1972.

HQ 222. Apollo 16: Nothing So Hidden. 28 min, Color, 1972.

b. Slides

V-0088 Apollo (26 slides)

c. Transparencies

V-2004 Space Travel (Book of Transparencies)

Transparency #: 5 Project Mercury

6 Project Gemini

8 Space "Walk"

9 Project Apollo - To The Moon

10 Project Apollo - Return to Earth

7. PROJECTS:

See textbook, page 167.

8. FURTHER READING:

See textbook, page 167.

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK AND/OR INSTRUCTOR'S GUIDE AND TEACHING TECHNIQUES MOST EFFECTIVE FOR THIS CHAPTER. TO BE COMPILED AT END OF TEXT AND SENT TO JRC

HUMAN REQUIREMENTS OF FLIGHT

CHAPTER VI - FLIGHT IN THE FUTURE

This chapter attempts to predict some of the human requirements of aircraft and spaceflight in the future. It considers human requirements of two advanced aircraft: the Air Force SR-71 and the commercial supersonic transport. It describes how life support is to be given on the space shuttle and how the space shuttle might be used to develop a space station. Finally, the chapter considers three problems of prolonged spaceflight: the closed life support system, prevention of contamination, and the mental condition of the passengers and crew.

1. OBJECTIVES:

   a. Traditional - Each student should:

      (1) Be familiar with the human requirements for flight in the most advanced high-performance aircraft.

      (2) Be familiar with the human requirements of the space shuttle.

      (3) Be familiar with some of the problems involved in manned spaceflight to the planets.

   b. Behavioral - Each student should be able to:

      (1) Identify the kind of life support provided on the SR-71 or a commercial SST.

      (2) Recall why the passengers on the space shuttle will not have to be astronauts once the shuttle is flight-tested.

      (3) Recognize some of the problems involved in manned spaceflight to the planets.

2. SUGGESTED OUTLINE:

   a. The problems of meeting the human requirements for aviation and spaceflight become more similar as development of both kinds of flight vehicles advances; beginning of the new US. Space Transportation System with the partially reusable space shuttle

   b. Advanced aircraft: SR-71 and commercial SSTs (Soviet Tu-144 and British-French Concorde)

(1) SR-71 reconnaissance aircraft (operational)

(a) Cruise speed of mach 3 and altitude higher than 80,000 feet (above 15 miles); excess aerodynamic heating and highly rarefied flight environment; Gemini-type full-pressure suit for crew, which is connected with an air conditioning system

(b) Difficulty of pinpointing a landing at such high speeds; multiplication of slight errors in navigation

(c) Inertial navigation system with star tracking

(d) Higher G-forces and more advanced requirements of military aircraft generally

(2) British-French Concorde

(a) Cruise at mach 2 and at altitudes above 50,000 feet (about 10 miles), or partial-space-equivalent zone; space cabin required

(b) Cabin has pressure altitude of about 6,000 feet

(c) Creation of a sonic boom; heard by people on ground but not by passengers

(d) Inertial navigation system

(e) Reduction of passenger fatigue with high speeds; fatigue not pronounced until after 3 to 4 hours of flight; jet-lag may become more of a problem

c. Future spaceflight

(1) Place of Skylab flights in indicating possibilities of advances in prolonged manned spaceflight in the future; indications that body makes adjustment to the weightless condition within about 40 days, changes produced by orbital flight leveling off at this time

(2) No plans as yet for a permanent US space station to follow the Skylab; could develop such a station from modules placed in orbit by the space shuttle (sortie cans and the RAM).

(3) Space shuttle

(a) When flown more like an aircraft, G-forces are reduced

(b) New space suit for shuttle; first suit for pilots making flight tests

(c) New launch escape system and biomedical instrumentation

(4) Prolonged spaceflights to planets

(a) Need for a life-support system approaching a closed system; a completely self-sufficient space ship, a miniature ecology: place of photosynthesis in the cycle of the closed system; experiments with closed systems

(b) Prevention of contamination in space ship; hazards with many persons living closely together in a confined space for long periods

(c) Problem of maintaining morale and proper attitudes among the crew and passengers; experience from confinement experiments; encouraging results from Project Tektite; need for high motivation

3. ORIENTATION:

a. This lesson ties together all previous lessons in the unit. It should give students a chance to apply what they have learned about meeting the human requirements of aviation and spaceflight and it should encourage them to project their imagination into the future.

b. Since this unit comes near the end of the AE-III program, it could give students the further opportunity of applying what they have learned about aviation and spaceflight throughout the entire course. The lesson could be used as a means of summarizing and interrelating these subjects.

4. SUGGESTED KEY POINTS:

a. In the seventy years that man has been flying in the atmosphere, he has progressed to high speeds and up to the ceiling for winged flight. Flight in the most advanced high-performance aircraft now presents problems of pilotage and life support approaching those of spaceflight. In the meantime man has advanced in spaceflight to the extent that he has reached the moon and solved basic problems for survival in spaceflight for periods of more than 80 days. Now the United States is preparing for flights with the space shuttle, the first vehicle to be developed in the new US Space Transportation System.

(1) Since the space shuttle is designed to return to the earth much in the manner of an aircraft and G-forces are to be better controlled at launch, the space shuttle will eventually be able to carry passengers who are not trained astronauts. The problems of making passengers comfortable and safe in the space shuttle will be similar to those faced by the airlines in making passengers secure on the new SSTs. In the near future, meeting the human requirements of aviation and spaceflight will become more nearly alike.

(2) Prolonged spaceflight to great distances from the earth--to the planets, for example--is another matter and may present new problems. These cannot be foreseen too clearly at present, but before this unit is finished, we shall make some educated guesses about long-range spaceflight.

b. We can project our ideas of what the human requirements for advanced aviation will be like in the immediate future by taking a look at some of the most advanced aircraft flying today or soon to be flying. We might use the Air Force SR-71 and the new British-French Concorde as examples.

(1) The SR-71, being a military aircraft, flies at higher altitudes and speeds than the most advanced commercial aircraft, and it carries escape equipment and presents greater stresses to the crew. Its crew wears Gemini-type pressure suits and heavy footgear. As the SR-71 prepares to make its flight pattern for a landing, its pilot faces problems similar to those that will face the pilot of the space shuttle when he lands at a spaceport. High accuracy is required in navigation. The SR-71 has an inertial navigation system that makes use of star guidance.

(2) The commercial SST (Concorde) will be flying at Mach 2 and at altitudes above 50,000 feet (partial space-equivalent zone). It will need a completely enclosed pressurized cabin (a space cabin) which must be

pressurized for a comfortable flight altitude (about 6,000 feet). Emergency oxygen masks for protection at altitudes of more than 50,000 feet will be needed in case of accidental decompression. The passengers will not hear sonic booms when the aircraft travels at Mach 1 and higher. Such booms must be avoided over populated areas, as they will be heard continuously at the surface and could cause damage from vibration. The passengers and crew will need some protection against radiation by shielding the fuselage of the aircraft. The passengers will not wear protective clothing. The problems facing the pilot of the SST approach those of the pilot of the SR-71. The SST has an inertial navigation system also.

c. The space shuttle will open a new era in spaceflight, one more nearly resembling aircraft flight, and new life support equipment is being designed for the space shuttle. It will be more advanced than that for the Apollo command module, as designers can make use of experience obtained during the flights leading to the moon landing and of information obtained on the Skylab.

(1) The first space suit for use on the shuttle will be designed for pilots who test the shuttle. It will be pressurized to about 5 psi and should be more comfortable than previous space suits. The shuttle suit is part of an escape system that is being designed to allow pilots to deorbit and return safely to earth in case of accidental decompression. The biomedical instrumentation system is being designed so that it can predict medical problems, not simply measure and record medical data.

(2) The shuttle was originally designed to take passengers back and forth between a space station and the earth. The United States at present has no definite plans for a permanent space station as a follow-on to the Skylab. It is hoped that the shuttle itself can take into orbit small research and applications modules (RAM) that can eventually be developed into a permenant space station. Emphasis in US manned spaceflight is now being placed on flights in earth orbit.

(3) Present plans are to have the space shuttle eventually take into orbit scientists and doctors who are not trained astronauts or pilots. The life support standards of safety and comfort for the space shuttle must eventually reach those of the commercial SST.

d. Long-range spaceflight to the planets would present problems not too clearly understood today. Nevertheless, present efforts are laying a foundation that will probably make such flights possible in the future, say about the year 2000 or later. Today we are actually studying some of the problems of prolonged spaceflight.

(1) On long spaceflights, the life-support system will have to approach a closed system concept. We are studying such systems in preparation for making such flights. The key to a closed system is the process of photo-synthesis, which is the key to the life cycle in an ecological system on earth. One of the problems of long spaceflight is to make possible more efficient management of all kinds of wastes and recycling these wastes to allow them to be reused. Plants will be grown on future space ships to supplement the food that is stored. Plants will also help to purify the atmosphere, producing oxygen from carbon dioxide exhaled by the crew.

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(2) Some scientists believe that one of the most critical problems on long spaceflights will be protecting the crews and passengers against contamination and infection in the cramped quarters of the space ship. A future space ship may have equipment resembling a doctor's office or a hospital. All kinds of devices for measuring physical fitness and helping to maintain it will be put on board. There will be special exercisers for keeping the crew in condition.

(3) Perhaps the biggest problem of future spaceflights will be keeping up the morale of the crew and fighting disorientation and depression from being isolated in space. Only astronauts and passengers who are highly motivated should be allowed to go on long spaceflights.

5. SUGGESTIONS FOR TEACHING:

a. Suggested time: 2-3-4

b. If you wish to consolidate the subject matter in this unit, you might project future human requirements at the end of the series of lessons on aviation and again at the end of the lessons on spaceflight. The chief advantage in keeping this chapter separate and using it for a final series of lessons is that you can integrate and relate the two sets of requirements--those for aviation and those for spaceflight. At the beginning, you pointed out that there was no sharp dividing line between the human requirements for aviation and spaceflight--that they merged within the partial space-equivalent zone. In this final series of lessons, you can return to the same theme and show how the human requirements of aviation and spaceflight should become more nearly alike in the near future. Research and findings from one area should be helpful in the other. Keeping this chapter separate also permits you to more easily summarize the entire course.

c. Your objective in teaching this final series of lessons should be not so much to teach facts as to teach application of facts and to encourage the students to use their imagination. The students should be allowed to be as "far out" as they want to be, but they should be required to give reasons for their projections.

d. In allowing the students freedom in arriving at their own projections, you can give them a sense of accomplishment. Make them see some of the things they have learned and realize how their new knowledge makes them understand better the era in which they live. One can, for example, really appreciate the accomplishments of the astronauts only when he understands some of the hidden aspects of spaceflight--the detailed problems that must be solved to provide the astronauts with life support in space and on the moon.

e. A thought-provoking exercise for your students would be to research and compare the writings of early science-fiction writers such as Jules Verne to the actual accomplishments and hardware in space programs today.

f. Your students might want to report and discuss or speculate on the writings of such people as Arthur C. Clarke, Isaac Asimov, and Ray Bradbury.

6. INSTRUCTIONAL AIDS:

a. Films

(1) NASA Films

HQ 206. Space in the 70s - Man In Space the Second Decade. 28 min, Color, 1971.

(2) FAA Films

FAC-134. Man's Reach Should Exceed His Grasp, A. 23 min, Color, 1971.

(3) US NAVY Films

MN-10841. Sixty Days Beneath The Sea - TEKTITE. 14 min, color, 1970.

b. Slides

V-0021. Advanced Manned Systems

V-0044. Military Man In Space

V-0056. Future Prospects for Military Space Operations

c. Transparencies

V-2004. Space Travel (Book of Transparencies).

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7. PROJECTS:

See textbook, pages 182-183.

8. FURTHER READING:

See textbook, page 183.

IDEAS FOR IMPROVEMENT OF THE TEXTBOOK AND/OR INSTRUCTOR'S GUIDE
AND TEACHING TECHNIQUES MOST EFFECTIVE FOR THIS CHAPTER.
TO BE COMPILED AT END OF TEXT AND SENT TO JRC

HUMAN REQUIREMENTS OF FLIGHT